EIC fast Monte Carlo Overview

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EIC fast Monte Carlo

- C++ based fast MC which outputs root files and text file for GEMC input

Cpp Script(TDISMC_EIC.cpp)-requires as input: range of Q2 and x and uses a header file for beam energy, beam polarization, structure function parameterization, physical constants, etc.
Calls 4 quantities...

1. CTEQ6 PDF table
2. f2π with various parameterization (the header file defines the structure function)
3. F2N, nucleon structure function (the header file defines the structure function)
4. Beam smearing function

Event generation
Random number generation uses TRandom3 (run3.SetSeed(#))

- Defining electron and proton/deuterium beam...
  - kbeamMC=kbeam*ran3.Gaus(1,eD/k), where eD/k=7.1e-4 is the fractional energy spread normalized emittance value
  - kbeamMCx=kbeamMC*ran3.Gaus(0,ϴex), where ϴex is smearing
  - PbeamMC=Pbeam*ran3.Gaus(0, iDp/p), where iDp/p=3e-4
  - PbeamMCx=PbeamMC*ran3.Gaus(0, ϴix)

Breaking Down Important Scripts

Currently have different scripts for different physics processes

- TDISMC_EIC.cpp : pion structure function with ep scattering
- TDISMC_EICn.cpp : pion structure function with eD scattering
- TDISMC_EICK.cpp : kaon structure function with ep scattering

All gather physics from here

- cteq/ : cteqpdf.h and data based call files (c++ wrapper)
- cteq-tbls/ : nucleon PDFs table
- tim_hobbs/ : various regularization form for pion FF

Collider vs. fixed target

Careful with kinematic definitions

- Original code was written for fixed target – found and fixed several instances with restrictions that apply to fixed target, but not to collider
- Examples:
  - Measurable proton range (for fixed target given by TPC – imposes limits on k, z)
  - Removed fixed target restrictions on x for structure function calculations

Kinematic Variables

$$Q^2 = Q^2_{max} uu + Q^2_{min}(1 - uu)$$

$$uu = ran3.Uniform(\,)$$

$$x_{Bj} = (x_{min})^{1-uu}(x_{max})^{uu}$$

$$x_\pi = \frac{x_{TDIS}}{1-(p2)_z}$$

$$(p2)_z = gRandom -> Uniform(1)$$

$$y_\pi = \frac{(pScatPion)_{rest}(qVirt)_{rest}}{(pScatPion)_{rest}(kIncident)_{rest}}$$

$$t_\pi = E^2_\pi - |pScatPion.v3|^2$$

$$x_D = x_{Bj}\left(\frac{M_{proton}}{M_{ion}}\right)$$

$$y_D = \frac{Q^2}{x_D(2p \cdot k)}$$

Generation of GEMC Input files

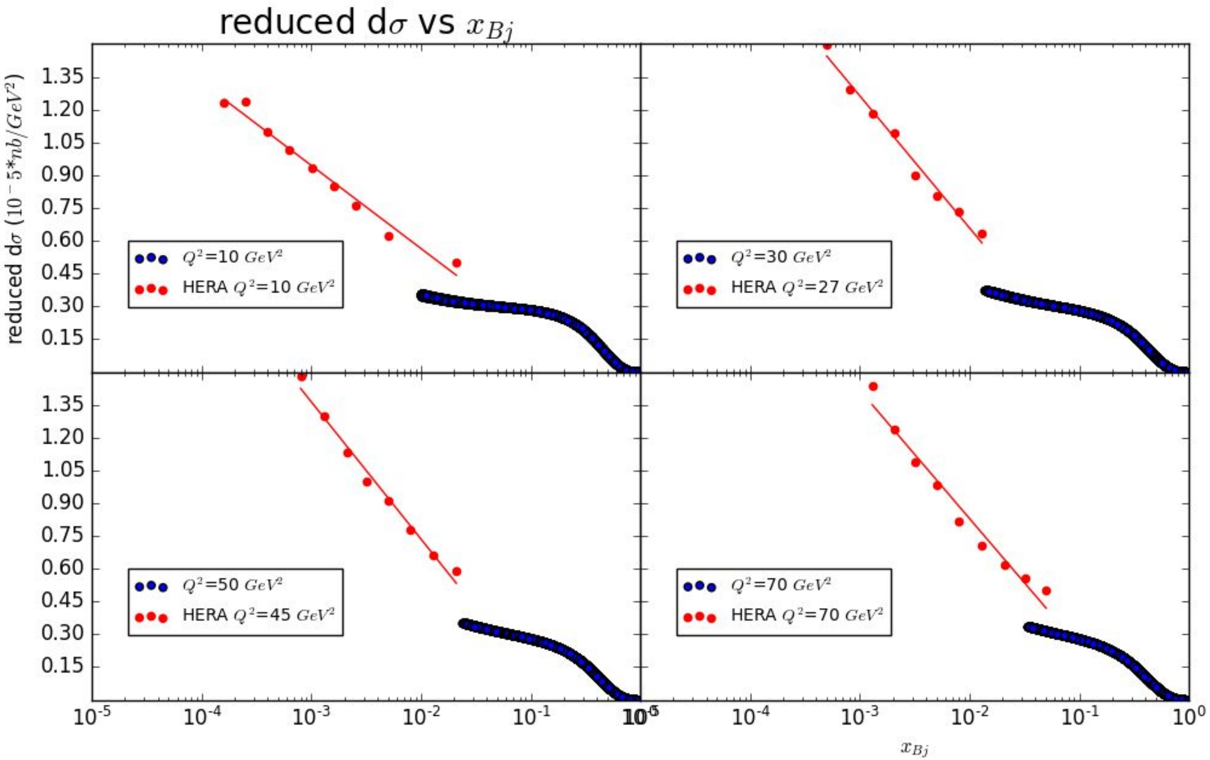
```
input_LUND="TDIS_lund_ek.txt"
output_EVIO="TDIS_lund_ek.evio"
gCARD="~/ResearchNP/gemc/detectors/gcard/detl_hybrid_full.gcard"

echo "Running input $input_LUND for geometry $gCARD"
eval "gemc -INPUT_GEN_FILE=\"LUND,$input_LUND\" -OUTPUT=\"evio, $output_EVIO\" -USE_GUI=0 $gCARD"

echo "Converting $output_EVIO to root file"
eval "evio2root -INPUTF=$input_EVIO"
```

```
         3.424325e-01   8.101021e+01   1.998974e+03   1.0    4.09074
e+00
        1         -1        1      11     0      1    -1.124053e-01
0e+00    0.000000e+00   0.000000e+00
        2          1        1    2212     0      1    -4.978166e+00
0e+00    0.000000e+00   0.000000e+00
        3         -1        1      11     0      1     8.083976e+00
0e+00    0.000000e+00   0.000000e+00
        4          1        1    2212     0      1    -6.112175e+00
0e+00    0.000000e+00   0.000000e+00
                   4    2.209909e-02   9.247694e+00   1.997787e+03
e+03    0.000000e+00
        1         -1        1      11     0      1    -1.059573e-02
0e+00    0.000000e+00   0.000000e+00
        2          1        1    2212     0      1    -5.012030e+00
0e+00    0.000000e+00   0.000000e+00
        3         -1        1      11     0      1     2.671578e+00
0e+00    0.000000e+00   0.000000e+00
        4          1        1    2212     0      1    -2.665217e+01
```

Validation: Reduced cross section compared with HERA

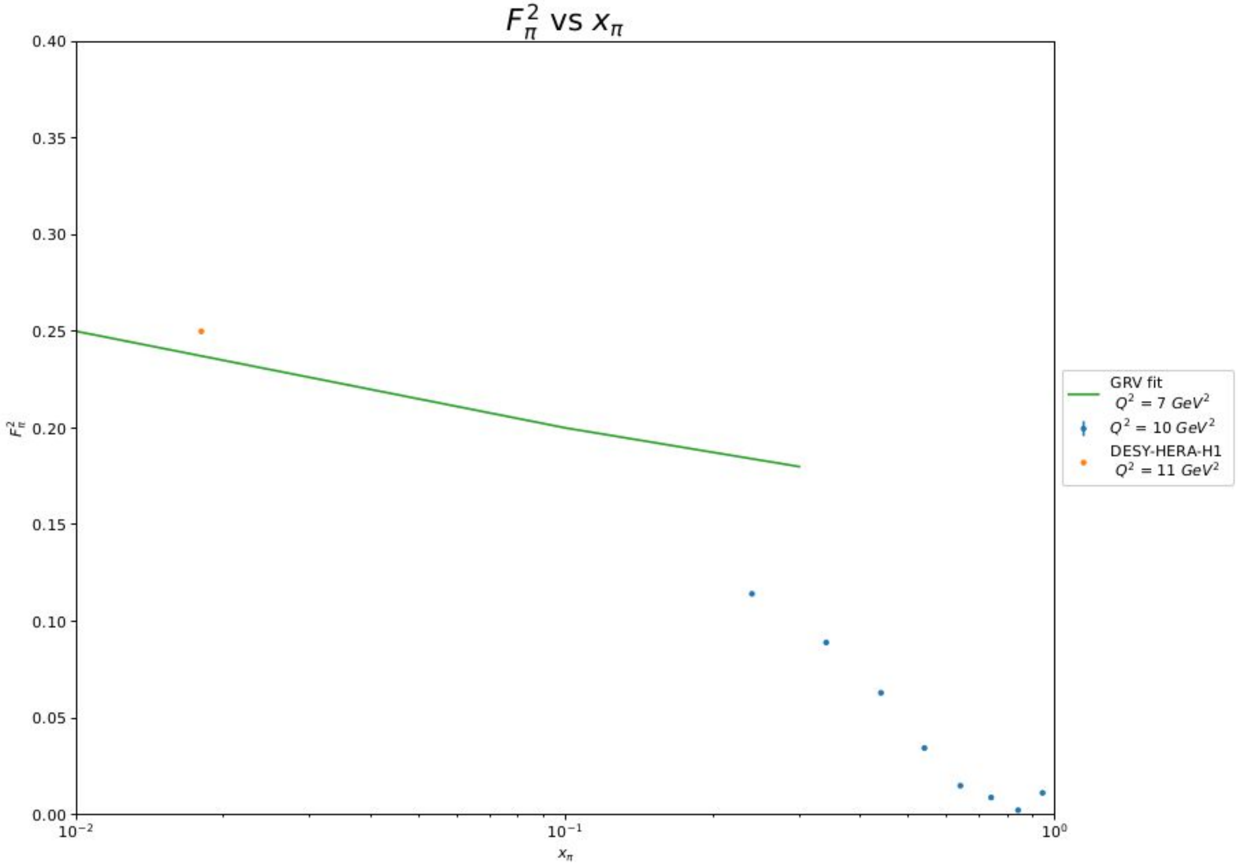
- HERA data from *ZEUS collab, Eur. Phys. J. C 21 (2001)*
- Proton beam = 100 GeV/c
- Electron beam = 5 GeV/c
- x_{Bj}=(0.01-1.0)
- Q^2=(10-100)

$$\tilde{\sigma}^{e^+p} = \left[\frac{2\pi\alpha^2}{xQ^4}Y_+\right]^{-1} \frac{d^2\sigma_{\text{Born}}^{e^+p}}{dx\, dQ^2}$$

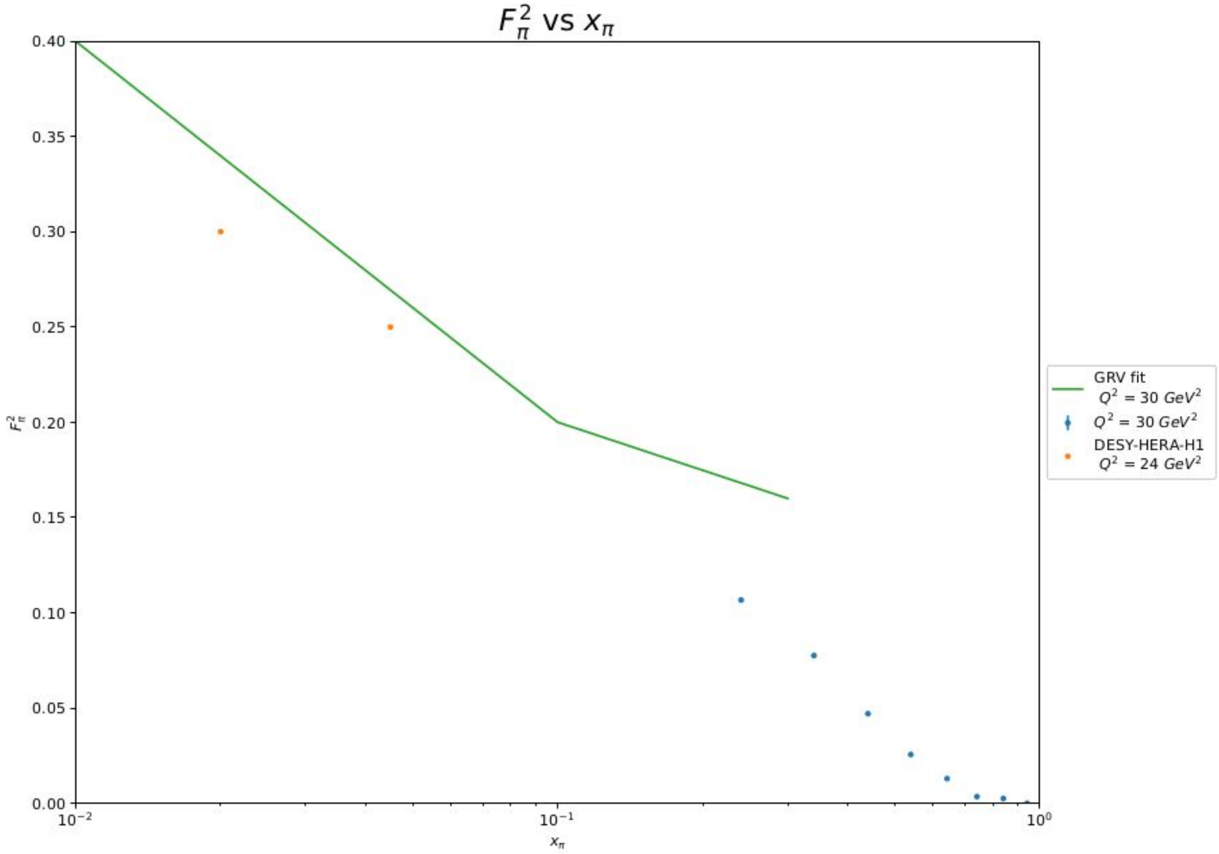


Validation: F2π with GRV fit/DESY-HERA-H1 data [Q^2= 10(7/11) GeV]

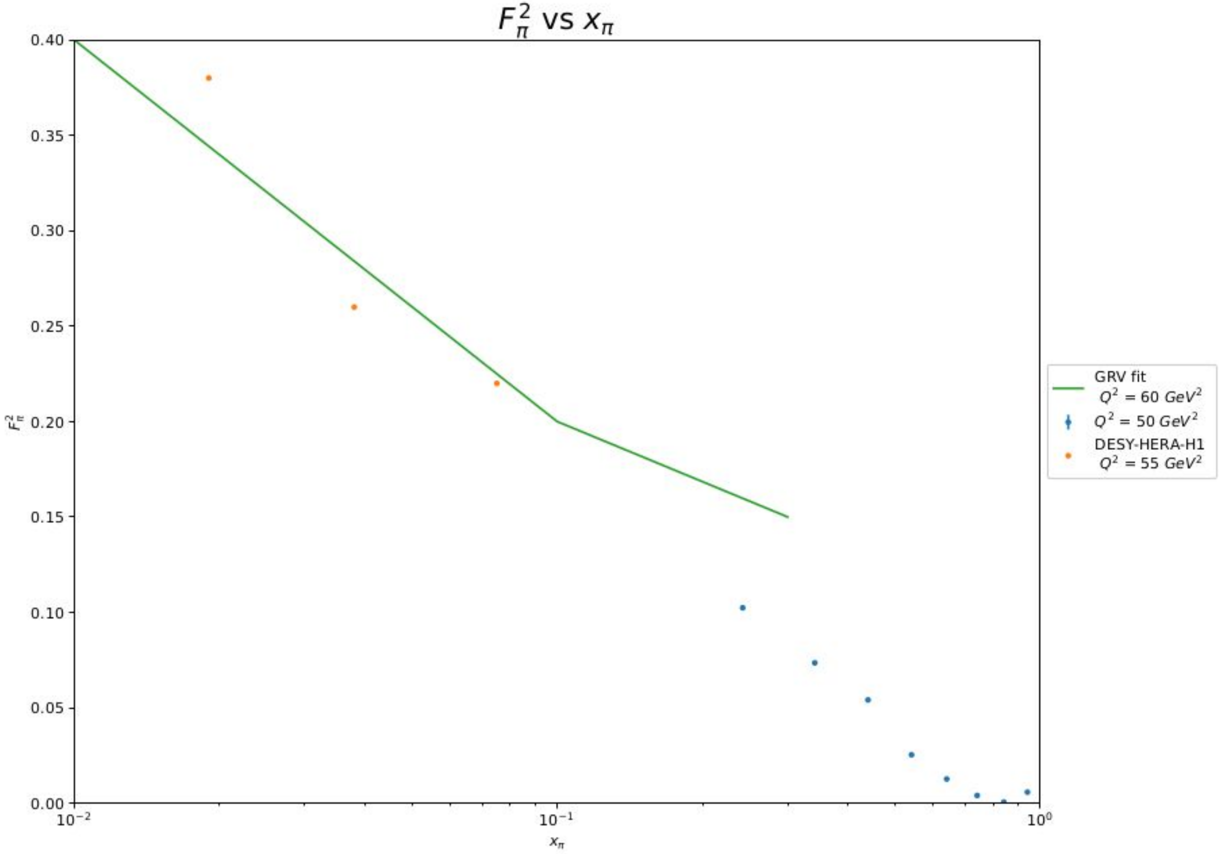
- F2π = (0.461)*F2P
    - (ZEUS Parameterization)
- DESY-HERA-H1 data and GRV fit (for three points) were eyeballed from plots
    - *J. Lan et. al., arXiv preprint (2019) arXiv:1907.01509*
- HERA F2pi data appear to be consistent with the MC projections though the x-dependence seems stronger at higher x



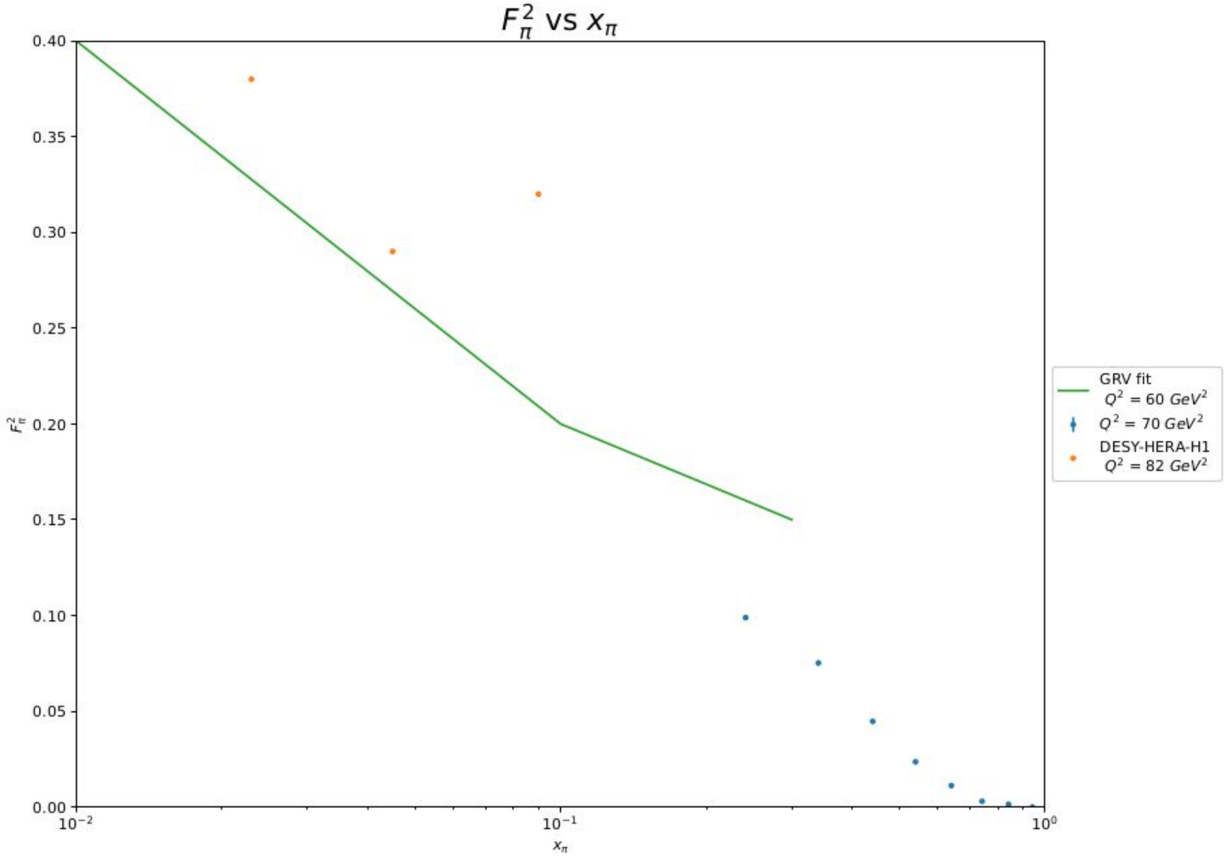
F2π with GRV fit/DESY-HERA-H1 data [Q^2= 30(30/24) GeV]



F2π with GRV fit/DESY-HERA-H1 data [Q^2= 50(60/55) GeV]



F2π with GRV fit/DESY-HERA-H1 data [Q^2= 70(60/82) GeV]



Projected F2π uncertainties – Rik's analytical estimates vs. MC

- The calculated values for f2π, xpi, and the stat uncertainty are very similar especially at low x.
- The high x comparison falls off as my calculated stat uncertainties stay below 1%

Richard	**Q2=10 GeV2**	**no cuts**							
F2pi	nan	0.114	0.089	0.063	0.034	0.015	0.009	0.002	0.011
xpi	nan	0.25	0.35	0.45	0.55	0.65	0.75	0.85	0.95
stat uncern %	nan	0.45%	0.51%	0.54%	0.64%	0.69%	0.67%	0.71%	0.82%
Rik	**Q2=9 GeV2**	**no cuts**							
F2pi	0.152	0.140	0.110	0.088	0.060	0.039	0.020	0.008	nan
xpi	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	nan
stat uncern %	0.42%	0.45%	0.50%	0.55%	0.28%	0.80%	1.90%	3.00%	nan

Q^2 vs x_{Bj} Phase Space