

reactionchecker

April 8, 2024

```
[ ]: import numpy as np
import pandas as pd
import pdg
from fractions import Fraction
import itertools

api = pdg.connect()
```

0.1 PDG dataset

I use PDG's python api to get the main data. Here is some code showing how to use the api.

```
[ ]: p = api.get_particle_by_name('p')
print(p.name,p.mass,p.charge,p.quantum_I,p.quantum_J)

Sigma_puls = api.get_particle_by_name('Sigma+')
print(Sigma_puls.name,Sigma_puls.mass,Sigma_puls.charge,Sigma_puls.
      ↪quantum_I,Sigma_puls.quantum_J)
```

```
p 0.93827208816 1.0 1/2 1/2
Sigma+ 1.18937004127302 None 1 1/2
```

0.2 My own addition

However PDG do not give some simple information such as Isospin third component I_3 .

```
[ ]: path = 'Dataset.xlsx'
selfdefine = pd.read_excel(path)
selfdefine.index=selfdefine['name'].values
selfdefine
```

```
[ ]:
```

| | name | mass | J | B | S | Q | I | I3 |
|-----|------|---------|---|-----|----|------|-----|------|
| pi+ | pi+ | 139.570 | 0 | 0.0 | 0 | 1.0 | 1 | 1 |
| pi0 | pi0 | 134.980 | 0 | 0.0 | 0 | 0.0 | 1 | 0 |
| pi- | pi- | 139.570 | 0 | 0.0 | 0 | -1.0 | 1 | -1 |
| K+ | K+ | 493.690 | 0 | 0.0 | 1 | 1.0 | 1/2 | +1/2 |
| K0 | K0 | 497.690 | 0 | 0.0 | 1 | 0.0 | 1/2 | -1/2 |
| K- | K- | 493.680 | 0 | 0.0 | -1 | -1.0 | 1/2 | -1/2 |
| -K0 | -K0 | 497.690 | 0 | 0.0 | -1 | 0.0 | 1/2 | +1/2 |

| | | | | | | | | |
|---------|---------|----------|-----|-----|----|------|-----|------|
| eta | eta | 547.300 | 0 | 0.0 | 0 | 0.0 | 0 | 0 |
| p | p | 938.272 | 1/2 | 1.0 | 0 | 1.0 | 1/2 | +1/2 |
| n | n | 939.567 | 1/2 | 1.0 | 0 | 0.0 | 1/2 | -1/2 |
| Lambda0 | Lambda0 | 1115.630 | 1/2 | 1.0 | -1 | 0.0 | 0 | 0 |
| Sigma+ | Sigma+ | 1189.370 | 1/2 | 1.0 | -1 | 1.0 | 1 | 1 |
| Sigma0 | Sigma0 | 1192.550 | 1/2 | 1.0 | -1 | 0.0 | 1 | 0 |
| Sigma- | Sigma- | 1197.430 | 1/2 | 1.0 | -1 | -1.0 | 1 | -1 |
| Xi0 | Xi0 | 1314.900 | 1/2 | 1.0 | -2 | 0.0 | 1/2 | +1/2 |
| Xi- | Xi- | 1321.320 | 1/2 | 1.0 | -2 | -1.0 | 1/2 | -1/2 |
| Omega- | Omega- | 1672.430 | 3/2 | 1.0 | -3 | -1.0 | 0 | 0 |
| s | s | NaN | NaN | NaN | 1 | NaN | NaN | NaN |

You can get data for a particular particle by this way

```
[ ]: selfdefine.loc['p']
```

```
[ ]: name      p
mass    938.272
J        1/2
B         1.0
S         0
Q         1.0
I         1/2
I3        +1/2
Name: p, dtype: object
```

You can search particles with particular property by this way

```
[ ]: selfdefine.loc[selfdefine['Q'] == 1]
```

```
[ ]:      name      mass    J    B  S    Q    I    I3
pi+    pi+    139.570    0  0.0  0  1.0    1    1
K+      K+    493.690    0  0.0  1  1.0  1/2  +1/2
p        p    938.272  1/2  1.0  0  1.0  1/2  +1/2
Sigma+  Sigma+ 1189.370  1/2  1.0 -1  1.0    1    1
```

0.3 My reaction checker

I will primarily utilize PDG's data. However, for S and I_3 , I rely on my own dataset.

This task proves more challenging than anticipated, as PDG's dataset API does not provide all the required data. Additionally, verifying I_3 violation necessitates expertise in angular momentum coupling techniques.

The names of particles align primarily with PDG conventions. However, for anti-particles, I prepend a '-' before their names. Regarding neutrinos, PDG combines three flavors into one name, 'mu', perhaps due to neutrino oscillation. For the verification of lepton number, I opt to use 'nu_e', 'nu_nu', and 'nu_tau'.

```

[ ]: def get_baryon_number(name):
    # a small assistant function to get baryon number
    if api.get_particle_by_name(name).is_baryon:
        return 1
    if api.get_particle_by_name(name).is_quark:
        return 1/3
    return 0

def get_lepton_number(name):
    if name in ['e', 'nu_e', 'e-']:
        L_e=1
    elif name in ['e+']:
        L_e=-1
    else:
        L_e=0
    if name in ['mu', 'nu_mu', 'mu-']:
        L_mu=1
    elif name in ['mu+']:
        L_mu=-1
    else:
        L_mu=0
    if name in ['tau', 'nu_tau', 'tau-']:
        L_tau=1
    elif name in ['tau+']:
        L_tau=-1
    else:
        L_tau=0
    return L_e, L_mu, L_tau

def convert_parity(parity): # '+' to 1, '-' to -1
    if parity=='+':
        return 1
    if parity=='-':
        return -1
    return None
convert_parity = np.vectorize(convert_parity)

# convert_bool=lambda x:False if x=='False' else True
# convert_bool = np.vectorize(convert_bool)

def get_isospin(name):
    if name == 'gamma':
        return 0
    # In PDG's data, the isospin of gamma is '0,1'

isospin = api.get_particle_by_name(name).quantum_I

```

```

if isospin == None:
    return 0
return Fraction(isospin)

def sum_isospin(I):
    # I is a list of isospin I not I3
    # get the result of all possible total isospin
    # In order to avoid floating-point errors, the result is doubled to
    ↪ describe the half-integer well.
    I = np.array(I)
    possible_result = set()
    for i in itertools.product([-2, 2], repeat=len(I)):
        possible_result.add(int(abs((I*np.array(i)).sum()))))
    return possible_result

def check_isospin(I_reactant, I_product):
    return bool(sum_isospin(I_reactant) & sum_isospin(I_product))

def get_charge(name):
    # As you see, PDG think that the charge of 'Sigma+' is None. So strange!
    PDGdata = api.get_particle_by_name(name)
    is_hardon = PDGdata.is_baryon or PDGdata.is_meson
    if is_hardon:
        return selfdefine.loc[name]['Q']
    if PDGdata.charge==None:
        return 0
    return PDGdata.charge

def find_subscript_index(input_string):
    if input_string[:2]=='nu':
        return input_string.find('_')
    for i in range(len(input_string) - 1, -1, -1):
        if input_string[i].isalpha():
            return i+1
    return 0

def get_particle_Latex(name):
    # from particle name in ASCII code to LaTeX code. For example, 'pi+' to
    ↪ '\pi^+'
    anti = ''
    if name[0]=='-':
        anti = r'\bar '
        name=name[1:]
    index = 0
    if name[:2]=='nu':
        index = name.find('_')

```

```

        nametext = name[:index]
        subscript = name[index+1:]
        nametext = '\\\' + nametext
        if len(subscript)>1:
            subscript = '\\\' + subscript
        final = anti + nametext+'_'+subscript
    else:
        for i in range(len(name) - 1, -1, -1):
            if name[i].isalpha():
                index = i
                break
        nametext = name[:index+1]
        subscript = name[index+1:]
        if len(nametext)>1:
            nametext = '\\\' + nametext
        if subscript:
            subscript = '^'+subscript
        final = anti + nametext +subscript
    return final

def get_reaction_Latex(reactant,product):
    # from reaction information to get the equation for reaction in latex
    reactantlatex_list=[]
    for i in reactant:
        reactantlatex_list.append(get_particle_Latex(i))
    productlatex_list=[]
    for i in product:
        productlatex_list.append(get_particle_Latex(i))

    reactantlatex = ' + '.join(reactantlatex_list)
    productlatex = ' + '.join(productlatex_list)
    return reactantlatex+r' \to '+productlatex

def reaction_checker(reactant,product):
    # print('CCCCCCCCCCCCHHHHHHHHHHH')
    # get in reaction datas
    reactant_df = pd.DataFrame({'name':reactant})
    reactant_df.index = [f'reactant{i+1}' for i in range(len(reactant))]
    product_df = pd.DataFrame({'name':product})
    product_df.index = [f'product{i+1}' for i in range(len(product))]

    # anti-particle, because PDG do not give some data about anti-particles
    anti_reactant = [1 for _ in range(len(reactant))]
    for i in range(len(reactant)):
        if reactant[i][0]=='-':
            anti_reactant[i]=-1

```

```

        reactant[i]=reactant[i][1:]
anti_reactant = np.array(anti_reactant)
anti_product = [1 for _ in range(len(product))]
for i in range(len(product)):
    if product[i][0]=='-':
        anti_product[i]=-1
        product[i]=product[i][1:]
anti_product = np.array(anti_product)

# neutrino: PDG gives three flavors of neutrino in one particle data 'nu'
# don't worry, the information with neutrino flavor is backed up and
↪seemingly only used in lepton number
neu_reactant = reactant[:]
for i in range(len(reactant)):
    if reactant[i][:2]=='nu':
        reactant[i]='nu'
neu_product = product[:]
for i in range(len(product)):
    if product[i][:2]=='nu':
        product[i]='nu'
# print(reactant,product)
# print(neu_reactant,neu_product)
# print('CCCCCCCCCCCCHHHHHHHHHH')

# check em-charge
reactant_df['Q']=[get_charge(i) for i in reactant]
product_df['Q']=[get_charge(i) for i in product]
reactant_df['Q']*=-anti_reactant
product_df['Q']*=-anti_product
# print('CCCCCCCCCCCCHHHHHHHHHH')
check_charge = ((abs(reactant_df['Q'].values.sum()-product_df['Q'].values.
↪sum()))<1e-3)
# print('CCCCCCCCCCCCHHHHHHHHHH')
# check baryon number
reactant_df['B']=[get_baryon_number(i) for i in reactant]
product_df['B']=[get_baryon_number(i) for i in product]
reactant_df['B']*=-anti_reactant
product_df['B']*=-anti_product
check_B = ((abs(reactant_df['B'].values.sum()-product_df['B'].values.
↪sum()))<1e-3)

# check lepton number
↪
↪reactant_df['L_e'],reactant_df['L_mu'],reactant_df['L_tau']=[[get_lepton_number(row)[i]]
↪for row in neu_reactant] for i in range(3)]

```

```

    product_df['L_e'], product_df['L_mu'], product_df['L_tau'] = [[get_lepton_number(row)[i]]
    for row in neu_product] for i in range(3)]

    reactant_df['L_e'] *= anti_reactant
    product_df['L_e'] *= anti_product
    reactant_df['L_mu'] *= anti_reactant
    product_df['L_mu'] *= anti_product
    reactant_df['L_tau'] *= anti_reactant
    product_df['L_tau'] *= anti_product

    check_L_e = (reactant_df['L_e'].values.sum() == product_df['L_e'].values.
    sum())
    check_L_mu = (reactant_df['L_mu'].values.sum() == product_df['L_mu'].values.
    sum())
    check_L_tau = (reactant_df['L_tau'].values.sum() == product_df['L_tau'].
    values.sum())
    # print(check_L_e, check_L_mu, check_L_tau)

    # check strange number
    reactant_df['S'] = [(0 if not(i in set(selfdefine.index.values))
                        else selfdefine.loc[i]['S'])
                        for i in reactant]
    product_df['S'] = [(0 if not(i in set(selfdefine.index.values))
                        else selfdefine.loc[i]['S'])
                        for i in product]
    reactant_df['S'] *= anti_reactant
    product_df['S'] *= anti_product
    check_S = ((abs(reactant_df['S'].values.sum() - product_df['S'].values.
    sum())) < 1e-3)

    # check isospin: total isospin cannot be added directly
    reactant_df['I'] = [get_isospin(i) for i in reactant]
    product_df['I'] = [get_isospin(i) for i in product]
    check_I = check_isospin(reactant_df['I'].values, product_df['I'].values)

    # check I3
    reactant_df['I3'] = [(0 if not(i in set(selfdefine.index.values))
                          else Fraction(selfdefine.loc[i]['I3']))
                          for i in reactant]
    product_df['I3'] = [(0 if not(i in set(selfdefine.index.values))
                          else Fraction(selfdefine.loc[i]['I3']))
                          for i in product]
    reactant_df['I3'] *= anti_reactant
    product_df['I3'] *= anti_product
    reactant_df.fillna(0, inplace=True)

```

```

product_df.fillna(0, inplace=True)
check_I3 = ((abs(reactant_df['I3'].values.sum()-product_df['I3'].values.
↪sum()))<1e-3)

# check C-parity
reactant_df['C']=[api.get_particle_by_name(i).quantum_C for i in reactant]
product_df['C']=[api.get_particle_by_name(i).quantum_C for i in product]
if (None in reactant_df['C'].values) or (None in product_df['C'].values):
    check_C = None
else:
    # pass
    reactant_parity = convert_parity(reactant_df['C']).prod()
    product_parity = convert_parity(product_df['C']).prod()
    check_C=(reactant_parity == product_parity)

# check G-parity
reactant_df['G']=[api.get_particle_by_name(i).quantum_G for i in reactant]
product_df['G']=[api.get_particle_by_name(i).quantum_G for i in product]
if (None in reactant_df['G'].values) or (None in product_df['G'].values):
    check_G = None
else:
    # pass
    reactant_parity = convert_parity(reactant_df['G']).prod()
    product_parity = convert_parity(product_df['G']).prod()
    check_G=(reactant_parity == product_parity)

# form result
analy_df=pd.concat([reactant_df,product_df])
analy_df.loc['checking']=['checking',
                        str(check_charge),
                        str(check_B),
                        str(check_L_e),
                        str(check_L_mu),
                        str(check_L_tau),
                        str(check_S),
                        str(check_I),
                        str(check_I3),
                        str(check_C),
                        str(check_G)]

Possibility = 'Yes'
strong = 'Yes'
EM = 'Yes'
weak = 'Yes'
# checking weather and how the reaction can happen

```



```

possi = analy_df.loc['checking']['Q':'L_tau']
violations = possi[possi=='False']
if len(violations)!=0:
    Possibility=', '.join(violations.index)+' violation'
    strong = 'No'
    EM = 'No'
    weak = 'No'

if Possibility=='Yes':
    # checking strong interaction
    strong_data = analy_df.loc['checking']['S':'G']
    violations = strong_data[strong_data=='False']
    if len(violations)!=0:
        strong = ', '.join(violations.index)+' violation'

    # checking EM interaction
    EM_data = analy_df.loc['checking']['S','I3','C']
    violations = EM_data[EM_data=='False']
    if len(violations)!=0:
        EM = ', '.join(violations.index)+' violation'

Checking_result = pd.DataFrame({'reaction':
↪ ['$'+get_reaction_Latex(reactant_df['name'].values,product_df['name']
↪ values)+'$'],
                                'Possibility':[Possibility],
                                'Strong':[strong],
                                'EM':[EM],
                                'Weak':[weak]})

return analy_df,Checking_result

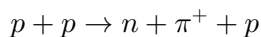
```

0.4 HW

My reaction checker generates two lists: one containing reactants and the other containing products.

It returns two dataframes. The first dataframe indicates the violated quantum numbers and the nature of the violations. The second dataframe provides information on the types of interactions in which the reaction can occur.

1



```

[ ]: reactant = ['p','p']
      product = ['n','pi+', 'p']
      reaction,result=reaction_checker(reactant,product)
      display(reaction,result)

```

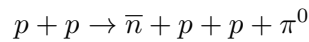
```
total_result = pd.DataFrame()
total_result = pd.concat([total_result, result], ignore_index=True)
```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|----------|------|------|------|------|-------|------|------|------|------|---|
| reactant1 | p | 1.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None | |
| reactant2 | p | 1.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None | |
| product1 | n | 0.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | -1/2 | None | |
| product2 | pi+ | 1.0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | None | |
| product3 | p | 1.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None | |
| checking | checking | True | True | True | True | True | True | True | True | None | |

| | G |
|-----------|------|
| reactant1 | None |
| reactant2 | None |
| product1 | None |
| product2 | - |
| product3 | None |
| checking | None |

| | reaction | Possibility | Strong | EM | Weak |
|---|-----------------------------|-------------|--------|-----|------|
| 0 | \$p + p \to n + \pi^+ + p\$ | Yes | Yes | Yes | Yes |

2



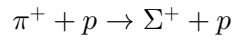
```
[ ]: reactant = ['p','p']
product = ['-n','pi+','p','pi0']
reaction,result=reaction_checker(reactant,product)
display(reaction,result)
total_result = pd.concat([total_result, result], ignore_index=True)
```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|----------|------|-------|------|------|-------|------|------|-------|------|---|
| reactant1 | p | 1.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None | |
| reactant2 | p | 1.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None | |
| product1 | -n | -0.0 | -1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None | |
| product2 | pi+ | 1.0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | None | |
| product3 | p | 1.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None | |
| product4 | pi0 | 0.0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | + | |
| checking | checking | True | False | True | True | True | True | True | False | None | |

| | G |
|-----------|------|
| reactant1 | None |
| reactant2 | None |
| product1 | None |
| product2 | - |
| product3 | None |
| product4 | - |
| checking | None |

| | reaction | Possibility | Strong | EM | Weak |
|---|---|-------------|--------|----|------|
| 0 | $\$p + p \rightarrow \bar{n} + \pi^+ + p + \pi^0\$$ | B violation | No | No | No |

3



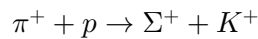
```
[ ]: reactant = ['pi+', 'p']
product = ['Sigma+', 'p']
reaction,result=reaction_checker(reactant,product)
display(reaction,result)
total_result = pd.concat([total_result, result], ignore_index=True)
```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|----------|------|-------|------|------|-------|-------|------|------|------|---|
| reactant1 | pi+ | 1.0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | None | |
| reactant2 | p | 1.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None | |
| product1 | Sigma+ | 1.0 | 1 | 0 | 0 | 0 | -1 | 1 | 1 | None | |
| product2 | p | 1.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None | |
| checking | checking | True | False | True | True | True | False | True | True | None | |

| | G |
|-----------|------|
| reactant1 | - |
| reactant2 | None |
| product1 | None |
| product2 | None |
| checking | None |

| | reaction | Possibility | Strong | EM | Weak |
|---|--|-------------|--------|----|------|
| 0 | $\$\pi^+ + p \rightarrow \Sigma^+ + p\$$ | B violation | No | No | No |

4



```
[ ]: reactant = ['pi+', 'p']
product = ['Sigma+', 'K+']
reaction,result=reaction_checker(reactant,product)
display(reaction,result)
total_result = pd.concat([total_result, result], ignore_index=True)
```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|----------|------|------|------|------|-------|------|------|------|------|---|
| reactant1 | pi+ | 1.0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | None | |
| reactant2 | p | 1.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None | |
| product1 | Sigma+ | 1.0 | 1 | 0 | 0 | 0 | -1 | 1 | 1 | None | |
| product2 | K+ | 1.0 | 0 | 0 | 0 | 0 | 1 | 1/2 | 1/2 | None | |
| checking | checking | True | True | True | True | True | True | True | True | None | |

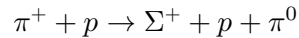
| | G |
|-----------|------|
| reactant1 | - |
| reactant2 | None |

```
product1    None
product2    None
checking    None
```

```

          reaction Possibility Strong  EM Weak
0  $\pi^+ + p \to \Sigma^+ + K^+$      Yes   Yes  Yes  Yes
```

5



```
[ ]: reactant = ['pi+', 'p']
      product = ['Sigma+', 'p', 'pi0']
      reaction,result=reaction_checker(reactant,product)
      display(reaction,result)
      total_result = pd.concat([total_result, result], ignore_index=True)
```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C \ |
|-----------|----------|------|-------|------|------|-------|-------|------|------|------|
| reactant1 | pi+ | 1.0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | None |
| reactant2 | p | 1.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None |
| product1 | Sigma+ | 1.0 | 1 | 0 | 0 | 0 | -1 | 1 | 1 | None |
| product2 | p | 1.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None |
| product3 | pi0 | 0.0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | + |
| checking | checking | True | False | True | True | True | False | True | True | None |

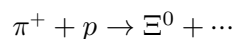
```

      G
reactant1  -
reactant2  None
product1   None
product2   None
product3   -
checking   None
```

```

          reaction Possibility Strong  EM Weak
0  $\pi^+ + p \to \Sigma^+ + p + \pi^0$  B violation    No  No  No
```

6



```
[ ]: reactant = ['pi+', 'p']
      product = ['Xi0']
      reaction,result=reaction_checker(reactant,product)
      display(reaction,result)
      total_result = pd.concat([total_result, result], ignore_index=True)
```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C \ |
|-----------|----------|-------|------|------|------|-------|-------|------|-------|------|
| reactant1 | pi+ | 1.0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | None |
| reactant2 | p | 1.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None |
| product1 | Xi0 | 0.0 | 1 | 0 | 0 | 0 | -2 | 1/2 | 1/2 | None |
| checking | checking | False | True | True | True | True | False | True | False | None |

```

G
reactant1 -
reactant2 None
product1 None
checking None

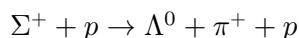
```

```

reaction Possibility Strong EM Weak
0 $\pi^+ + p \to \Lambda^0$ Q violation No No No

```

7



```

[ ]: reactant = ['Sigma+', 'p']
product = ['Lambda0', 'pi+', 'p']
reaction,result=reaction_checker(reactant,product)
display(reaction,result)
total_result = pd.concat([total_result, result], ignore_index=True)

```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|----------|------|------|------|------|-------|------|------|------|------|---|
| reactant1 | Sigma+ | 1.0 | 1 | 0 | 0 | 0 | -1 | 1 | 1 | None | |
| reactant2 | p | 1.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None | |
| product1 | Lambda0 | 0.0 | 1 | 0 | 0 | 0 | -1 | 0 | 0 | None | |
| product2 | pi+ | 1.0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | None | |
| product3 | p | 1.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None | |
| checking | checking | True | True | True | True | True | True | True | True | None | |

```

G
reactant1 None
reactant2 None
product1 None
product2 -
product3 None
checking None

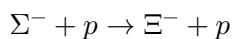
```

```

reaction Possibility Strong EM Weak
0 $\Sigma^+ + p \to \Lambda^0 + \pi^+ + p$ Yes Yes Yes Yes

```

8



```

[ ]: reactant = ['Sigma-', 'p']
product = ['Xi-', 'p']
reaction,result=reaction_checker(reactant,product)
display(reaction,result)
total_result = pd.concat([total_result, result], ignore_index=True)

```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|--------|------|---|-----|------|-------|----|---|----|------|---|
| reactant1 | Sigma- | -1.0 | 1 | 0 | 0 | 0 | -1 | 1 | -1 | None | |

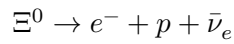
| | | | | | | | | | | |
|-----------|----------|------|------|------|------|------|-------|-------|-------|------|
| reactant2 | p | 1.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None |
| product1 | Xi- | -1.0 | 1 | 0 | 0 | 0 | -2 | 1/2 | -1/2 | None |
| product2 | p | 1.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None |
| checking | checking | True | True | True | True | True | False | False | False | None |

G

| | |
|-----------|------|
| reactant1 | None |
| reactant2 | None |
| product1 | None |
| product2 | None |
| checking | None |

| | reaction | Possibility | Strong | EM \ |
|---|--------------------------------------|-------------|------------------|----------------|
| 0 | $\Sigma^- + p \rightarrow \Xi^- + p$ | Yes | S,I,I3 violation | S,I3 violation |
| | Weak | | | |
| 0 | Yes | | | |

9



```
[ ]: reactant = ['Xi0']
      product = ['e-', 'p', '-nu_e']
      reaction,result=reaction_checker(reactant,product)
      display(reaction,result)
      total_result = pd.concat([total_result, result], ignore_index=True)
```

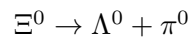
| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C \ |
|-----------|----------|------|------|------|------|-------|-------|------|------|------|
| reactant1 | Xi0 | 0.0 | 1 | 0 | 0 | 0 | -2 | 1/2 | 1/2 | None |
| product1 | e- | -1.0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | None |
| product2 | p | 1.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None |
| product3 | -nu_e | -0.0 | 0 | -1 | 0 | 0 | 0 | 0 | 0 | None |
| checking | checking | True | True | True | True | True | False | True | True | None |

G

| | |
|-----------|------|
| reactant1 | None |
| product1 | None |
| product2 | None |
| product3 | None |
| checking | None |

| | reaction | Possibility | Strong | EM Weak |
|---|---|-------------|-------------|-----------------|
| 0 | $\Xi^0 \rightarrow e^- + p + \bar{\nu}_e$ | Yes | S violation | S violation Yes |

10



```
[ ]: reactant = ['Xi0']
product = ['Lambda0','pi0']
reaction,result=reaction_checker(reactant,product)
display(reaction,result)
total_result = pd.concat([total_result, result], ignore_index=True)
```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|----------|------|------|------|------|-------|-------|-------|-------|------|---|
| reactant1 | Xi0 | 0.0 | 1 | 0 | 0 | 0 | -2 | 1/2 | 1/2 | None | |
| product1 | Lambda0 | 0.0 | 1 | 0 | 0 | 0 | -1 | 0 | 0 | None | |
| product2 | pi0 | 0.0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | + | |
| checking | checking | True | True | True | True | True | False | False | False | None | |

G

| | |
|-----------|------|
| reactant1 | None |
| product1 | None |
| product2 | - |
| checking | None |

| | reaction Possibility | Strong | \ |
|----------------------------------|----------------------|------------------|---|
| 0 \$Xi^0 \to \Lambda^0 + \pi^0\$ | Yes | S,I,I3 violation | |

EM Weak

| | |
|------------------|-----|
| 0 S,I3 violation | Yes |
|------------------|-----|

11



```
[ ]: reactant = ['Xi-']
product = ['Lambda0','pi-']
reaction,result=reaction_checker(reactant,product)
display(reaction,result)
total_result = pd.concat([total_result, result], ignore_index=True)
```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|----------|------|------|------|------|-------|-------|-------|-------|------|---|
| reactant1 | Xi- | -1.0 | 1 | 0 | 0 | 0 | -2 | 1/2 | -1/2 | None | |
| product1 | Lambda0 | 0.0 | 1 | 0 | 0 | 0 | -1 | 0 | 0 | None | |
| product2 | pi- | -1.0 | 0 | 0 | 0 | 0 | 0 | 1 | -1 | None | |
| checking | checking | True | True | True | True | True | False | False | False | None | |

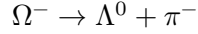
G

| | |
|-----------|------|
| reactant1 | None |
| product1 | None |
| product2 | - |
| checking | None |

| | reaction Possibility | Strong | \ |
|----------------------------------|----------------------|------------------|---|
| 0 \$Xi^- \to \Lambda^0 + \pi^-\$ | Yes | S,I,I3 violation | |

EM Weak
0 S,I3 violation Yes

0.5 12



```
[ ]: reactant = ['Omega-']
product = ['Lambda0', 'pi-']
reaction,result=reaction_checker(reactant,product)
display(reaction,result)
total_result = pd.concat([total_result, result], ignore_index=True)
```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|----------|------|------|------|------|-------|-------|-------|-------|------|---|
| reactant1 | Omega- | -1.0 | 1 | 0 | 0 | 0 | -3 | 0 | 0 | None | |
| product1 | Lambda0 | 0.0 | 1 | 0 | 0 | 0 | -1 | 0 | 0 | None | |
| product2 | pi- | -1.0 | 0 | 0 | 0 | 0 | 0 | 1 | -1 | None | |
| checking | checking | True | True | True | True | True | False | False | False | None | |

G

| | |
|-----------|------|
| reactant1 | None |
| product1 | None |
| product2 | - |
| checking | None |

| | reaction Possibility | Strong | \ |
|--|----------------------|--------|---|
| 0 $\Omega^- \rightarrow \Lambda^0 + \pi^-$ | Yes S,I,I3 violation | | |

EM Weak
0 S,I3 violation Yes

13



```
[ ]: reactant = ['Omega-']
product = ['Lambda0', 'K-']
reaction,result=reaction_checker(reactant,product)
display(reaction,result)
total_result = pd.concat([total_result, result], ignore_index=True)
```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|----------|------|------|------|------|-------|-------|-------|-------|------|---|
| reactant1 | Omega- | -1.0 | 1 | 0 | 0 | 0 | -3 | 0 | 0 | None | |
| product1 | Lambda0 | 0.0 | 1 | 0 | 0 | 0 | -1 | 0 | 0 | None | |
| product2 | K- | -1.0 | 0 | 0 | 0 | 0 | -1 | 1/2 | -1/2 | None | |
| checking | checking | True | True | True | True | True | False | False | False | None | |

G

| | |
|-----------|------|
| reactant1 | None |
| product1 | None |


```
product2    None
checking    None
```

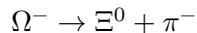
```

          reaction Possibility          Strong \
0  $\Omega^- \to \Lambda^0 + K^- $          Yes S,I,I3 violation
```

```

          EM Weak
0  S,I3 violation Yes
```

14



```
[ ]: reactant = ['Omega-']
      product = ['Xi0','pi-']
      reaction,result=reaction_checker(reactant,product)
      display(reaction,result)
      total_result = pd.concat([total_result, result], ignore_index=True)
```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|----------|------|------|------|------|-------|-------|-------|-------|------|---|
| reactant1 | Omega- | -1.0 | 1 | 0 | 0 | 0 | -3 | 0 | 0 | None | |
| product1 | Xi0 | 0.0 | 1 | 0 | 0 | 0 | -2 | 1/2 | 1/2 | None | |
| product2 | pi- | -1.0 | 0 | 0 | 0 | 0 | 0 | 1 | -1 | None | |
| checking | checking | True | True | True | True | True | False | False | False | None | |

```

          G
reactant1  None
product1   None
product2   -
checking   None
```

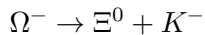
```

          reaction Possibility          Strong          EM \
0  $\Omega^- \to \Xi^0 + \pi^- $          Yes S,I,I3 violation S,I3 violation
```

```

          Weak
0  Yes
```

15



```
[ ]: reactant = ['Omega-']
      product = ['Xi0','K-']
      reaction,result=reaction_checker(reactant,product)
      display(reaction,result)
      total_result = pd.concat([total_result, result], ignore_index=True)
```

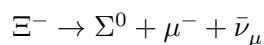
| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|--------|------|---|-----|------|-------|----|-----|------|------|---|
| reactant1 | Omega- | -1.0 | 1 | 0 | 0 | 0 | -3 | 0 | 0 | None | |
| product1 | Xi0 | 0.0 | 1 | 0 | 0 | 0 | -2 | 1/2 | 1/2 | None | |
| product2 | K- | -1.0 | 0 | 0 | 0 | 0 | -1 | 1/2 | -1/2 | None | |

| | | | | | | | | | | | |
|----------|----------|------|------|------|------|------|------|------|------|------|------|
| checking | checking | True | True | True | True | True | True | True | True | True | None |
|----------|----------|------|------|------|------|------|------|------|------|------|------|

| | |
|-----------|------|
| | G |
| reactant1 | None |
| product1 | None |
| product2 | None |
| checking | None |

| | | | | |
|---|------------------------------------|----------------------|--------|---------|
| | | reaction Possibility | Strong | EM Weak |
| 0 | $\Omega^- \rightarrow \Xi^0 + K^-$ | Yes | Yes | Yes Yes |

16



```
[ ]: reactant = ['Xi-']
product = ['Sigma0', 'mu-', '-nu_mu']
reaction,result=reaction_checker(reactant,product)
display(reaction,result)
total_result = pd.concat([total_result, result], ignore_index=True)
```

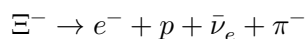
| | | | | | | | | | | | |
|-----------|----------|------|------|------|------|-------|-------|-------|-------|------|---|
| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
| reactant1 | Xi- | -1.0 | 1 | 0 | 0 | 0 | -2 | 1/2 | -1/2 | None | |
| product1 | Sigma0 | 0.0 | 1 | 0 | 0 | 0 | -1 | 1 | 0 | None | |
| product2 | mu- | -1.0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | None | |
| product3 | -nu_mu | -0.0 | 0 | 0 | -1 | 0 | 0 | 0 | 0 | None | |
| checking | checking | True | True | True | True | True | False | False | False | None | |

| | |
|-----------|------|
| | G |
| reactant1 | None |
| product1 | None |
| product2 | None |
| product3 | None |
| checking | None |

| | | | | |
|---|--|----------------------|------------------|---|
| | | reaction Possibility | Strong | \ |
| 0 | $\Xi^- \rightarrow \Sigma^0 + \mu^- + \bar{\nu}_\mu$ | Yes | S,I,I3 violation | |

| | |
|---|--------------------|
| | EM Weak |
| 0 | S,I3 violation Yes |

17



```
[ ]: reactant = ['Xi-']
product = ['e-', 'p', '-nu_e', 'pi-']
reaction,result=reaction_checker(reactant,product)
display(reaction,result)
total_result = pd.concat([total_result, result], ignore_index=True)
```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|----------|------|------|------|------|-------|-------|------|------|------|---|
| reactant1 | Xi- | -1.0 | 1 | 0 | 0 | 0 | -2 | 1/2 | -1/2 | None | |
| product1 | e- | -1.0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | None | |
| product2 | p | 1.0 | 1 | 0 | 0 | 0 | 0 | 1/2 | 1/2 | None | |
| product3 | -nu_e | -0.0 | 0 | -1 | 0 | 0 | 0 | 0 | 0 | None | |
| product4 | pi- | -1.0 | 0 | 0 | 0 | 0 | 0 | 1 | -1 | None | |
| checking | checking | True | True | True | True | True | False | True | True | None | |

G

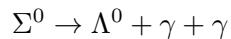
| | |
|-----------|------|
| reactant1 | None |
| product1 | None |
| product2 | None |
| product3 | None |
| product4 | - |
| checking | None |

| | reaction | Possibility | Strong | \ |
|---|--|-------------|-------------|---|
| 0 | $\Sigma^- \rightarrow e^- + p + \bar{\nu}_e + \pi^-$ | Yes | S violation | |

EM Weak

0 S violation Yes

18



```
[ ]: reactant = ['Sigma0']
product = ['Lambda0', 'gamma', 'gamma']
reaction,result=reaction_checker(reactant,product)
display(reaction,result)
total_result = pd.concat([total_result, result], ignore_index=True)
```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|----------|------|------|------|------|-------|------|-------|------|------|---|
| reactant1 | Sigma0 | 0.0 | 1 | 0 | 0 | 0 | -1 | 1 | 0 | None | |
| product1 | Lambda0 | 0.0 | 1 | 0 | 0 | 0 | -1 | 0 | 0 | None | |
| product2 | gamma | 0.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | |
| product3 | gamma | 0.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | |
| checking | checking | True | True | True | True | True | True | False | True | None | |

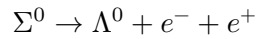
G

| | |
|-----------|------|
| reactant1 | None |
| product1 | None |
| product2 | None |
| product3 | None |
| checking | None |

| | reaction | Possibility | Strong | EM | \ |
|---|--|-------------|-------------|-----|---|
| 0 | $\Sigma^0 \rightarrow \Lambda^0 + \gamma + \gamma$ | Yes | I violation | Yes | |

Weak
0 Yes

19



```
[ ]: reactant = ['Sigma0']
product = ['Lambda0','e-','e+']
reaction,result=reaction_checker(reactant,product)
display(reaction,result)
total_result = pd.concat([total_result, result], ignore_index=True)
```

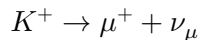
| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|----------|------|------|------|------|-------|------|-------|------|------|---|
| reactant1 | Sigma0 | 0.0 | 1 | 0 | 0 | 0 | -1 | 1 | 0 | None | |
| product1 | Lambda0 | 0.0 | 1 | 0 | 0 | 0 | -1 | 0 | 0 | None | |
| product2 | e- | -1.0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | None | |
| product3 | e+ | 1.0 | 0 | -1 | 0 | 0 | 0 | 0 | 0 | None | |
| checking | checking | True | True | True | True | True | True | False | True | None | |

G

| | |
|-----------|------|
| reactant1 | None |
| product1 | None |
| product2 | None |
| product3 | None |
| checking | None |

| | reaction Possibility | Strong | EM | Weak |
|---|--|--------|-------------|------|
| 0 | $\Sigma^0 \rightarrow \Lambda^0 + e^- + e^+$ | Yes | I violation | Yes |

20



```
[ ]: reactant = ['K+']
product = ['mu+','nu_mu']
reaction,result=reaction_checker(reactant,product)
display(reaction,result)
total_result = pd.concat([total_result, result], ignore_index=True)
```

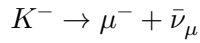
| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|----------|------|------|------|------|-------|-------|-------|-------|------|---|
| reactant1 | K+ | 1.0 | 0 | 0 | 0 | 0 | 1 | 1/2 | 1/2 | None | |
| product1 | mu+ | 1.0 | 0 | 0 | -1 | 0 | 0 | 0 | 0 | None | |
| product2 | nu_mu | 0.0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | None | |
| checking | checking | True | True | True | True | True | False | False | False | None | |

G

| | |
|-----------|------|
| reactant1 | None |
| product1 | None |
| product2 | None |
| checking | None |

| | reaction | Possibility | Strong | EM | \ |
|---|-----------------------------------|-------------|------------------|----------------|---|
| 0 | $K^+ \rightarrow \mu^+ + \nu_\mu$ | Yes | S,I,I3 violation | S,I3 violation | |
| | | | | Weak | |
| 0 | Yes | | | | |

21



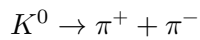
```
[ ]: reactant = ['K-']
product = ['mu-', '-nu_mu']
reaction,result=reaction_checker(reactant,product)
display(reaction,result)
total_result = pd.concat([total_result, result], ignore_index=True)
```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|----------|------|------|------|------|-------|-------|-------|-------|------|---|
| reactant1 | K- | -1.0 | 0 | 0 | 0 | 0 | -1 | 1/2 | -1/2 | None | |
| product1 | mu- | -1.0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | None | |
| product2 | -nu_mu | -0.0 | 0 | 0 | -1 | 0 | 0 | 0 | 0 | None | |
| checking | checking | True | True | True | True | True | False | False | False | None | |

| | G |
|-----------|------|
| reactant1 | None |
| product1 | None |
| product2 | None |
| checking | None |

| | reaction | Possibility | Strong | \ |
|---|---|-------------|------------------|---------|
| 0 | $K^- \rightarrow \mu^- + \bar{\nu}_\mu$ | Yes | S,I,I3 violation | |
| | | | | EM Weak |
| 0 | S,I3 violation | Yes | | |

22



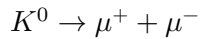
```
[ ]: reactant = ['K0']
product = ['pi+', 'pi-']
reaction,result=reaction_checker(reactant,product)
display(reaction,result)
total_result = pd.concat([total_result, result], ignore_index=True)
```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|----------|------|------|------|------|-------|-------|-------|-------|------|---|
| reactant1 | K0 | 0.0 | 0 | 0 | 0 | 0 | 1 | 1/2 | -1/2 | None | |
| product1 | pi+ | 1.0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | None | |
| product2 | pi- | -1.0 | 0 | 0 | 0 | 0 | 0 | 1 | -1 | None | |
| checking | checking | True | True | True | True | True | False | False | False | None | |

G
 reactant1 None
 product1 -
 product2 -
 checking None

| | | reaction Possibility | Strong | EM Weak |
|---|---------------------------------|----------------------|------------------|--------------------|
| 0 | $K^0 \rightarrow \pi^+ + \pi^-$ | Yes | S,I,I3 violation | S,I3 violation Yes |

23



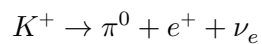
```
[ ]: reactant = ['K0']
      product = ['mu+', 'mu-']
      reaction,result=reaction_checker(reactant,product)
      display(reaction,result)
      total_result = pd.concat([total_result, result], ignore_index=True)
```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C \ |
|-----------|----------|------|------|------|------|-------|-------|-------|-------|------|
| reactant1 | K0 | 0.0 | 0 | 0 | 0 | 0 | 1 | 1/2 | -1/2 | None |
| product1 | mu+ | 1.0 | 0 | 0 | -1 | 0 | 0 | 0 | 0 | None |
| product2 | mu- | -1.0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | None |
| checking | checking | True | True | True | True | True | False | False | False | None |

G
 reactant1 None
 product1 None
 product2 None
 checking None

| | | reaction Possibility | Strong | EM Weak |
|---|---------------------------------|----------------------|------------------|--------------------|
| 0 | $K^0 \rightarrow \mu^+ + \mu^-$ | Yes | S,I,I3 violation | S,I3 violation Yes |

24



```
[ ]: reactant = ['K+']
      product = ['pi0', 'e+', 'nu_e']
      reaction,result=reaction_checker(reactant,product)
      display(reaction,result)
      total_result = pd.concat([total_result, result], ignore_index=True)
```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C \ |
|-----------|----------|------|------|------|------|-------|-------|-------|-------|------|
| reactant1 | K+ | 1.0 | 0 | 0 | 0 | 0 | 1 | 1/2 | 1/2 | None |
| product1 | pi0 | 0.0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | + |
| product2 | e+ | 1.0 | 0 | -1 | 0 | 0 | 0 | 0 | 0 | None |
| product3 | nu_e | 0.0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | None |
| checking | checking | True | True | True | True | True | False | False | False | None |

```

G
reactant1  None
product1   -
product2   None
product3   None
checking   None

```

```

          reaction Possibility      Strong \
0  $K^+ \to \pi^0 + e^+ + \nu_e$      Yes  S,I,I3 violation

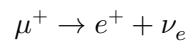
```

```

          EM Weak
0  S,I3 violation  Yes

```

25



```

[ ]: reactant = ['mu+']
      product = ['e+', 'nu_e']
      reaction,result=reaction_checker(reactant,product)
      display(reaction,result)
      total_result = pd.concat([total_result, result], ignore_index=True)

```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|----------|------|------|------|-------|-------|------|------|------|------|---|
| reactant1 | mu+ | 1.0 | 0 | 0 | -1 | 0 | 0 | 0 | 0 | None | |
| product1 | e+ | 1.0 | 0 | -1 | 0 | 0 | 0 | 0 | 0 | None | |
| product2 | nu_e | 0.0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | None | |
| checking | checking | True | True | True | False | True | True | True | True | None | |

```

G
reactant1  None
product1   None
product2   None
checking   None

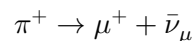
```

```

          reaction      Possibility Strong  EM Weak
0  $\mu^+ \to e^+ + \nu_e$  L_mu violation    No  No  No

```

26



```

[ ]: reactant = ['pi+']
      product = ['mu+', '-nu_mu']
      reaction,result=reaction_checker(reactant,product)
      display(reaction,result)
      total_result = pd.concat([total_result, result], ignore_index=True)

```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|------|-----|---|-----|------|-------|---|---|----|------|---|
| reactant1 | pi+ | 1.0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | None | |
| product1 | mu+ | 1.0 | 0 | 0 | -1 | 0 | 0 | 0 | 0 | None | |

| | | | | | | | | | | |
|----------|----------|------|------|------|-------|------|------|-------|-------|------|
| product2 | -nu_mu | -0.0 | 0 | 0 | -1 | 0 | 0 | 0 | 0 | None |
| checking | checking | True | True | True | False | True | True | False | False | None |

| | |
|-----------|------|
| | G |
| reactant1 | - |
| product1 | None |
| product2 | None |
| checking | None |

| | reaction | Possibility | Strong | EM | Weak |
|---|---|----------------|--------|----|------|
| 0 | $\pi^+ \rightarrow \mu^+ + \bar{\nu}_\mu$ | L_mu violation | No | No | No |

27

$$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$$

```
[ ]: reactant = ['pi-']
product = ['mu-', '-nu_mu']
reaction,result=reaction_checker(reactant,product)
display(reaction,result)
total_result = pd.concat([total_result, result], ignore_index=True)
```

| | name | Q | B | L_e | L_mu | L_tau | S | I | I3 | C | \ |
|-----------|----------|------|------|------|------|-------|------|-------|-------|------|---|
| reactant1 | pi- | -1.0 | 0 | 0 | 0 | 0 | 0 | 1 | -1 | None | |
| product1 | mu- | -1.0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | None | |
| product2 | -nu_mu | -0.0 | 0 | 0 | -1 | 0 | 0 | 0 | 0 | None | |
| checking | checking | True | True | True | True | True | True | False | False | None | |

| | |
|-----------|------|
| | G |
| reactant1 | - |
| product1 | None |
| product2 | None |
| checking | None |

| | reaction | Possibility | Strong | EM | \ |
|---|---|-------------|----------------|--------------|---|
| 0 | $\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$ | Yes | I,I3 violation | I3 violation | |

Weak

0 Yes

```
[ ]: total_result.index+=1
total_result
```

| | reaction | Possibility | \ |
|---|---|-------------|---|
| 1 | $p + p \rightarrow n + \pi^+ + p$ | Yes | |
| 2 | $p + p \rightarrow \bar{n} + \pi^+ + p + \pi^0$ | B violation | |
| 3 | $\pi^+ + p \rightarrow \Sigma^+ + p$ | B violation | |
| 4 | $\pi^+ + p \rightarrow \Sigma^+ + K^+$ | Yes | |
| 5 | $\pi^+ + p \rightarrow \Sigma^+ + p + \pi^0$ | B violation | |
| 6 | $\pi^+ + p \rightarrow \Xi^0$ | Q violation | |

| | | |
|----|--|----------------|
| 7 | $\Sigma^+ + p \rightarrow \Lambda^0 + \pi^+ + p$ | Yes |
| 8 | $\Sigma^- + p \rightarrow \Xi^- + p$ | Yes |
| 9 | $\Xi^0 \rightarrow e^- + p + \bar{\nu}_e$ | Yes |
| 10 | $\Xi^0 \rightarrow \Lambda^0 + \pi^0$ | Yes |
| 11 | $\Xi^- \rightarrow \Lambda^0 + \pi^-$ | Yes |
| 12 | $\Omega^- \rightarrow \Lambda^0 + \pi^-$ | Yes |
| 13 | $\Omega^- \rightarrow \Lambda^0 + K^-$ | Yes |
| 14 | $\Omega^- \rightarrow \Xi^0 + \pi^-$ | Yes |
| 15 | $\Omega^- \rightarrow \Xi^0 + K^-$ | Yes |
| 16 | $\Xi^- \rightarrow \Sigma^0 + \mu^- + \bar{\nu}_\mu$ | Yes |
| 17 | $\Xi^- \rightarrow e^- + p + \bar{\nu}_e + \pi^-$ | Yes |
| 18 | $\Sigma^0 \rightarrow \Lambda^0 + \gamma + \gamma$ | Yes |
| 19 | $\Sigma^0 \rightarrow \Lambda^0 + e^- + e^+$ | Yes |
| 20 | $K^+ \rightarrow \mu^+ + \nu_\mu$ | Yes |
| 21 | $K^- \rightarrow \mu^- + \bar{\nu}_\mu$ | Yes |
| 22 | $K^0 \rightarrow \pi^+ + \pi^-$ | Yes |
| 23 | $K^0 \rightarrow \mu^+ + \mu^-$ | Yes |
| 24 | $K^+ \rightarrow \pi^0 + e^+ + \nu_e$ | Yes |
| 25 | $\mu^+ \rightarrow e^+ + \nu_e$ | L_mu violation |
| 26 | $\pi^+ \rightarrow \mu^+ + \bar{\nu}_\mu$ | L_mu violation |
| 27 | $\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$ | Yes |

| | Strong | EM | Weak |
|----|------------------|----------------|------|
| 1 | Yes | Yes | Yes |
| 2 | No | No | No |
| 3 | No | No | No |
| 4 | Yes | Yes | Yes |
| 5 | No | No | No |
| 6 | No | No | No |
| 7 | Yes | Yes | Yes |
| 8 | S,I,I3 violation | S,I3 violation | Yes |
| 9 | S violation | S violation | Yes |
| 10 | S,I,I3 violation | S,I3 violation | Yes |
| 11 | S,I,I3 violation | S,I3 violation | Yes |
| 12 | S,I,I3 violation | S,I3 violation | Yes |
| 13 | S,I,I3 violation | S,I3 violation | Yes |
| 14 | S,I,I3 violation | S,I3 violation | Yes |
| 15 | Yes | Yes | Yes |
| 16 | S,I,I3 violation | S,I3 violation | Yes |
| 17 | S violation | S violation | Yes |
| 18 | I violation | Yes | Yes |
| 19 | I violation | Yes | Yes |
| 20 | S,I,I3 violation | S,I3 violation | Yes |
| 21 | S,I,I3 violation | S,I3 violation | Yes |
| 22 | S,I,I3 violation | S,I3 violation | Yes |
| 23 | S,I,I3 violation | S,I3 violation | Yes |
| 24 | S,I,I3 violation | S,I3 violation | Yes |

| | | | |
|----|-----------------|--------------|-----|
| 25 | No | No | No |
| 26 | No | No | No |
| 27 | I, I3 violation | I3 violation | Yes |

```
[ ]: print(total_result.to_markdown())
```

| | reaction | Possibility | Strong |
|----|---|-------------|----------|
| EM | Weak | | |
| 1 | $p + p \rightarrow n + \pi^+ + p$ | Yes | Yes |
| 2 | $p + p \rightarrow \bar{n} + \pi^+ + p + \pi^0$ | B violation | No |
| 3 | $\pi^+ + p \rightarrow \Sigma^+ + p$ | B violation | No |
| 4 | $\pi^+ + p \rightarrow \Sigma^+ + K^+$ | Yes | Yes |
| 5 | $\pi^+ + p \rightarrow \Sigma^+ + p + \pi^0$ | B violation | No |
| 6 | $\pi^+ + p \rightarrow \Xi^0$ | Q violation | No |
| 7 | $\Sigma^+ + p \rightarrow \Lambda^0 + \pi^+ + p$ | Yes | Yes |
| 8 | $\Sigma^- + p \rightarrow \Xi^- + p$ violation S, I3 violation | Yes | S, I, I3 |
| 9 | $\Xi^0 \rightarrow e^- + p + \bar{\nu}_e$ violation S violation | Yes | S |
| 10 | $\Xi^0 \rightarrow \Lambda^0 + \pi^0$ violation S, I3 violation | Yes | S, I, I3 |
| 11 | $\Xi^- \rightarrow \Lambda^0 + \pi^-$ violation S, I3 violation | Yes | S, I, I3 |
| 12 | $\Omega^- \rightarrow \Lambda^0 + \pi^-$ violation S, I3 violation | Yes | S, I, I3 |
| 13 | $\Omega^- \rightarrow \Lambda^0 + K^-$ violation S, I3 violation | Yes | S, I, I3 |
| 14 | $\Omega^- \rightarrow \Xi^0 + \pi^-$ violation S, I3 violation | Yes | S, I, I3 |
| 15 | $\Omega^- \rightarrow \Xi^0 + K^-$ | Yes | Yes |
| 16 | $\Xi^- \rightarrow \Sigma^0 + \mu^- + \bar{\nu}_\mu$ violation S, I3 violation | Yes | S, I, I3 |
| 17 | $\Xi^- \rightarrow e^- + p + \bar{\nu}_e + \pi^-$ violation S violation | Yes | S |
| 18 | $\Sigma^0 \rightarrow \Lambda^0 + \gamma$ violation Yes | Yes | I |
| 19 | $\Sigma^0 \rightarrow \Lambda^0 + e^- + e^+$ violation Yes | Yes | I |

| | | | |
|-----------|---|----------------|--------|
| 20 | $K^+ \rightarrow \mu^+ + \nu_\mu$ | Yes | S,I,I3 |
| violation | S,I3 violation Yes | | |
| 21 | $K^- \rightarrow \mu^- + \bar{\nu}_\mu$ | Yes | S,I,I3 |
| violation | S,I3 violation Yes | | |
| 22 | $K^0 \rightarrow \pi^+ + \pi^-$ | Yes | S,I,I3 |
| violation | S,I3 violation Yes | | |
| 23 | $K^0 \rightarrow \mu^+ + \mu^-$ | Yes | S,I,I3 |
| violation | S,I3 violation Yes | | |
| 24 | $K^+ \rightarrow \pi^0 + e^+ + \nu_e$ | Yes | S,I,I3 |
| violation | S,I3 violation Yes | | |
| 25 | $\mu^+ \rightarrow e^+ + \nu_e$ | L_mu violation | No |
| No | No | | |
| 26 | $\pi^+ \rightarrow \mu^+ + \bar{\nu}_\mu$ | L_mu violation | No |
| No | No | | |
| 27 | $\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$ | Yes | I,I3 |
| violation | I3 violation Yes | | |

0.5.1 So I get the whole answer

| reaction | Possibility | Strong | EM | Weak |
|---|-------------|---------------------|-------------------|------|
| 1 $p + p \rightarrow n + \pi^+ + p$ | Yes | Yes | Yes | Yes |
| 2 $p + p \rightarrow \bar{n} + \pi^+ + p + \pi^0$ | B violation | No | No | No |
| 3 $\pi^+ + p \rightarrow \Sigma^+ + p$ | B violation | No | No | No |
| 4 $\pi^+ + p \rightarrow \Sigma^+ + K^+$ | Yes | Yes | Yes | Yes |
| 5 $\pi^+ + p \rightarrow \Sigma^+ + p + \pi^0$ | B violation | No | No | No |
| 6 $\pi^+ + p \rightarrow \Xi^0$ | Q violation | No | No | No |
| 7 $\Sigma^+ + p \rightarrow \Lambda^0 + \pi^+ + p$ | Yes | Yes | Yes | Yes |
| 8 $\Sigma^- + p \rightarrow \Xi^- + p$ | Yes | S,I,I3 violation | S,I3 violation | Yes |
| 9 $\Xi^0 \rightarrow e^- + p + \bar{\nu}_e$ | Yes | S violation | S violation | Yes |
| 10 $\Xi^0 \rightarrow \Lambda^0 + \pi^0$ | Yes | S,I,I3 violation | S,I3 violation | Yes |
| 11 $\Xi^- \rightarrow \Lambda^0 + \pi^-$ | Yes | S,I,I3 violation | S,I3 violation | Yes |
| 12 $\Omega^- \rightarrow \Lambda^0 + \pi^-$ | Yes | S,I,I3 violation | S,I3 violation | Yes |
| 13 $\Omega^- \rightarrow \Lambda^0 + K^-$ | Yes | S,I,I3 violation | S,I3 violation | Yes |
| 14 $\Omega^- \rightarrow \Xi^0 + \pi^-$ | Yes | S,I,I3 violation | S,I3 violation | Yes |
| 15 $\Omega^- \rightarrow \Xi^0 + K^-$ | Yes | Yes | Yes | Yes |
| 16 $\Xi^- \rightarrow \Sigma^0 + \mu^- + \bar{\nu}_\mu$ | Yes | S,I,I3 violation | S,I3 violation | Yes |
| 17 $\Xi^- \rightarrow e^- + p + \bar{\nu}_e + \pi^-$ | Yes | S violation | S violation | Yes |
| 18 $\Sigma^0 \rightarrow \Lambda^0 + \gamma + \gamma$ | Yes | I violation | Yes | Yes |
| 19 $\Sigma^0 \rightarrow \Lambda^0 + e^- + e^+$ | Yes | I violation | Yes | Yes |

| | reaction | Possibility | Strong | EM | Weak |
|----|---|-------------------|---------------------|-------------------|------|
| 20 | $K^+ \rightarrow \mu^+ + \nu_\mu$ | Yes | S,I,I3 violation | S,I3 violation | Yes |
| 21 | $K^- \rightarrow \mu^- + \bar{\nu}_\mu$ | Yes | S,I,I3 violation | S,I3 violation | Yes |
| 22 | $K^0 \rightarrow \pi^+ + \pi^-$ | Yes | S,I,I3 violation | S,I3 violation | Yes |
| 23 | $K^0 \rightarrow \mu^+ + \mu^-$ | Yes | S,I,I3 violation | S,I3 violation | Yes |
| 24 | $K^+ \rightarrow \pi^0 + e^+ + \nu_e$ | Yes | S,I,I3 violation | S,I3 violation | Yes |
| 25 | $\mu^+ \rightarrow e^+ + \nu_e$ | L_mu violation | No | No | No |
| 26 | $\pi^+ \rightarrow \mu^+ + \bar{\nu}_\mu$ | L_mu violation | No | No | No |
| 27 | $\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$ | Yes | I,I3 violation | I3 violation | Yes |