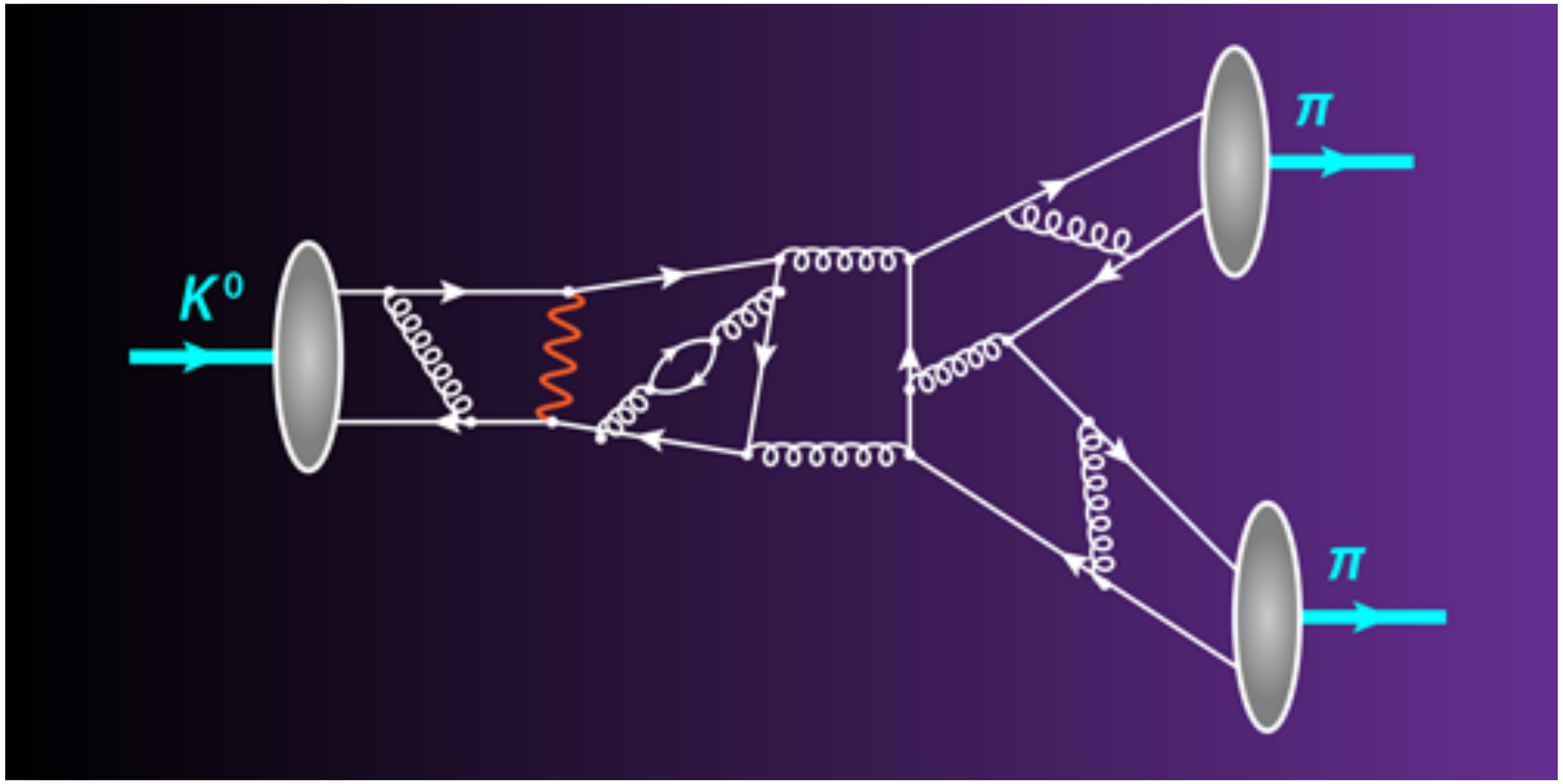
Particle Physics Lecture 6



PHYS 246 class 6
Fall 2025
J Noronha-Hostler

https://jnoronhahostler.github.io/IntroductionToComputationalPhysics/intro.html

Announcements/notes

- Oct 7th, there's a CS+Phys lunch:
  Date/Time: Tuesday, October 7 at 12pm to 1:30pm
  Location: 204 Loomis Lab
  To RSVP click here.
- TBD

Particle Physics 101

Smallest building blocks of matter

- There are many, many different types of particles!
- You probably know of a few already like:
  - Electrons e^-
  - Protons p or neutrons n
  - Photons γ
  - Pions π
- These are all different types of particles and if you take Subatomic physics (either with me or someone else), you'll learn about them more

When particles decay

Particles are weird

- Let's say we have particle A. The vast majority of particles are "unstable" which means that they will spontaneously break apart into smaller particles after some time τ (called the lifetime)
- "Parent" particles decay into their "children" particles: $A \to B + C$
- Certain properties need to be conserved (we won't go into all of them) but for this class it's important to know that electric charge needs to be conserved $Q_A = Q_B + Q_C$

Kaon decays

STRANGE particles!

- Kaons are very strange particles
  - Literally, they "carry" a strangeness number of $S = \pm 1$
  - While other kaons exist, we'll consider neutral kaons $Q_{K^0} = 0$
- Kaons are unstable particles and can decay into pions:
  - $K^0 \to \pi^+\pi^-$
  - $K^0 \to \pi^0\pi^0$
- Kaons are extremely tiny, length scales of $L_{K^0} \sim 10^{-15}\,m = 1\,fm$
  - fm is femto-meter

Relativity

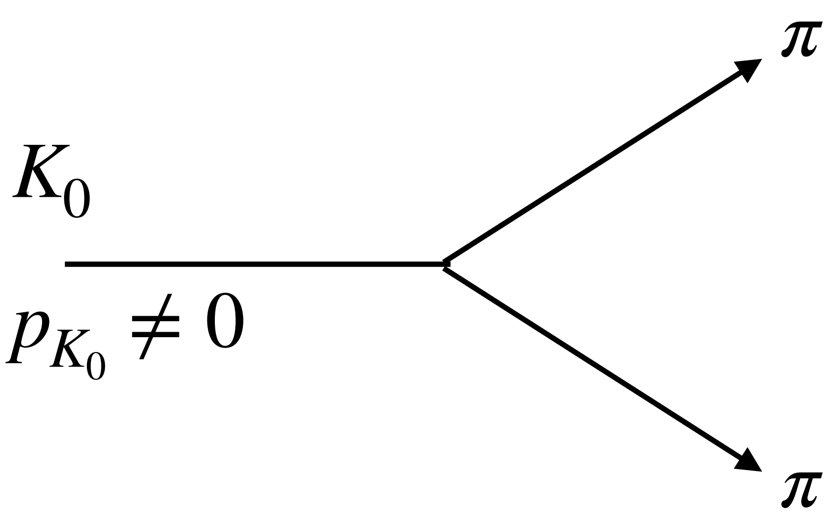
Small and FAST

- Recall relativistic energy is $E = \sqrt{m^2c^4 + p^2c^2}$
- In relativistic systems, mass is no longer conserved.
- However, we can talk about the **invariant mass**
  - $m_0 = \frac{1}{c^2}\sqrt{E^2 - p^2c^2}$
  - Frame independent!
  - Can think of as the rest mass as well when $p \to 0$
  - Experimentalists measure the invariant mass to find particles

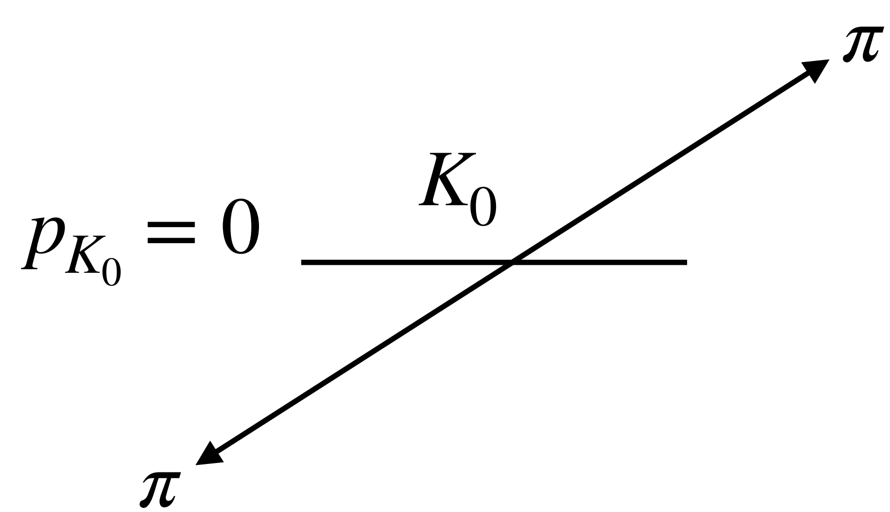
Frames of reference

Lab frame vs rest frame

Lab Frame

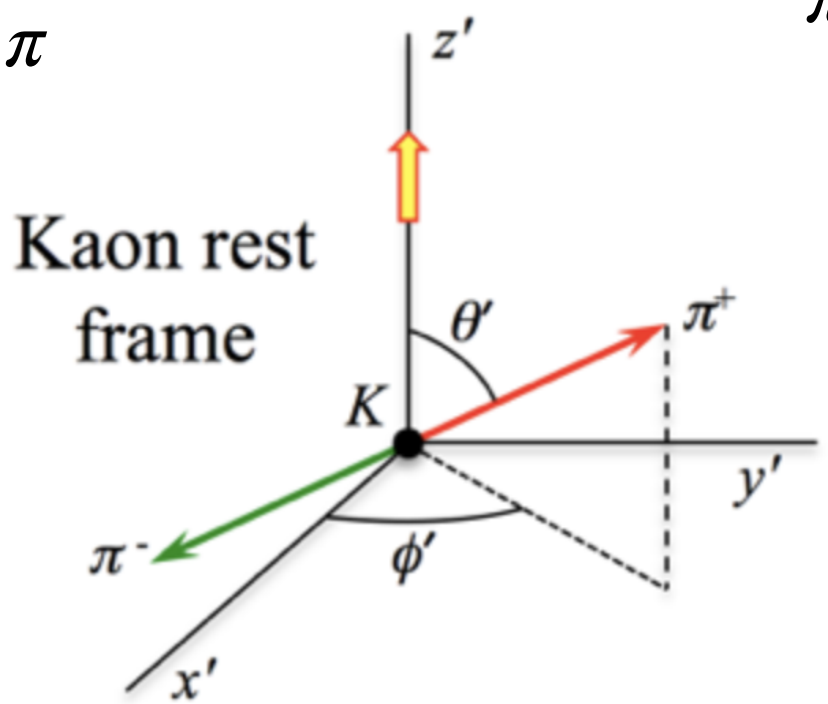


Rest Frame



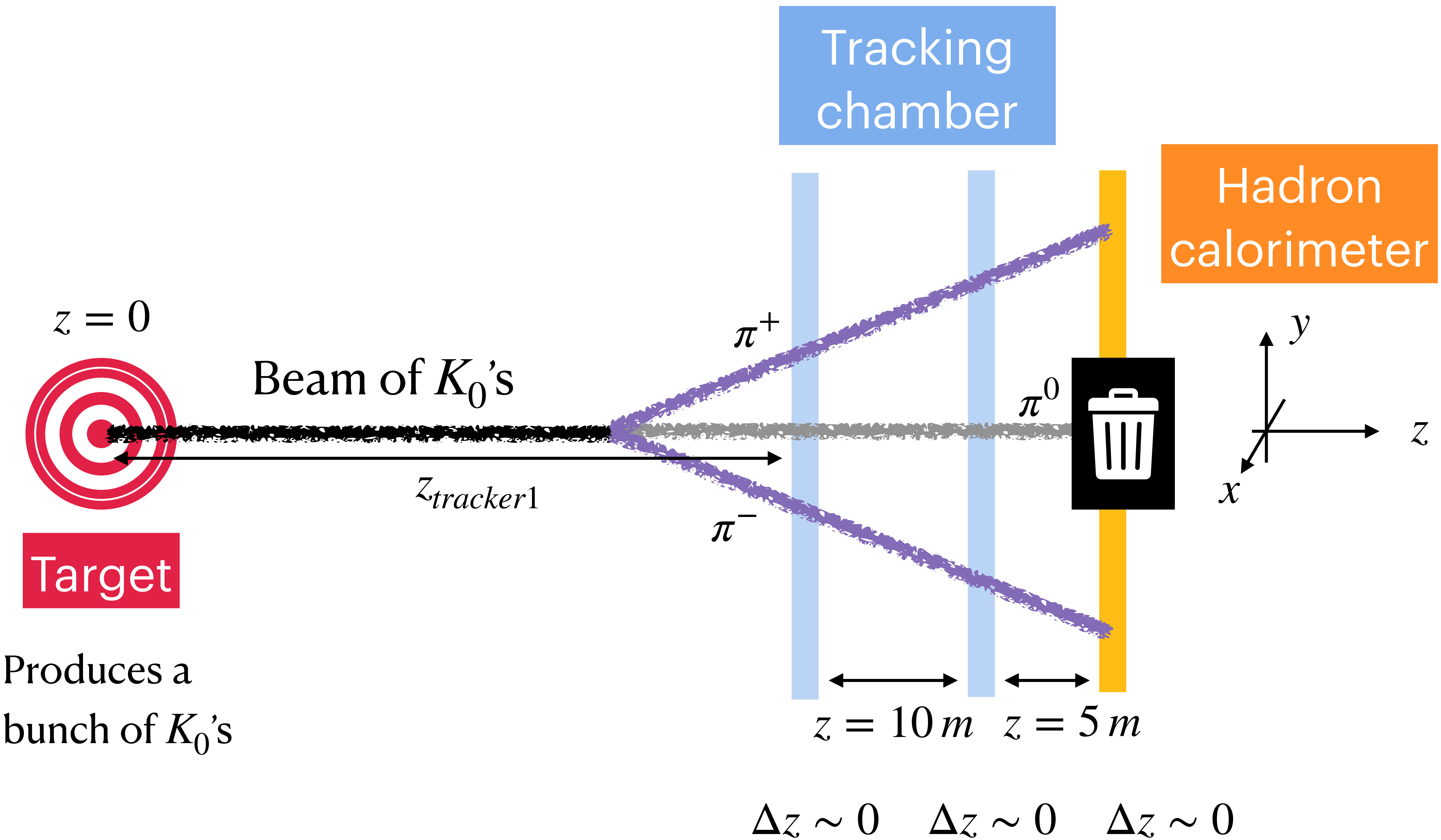
All kaons have the same initial energy

$$E_{K_0} = 60\,GeV$$



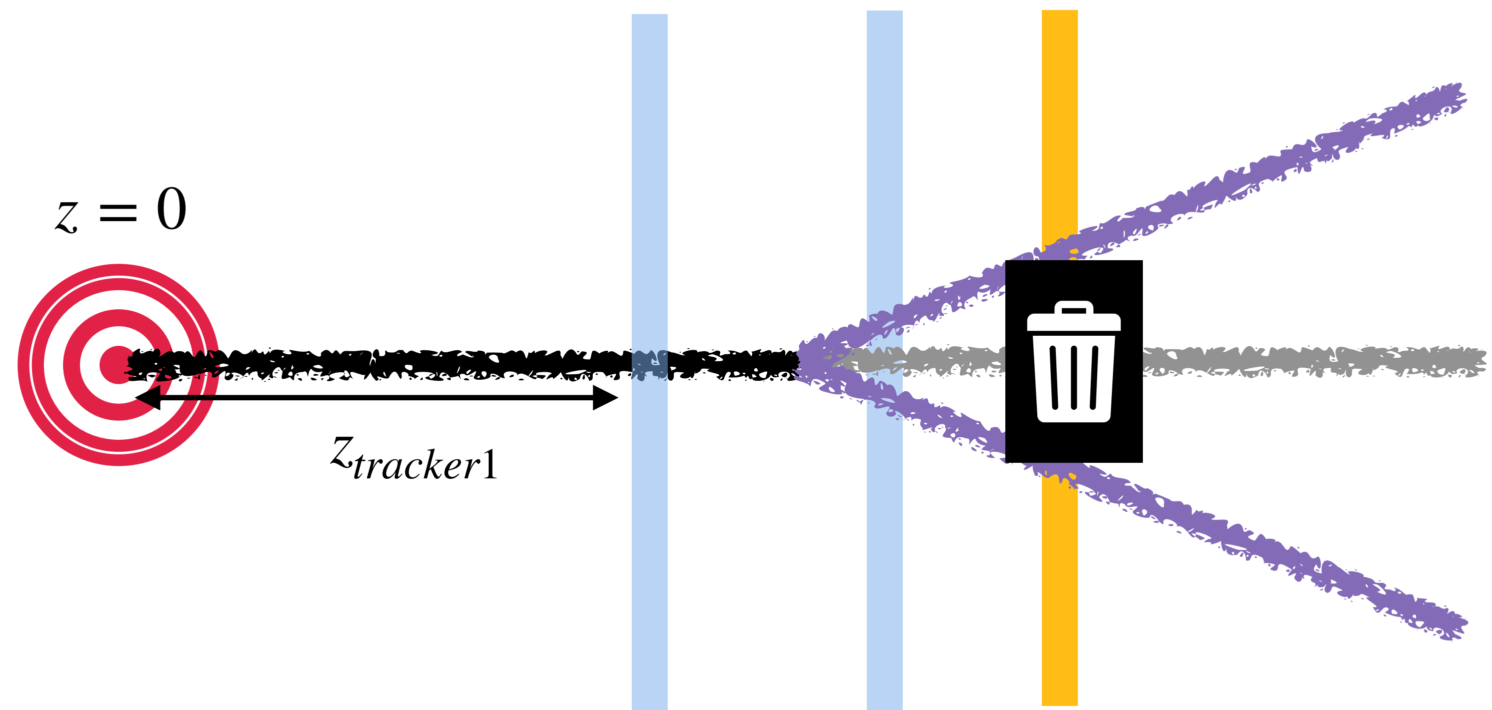
How do we measure insanely fast and tiny particles?

Beams

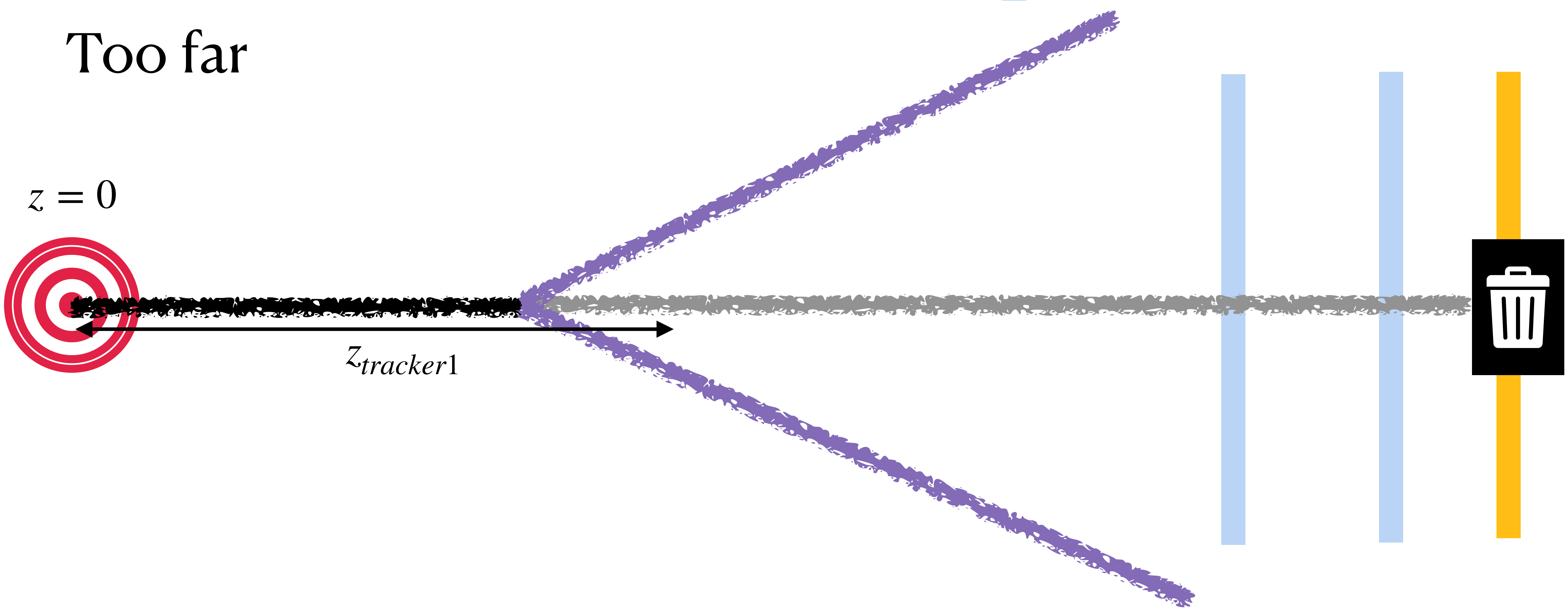


Optimizing $z_{tracker1}$

Too close

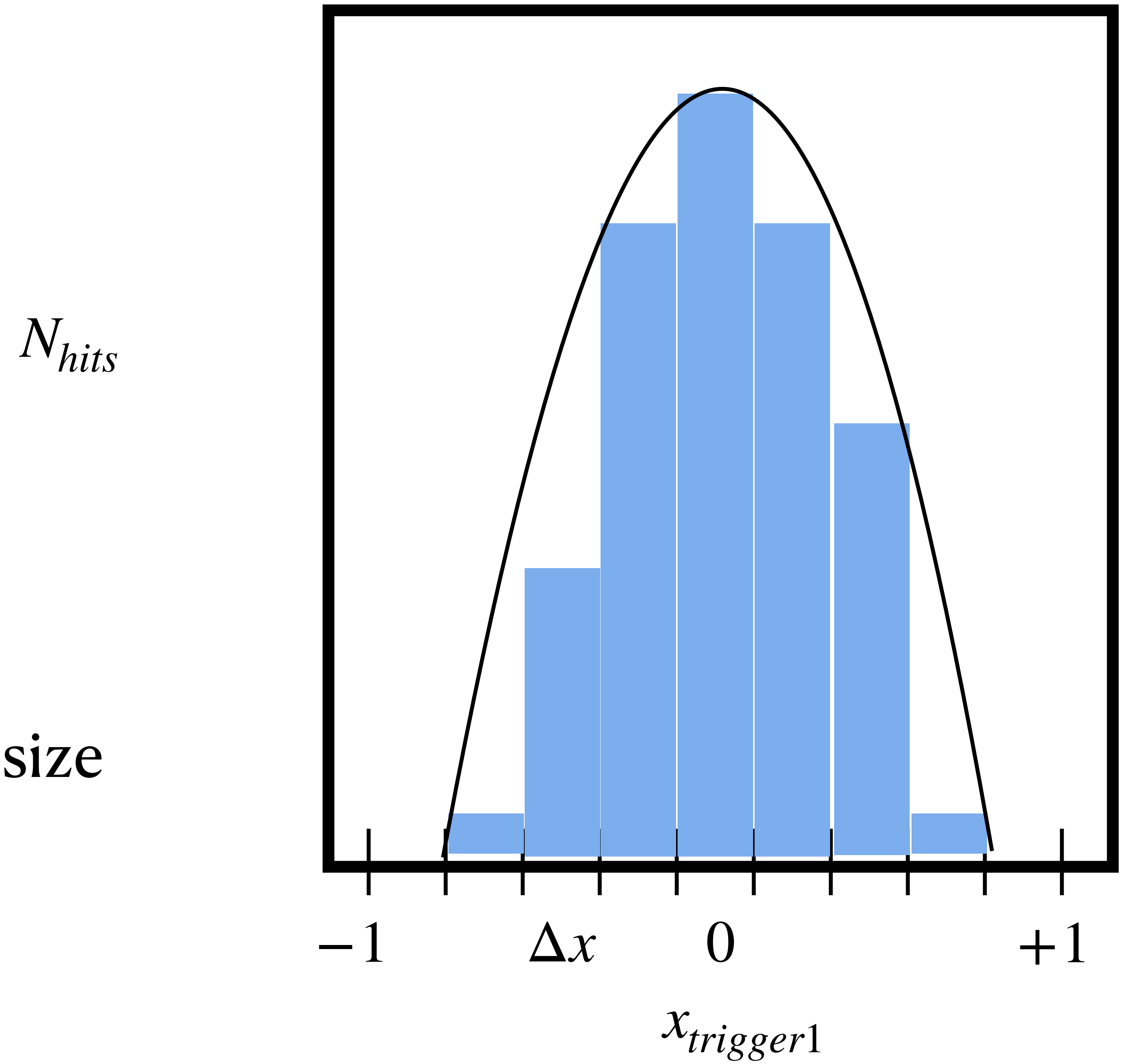


Too far



Histograms

Particle and nuclear physicists's BFF



Δx Bin size

Python help

Logical

- np.logical
  - out=np.logical_and(x<0.6,y>1)
  - If x=0.5 and y=1.1, then out=true
  - If x=0.7 and y=1.1, then out=false
  - If x=0.5 and y=0.9, then out=false
  - If x=0.7 and y=0.9, then out=false

- np.logical_not
  - out=np.logical_not(x<0.6,y>1)
  - If x=0.5 and y=1.1, then out=false
  - If x=0.7 and y=1.1, then out=false
  - If x=0.5 and y=0.9, then out=false
  - If x=0.7 and y=0.9, then out=true

How to deal with multiple constraints: don’t use a million nested if statements!

Python help

Mask

```python
x = np.array([0, 0.5, 1, 1.5, 2, 2.5])
y = np.array([1, 1.5, 2, 2.5, 3, 3.5])
mask = np.logical_not(x < 0.6, y > 1)
z = x[mask]
print(z)
print(mask)
```

[27] ✓ 0.0s

```
[1.  1.5 2.  2.5]
[False False  True  True  True  True]
```

```python
x = np.array([0, 0.5, 1, 1.5, 2, 2.5])
y = np.array([1, 1.5, 2, 2.5, 3, 3.5])
mask = np.logical_and(x < 0.6, y > 1)
z = x[mask]
print(z)
print(mask)
```

[28] ✓ 0.0s

```
[0.5]
[False  True False False False False]
```

Selects elements of the array that are “true”

Strategies to code when the physics is new?

Real life scenario…

- Often when you enter a new research group, the physics is totally new and you're asked to start right away. How do you approach such a problem? Strategies?