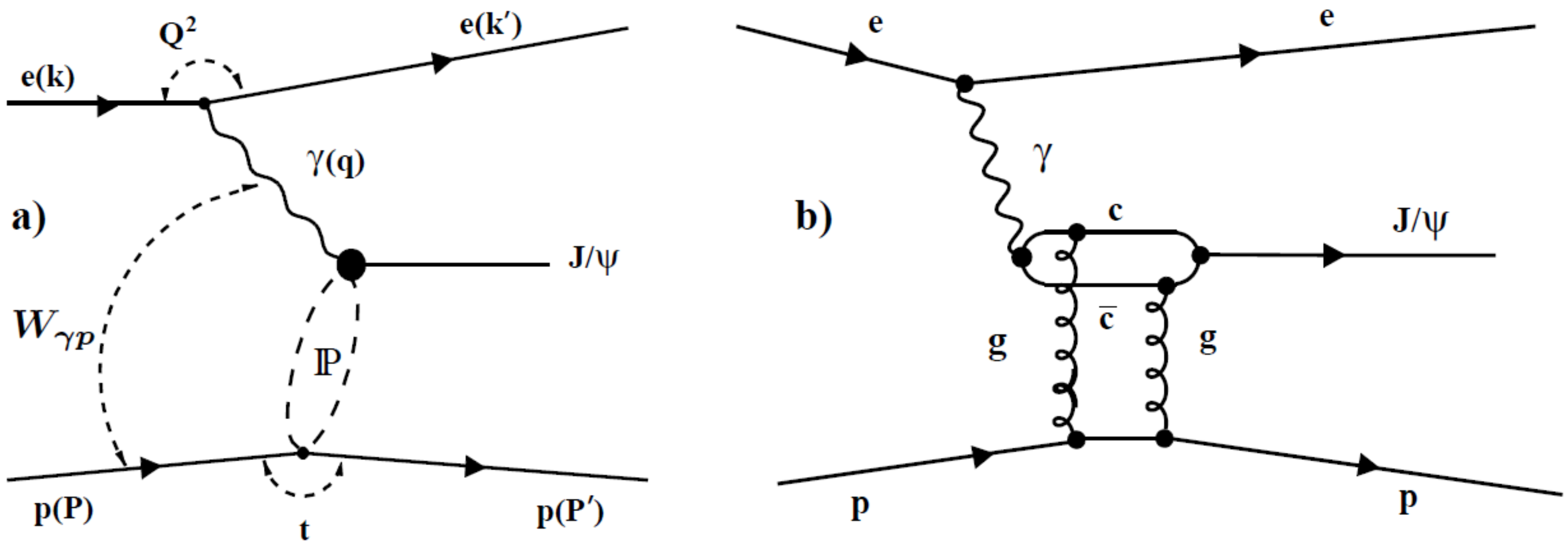
Elastic J/ψ Production in *Pythia6* and *Sartre*

Barak Schmookler

Motivation

- We are interested in the process e + p → e’ + p’ + J/ψ



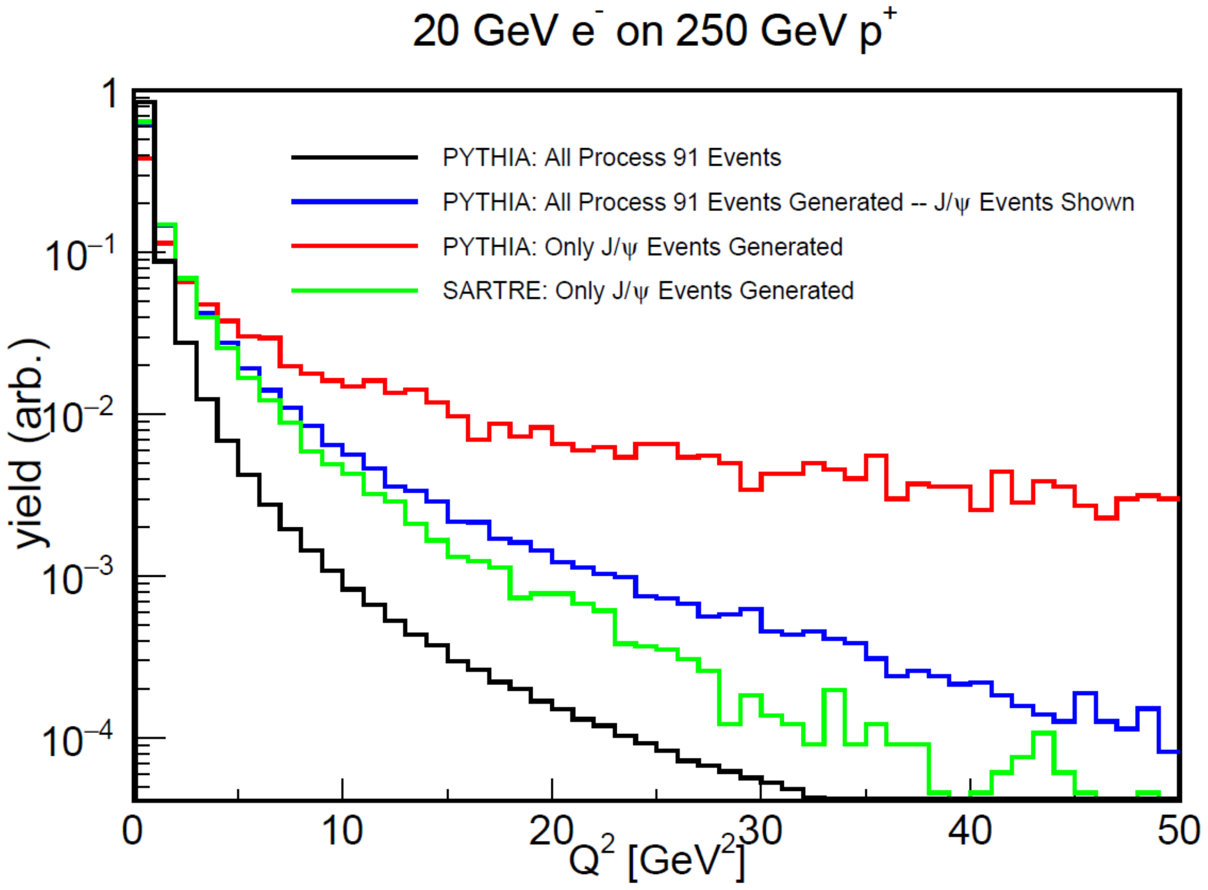
Motivation

- We are interested in the process e + p → e’ + p’ + J/$\psi\ldots$
- …and we want to test how well *Pythia6* and *Sartre* are simulating this process.

- In addition, we want to see how well we can:
  1. Reconstruct this process if we do (not) detect the scattered proton
  2. Separate the elastic production – where the proton remains intact – from the inelastic background – where the proton breaks apart

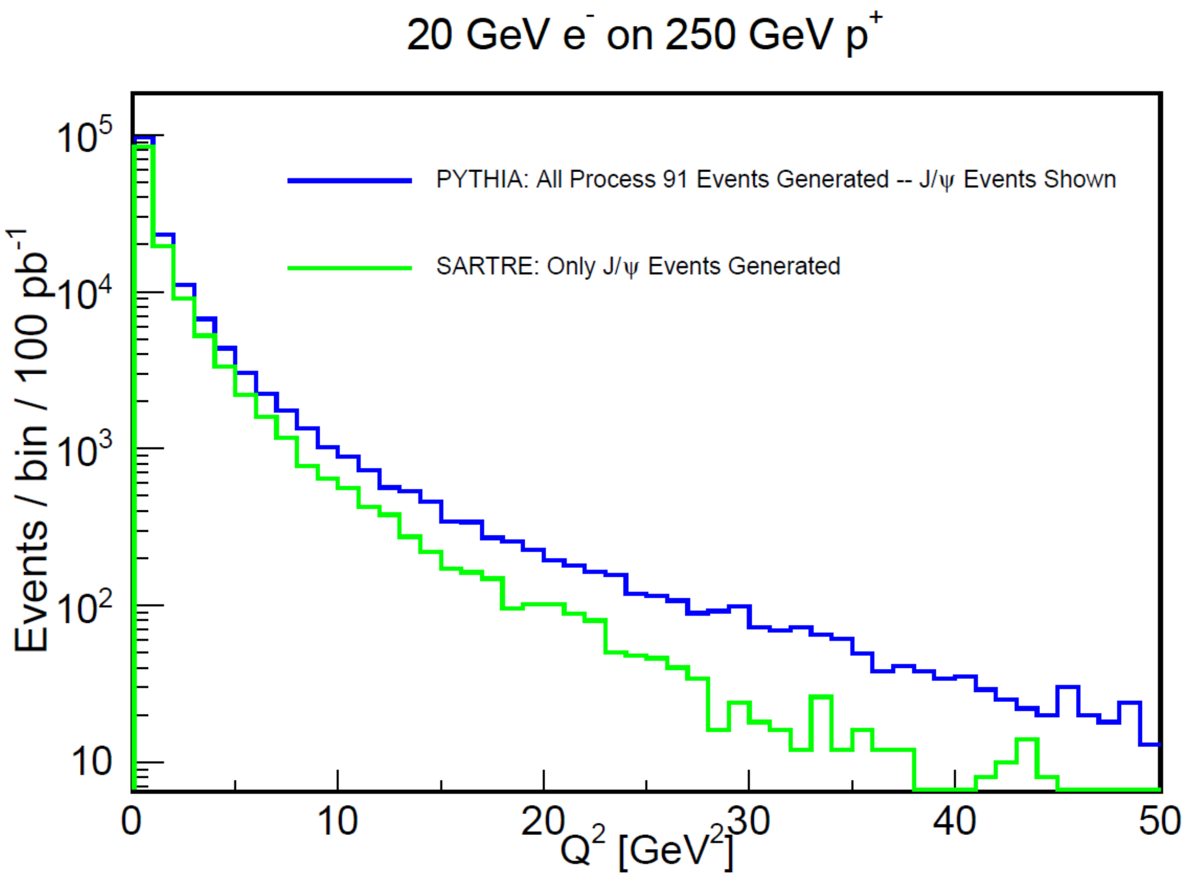
Previous work

- We found a way to simulate only elastic J/ψ events in *Pythia6*.
- However, the simulation does not return a total cross section (for normalization).
- And the Q^2 distribution, for example, is different than when all elastic vector mesons (process 91 events) are generated in *Pythia6* (with the J/ψ events drawn) or for the *Sartre* J/ψ simulation.



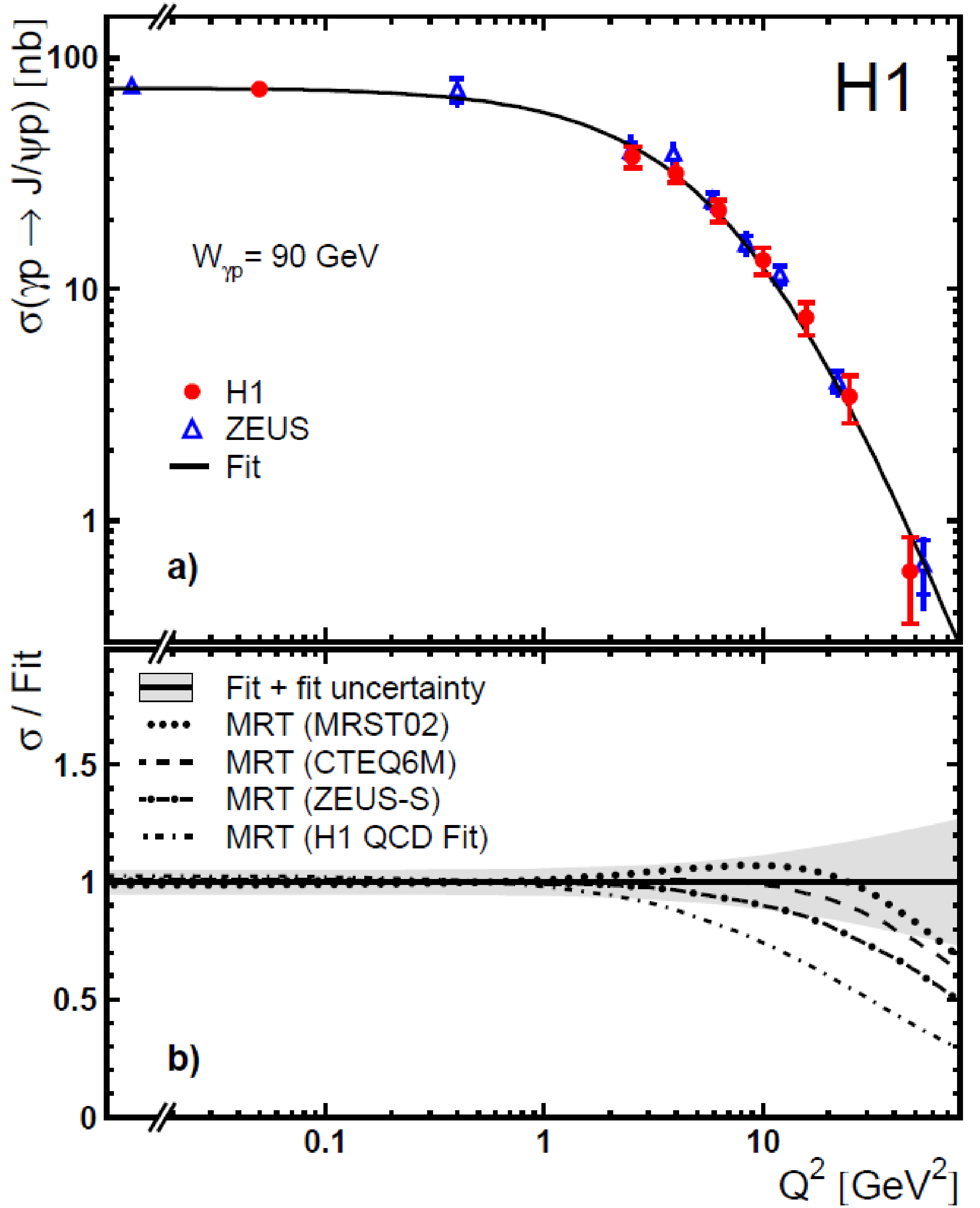
Previous work

- If we simulate elastic vector meson (process 91) events in *Pythia6*, a total cross section is given. We can then select the J/ψ events and compare the predicted yield (e.g. as a function of Q^2) to the Sartre J/ψ simulation.
- When we do this, we see a difference in the absolute yields predicted by the two simulation programs at *EIC* energies.
- In order to study this further, we decided to compare the simulations directly to *HERA* data.



HERA Data

|t|< 1.2 GeV^2 cut applied



Eur. Phys. J. C **46,** 585–603 (2006)

Simulation procedure

- We simulated events in *Pythia6* and *Sartre* for a 27.5 GeV incoming electron on a 920 GeV incoming proton.
- We simulated 500,000 elastic J/ψ events in *Sartre* with no generation cuts applied. This corresponds to an integrated luminosity of 81.1 pb^{-1}
- We simulated 15,000,000 elastic vector meson events in *Pythia6* with a $Q^2 > 0.01$ GeV^2 cut. This corresponds to an integrated luminosity of 19.0 pb^{-1}. Of these, ~0.65% were J/ψ events.

Cross section extraction

- We apply the cut $|t| < 1.2$ GeV^2
- A single W^2 bin 'centered' at W = 90 GeV is used:

85×85 GeV^2 $< W^2 <$ 95×95 GeV^2

- 25 Q^2 bins in the range in the range 0.01 GeV^2 $< Q^2 <$ 100 GeV^2 are used
- For each bin, the e + p → e' + p' + J/ψ cross section is calculated as

$$\frac{d^2\sigma}{dQ^2 dW^2} = \frac{N_{bin}}{\mathcal{L}_{sim} \Delta Q^2 \Delta W^2}$$

Cross section extraction

- This differential cross section can be written as the product of the photon flux and the photon-proton cross section:

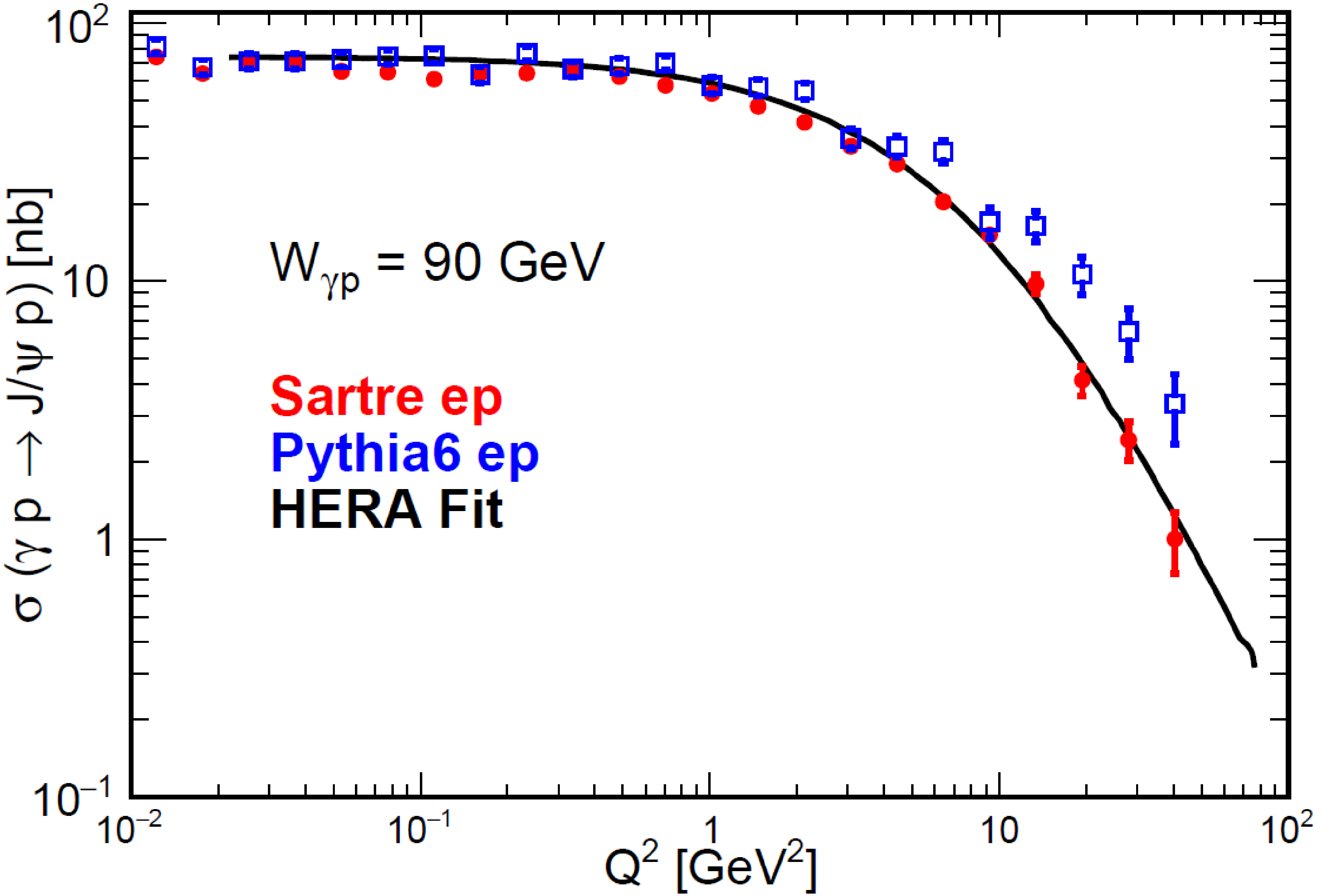
$$\frac{d^2\sigma}{dQ^2 dW^2} = \Phi_\gamma \times \sigma_{\gamma\, p \to J/\psi\, p}$$

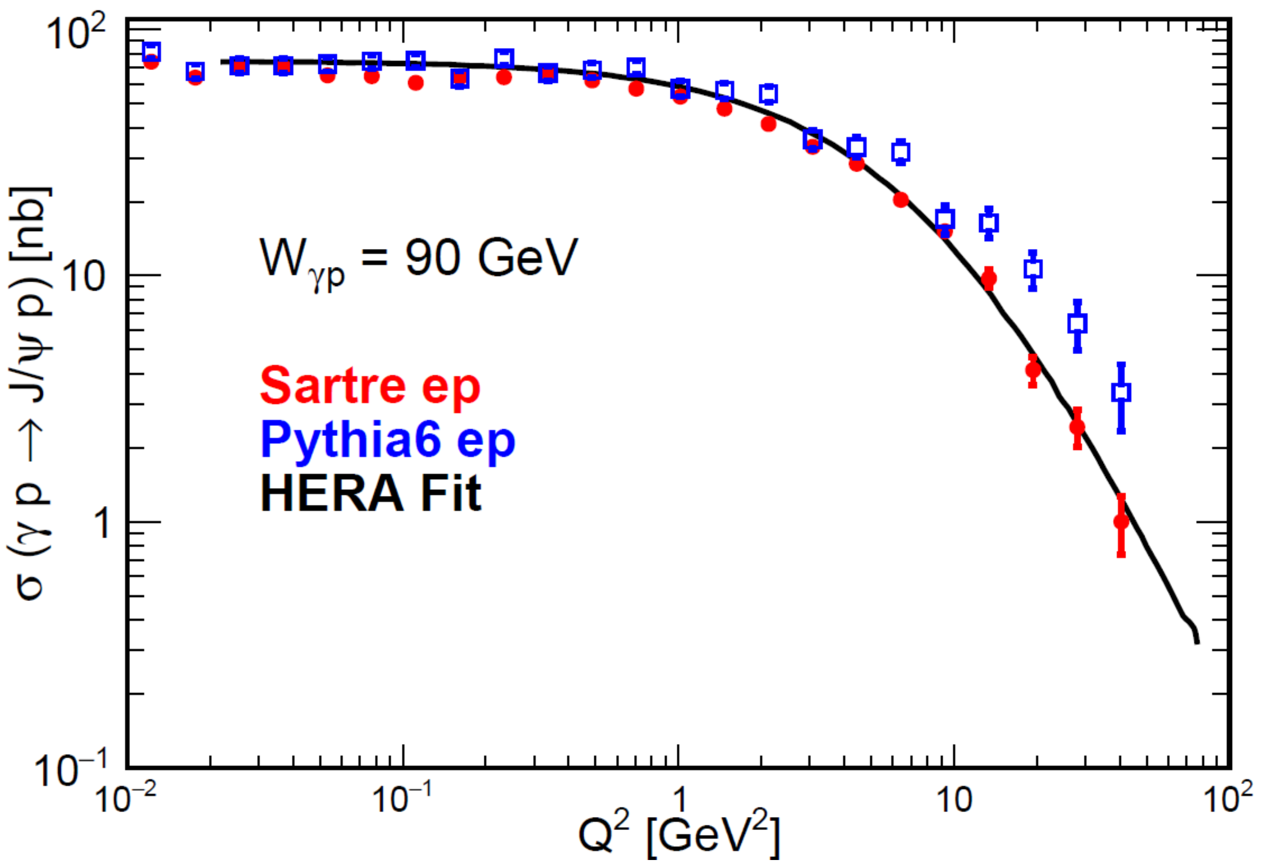
- The photon flux is calculated for each bin as

$$\Phi_\gamma = \frac{\alpha x \left(1 - y + \frac{y^2}{2}\right)}{\pi Q^4}$$

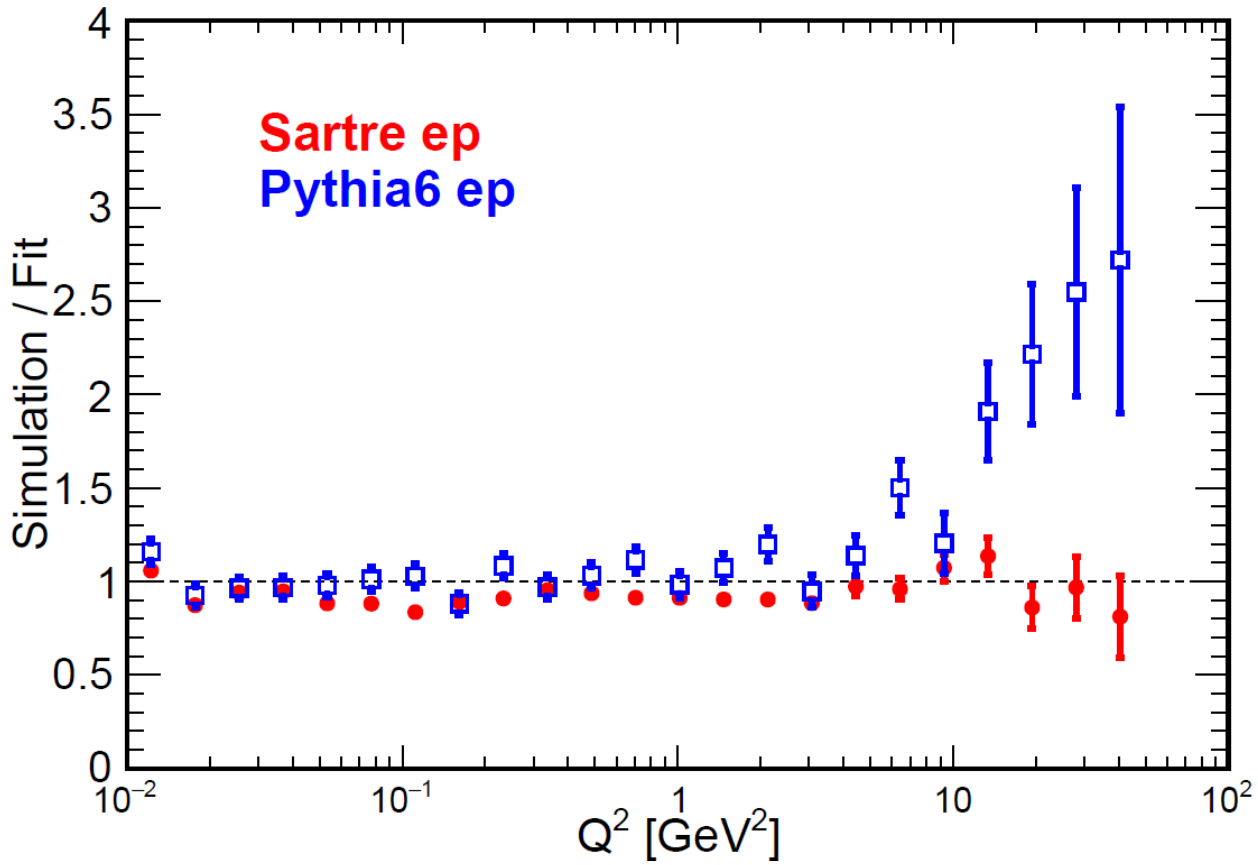
- The photon-proton cross section is then extracted for each bin

Simulation and data comparison

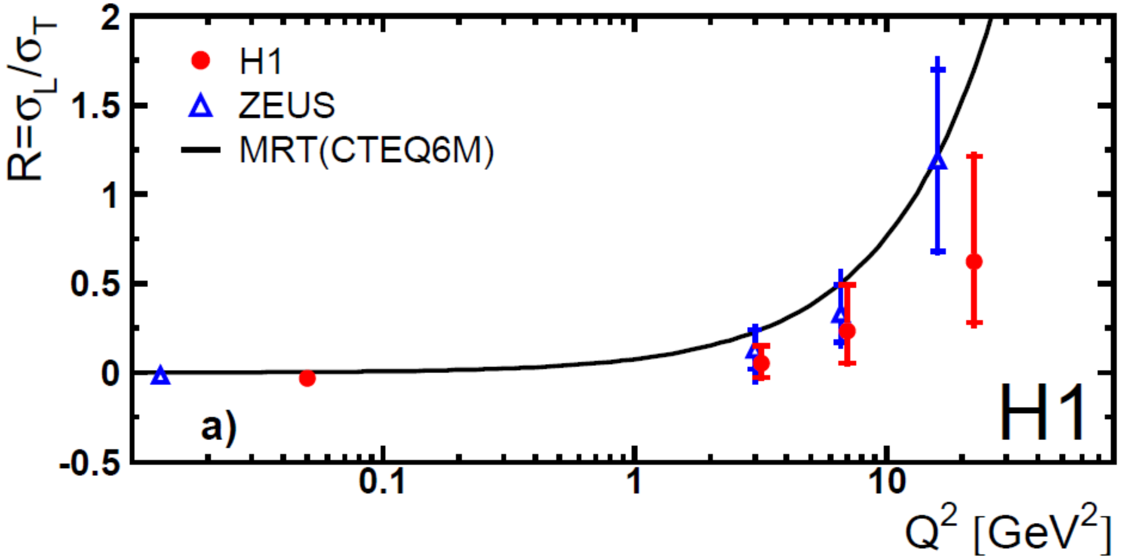




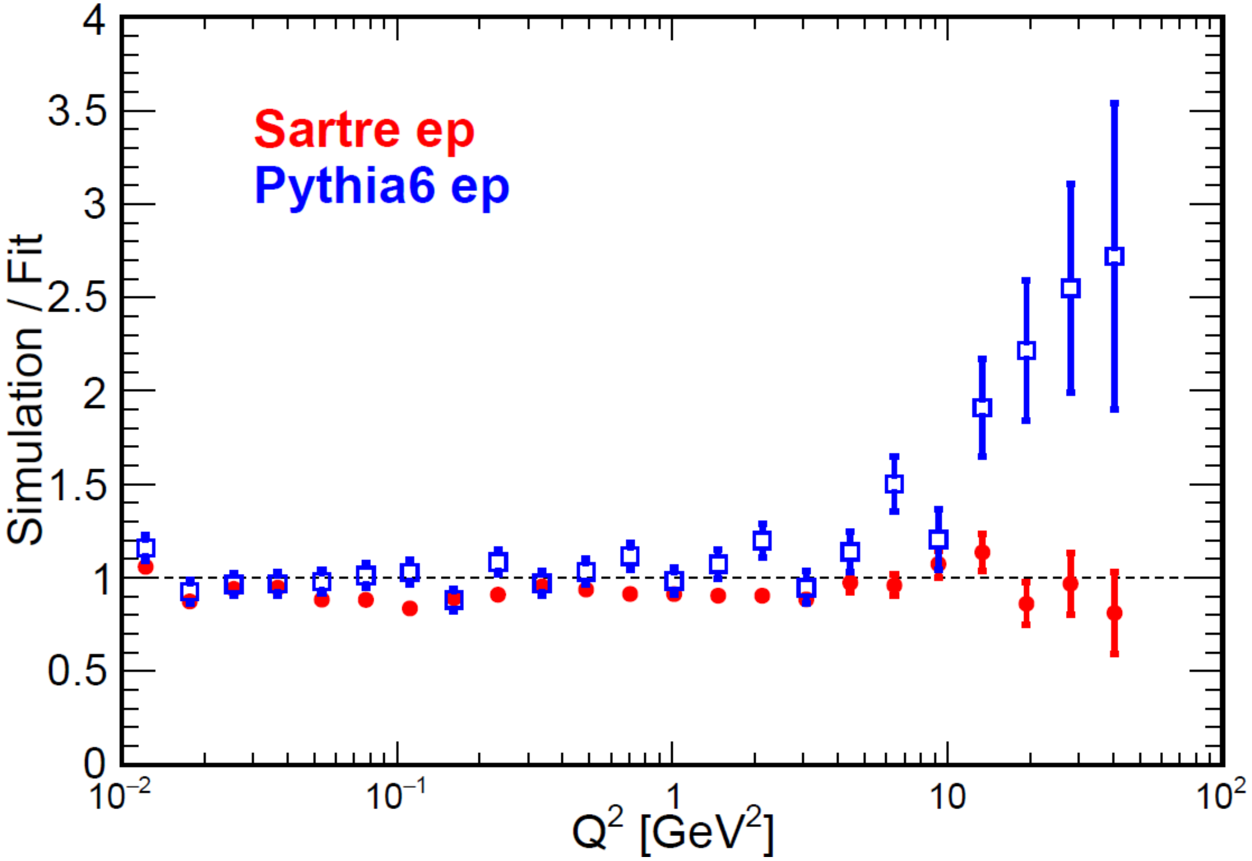
$W_{\gamma p}$ = 90 GeV
Sartre ep
Pythia6 ep
HERA Fit
σ (γ p → J/ψ p) [nb]
Q^2 [GeV^2]



Sartre ep
Pythia6 ep
Simulation / Fit
Q^2 [GeV^2]



$$\sigma_{\gamma p\to J/\psi p} = \sigma^{T}_{\gamma p\to J/\psi p} + \epsilon\sigma^{L}_{\gamma p\to J/\psi p}$$



For *HERA* kinematics $\varepsilon > 0.9$
So problem in Pythia6 very likely comes from longitudinal term

Halftime Summary

- *Sartre* seems to be the better option for generating the elastic J/ψ events
- For the background generation, however, we have to use Pythia6 (process 93) events
- The next question is the reconstruction and background studies. For this we combine the fast simulation (*eic-smear*) for the central detector and *EicRoot* for the forward spectrometer.

Modification of *Sartre* Output

- ➢ First, we had to modify the Sartre output so that it could be used in *eic-smear* and *EICRoot*
- ➢ This change has now been incorporated into the main version of the *eic-smear* (and *EICRoot*) packages

Overview

eic-smear is a Monte Carlo analysis package originally developed by the BNL EIC task force.

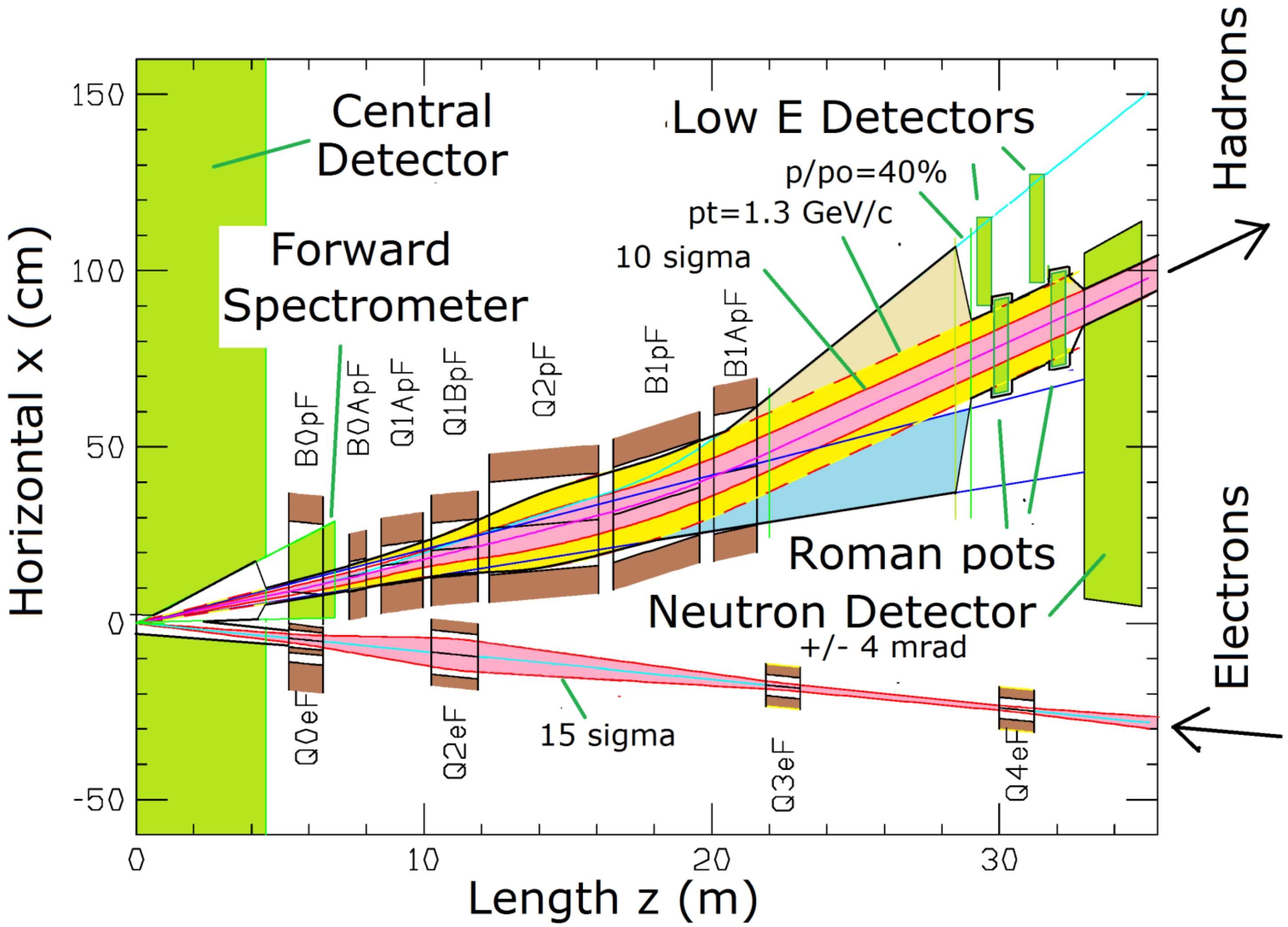
It contains classes and routines for:

1. Building events in a C++ object and writing them to a ROOT file in a tree data structure.
2. Performing fast detector smearing on those Monte Carlo events.

The tree-building portion processes plain text files, formatted according to the EIC convention, into a ROOT TTree containing events. The following Monte Carlo generators are supported:

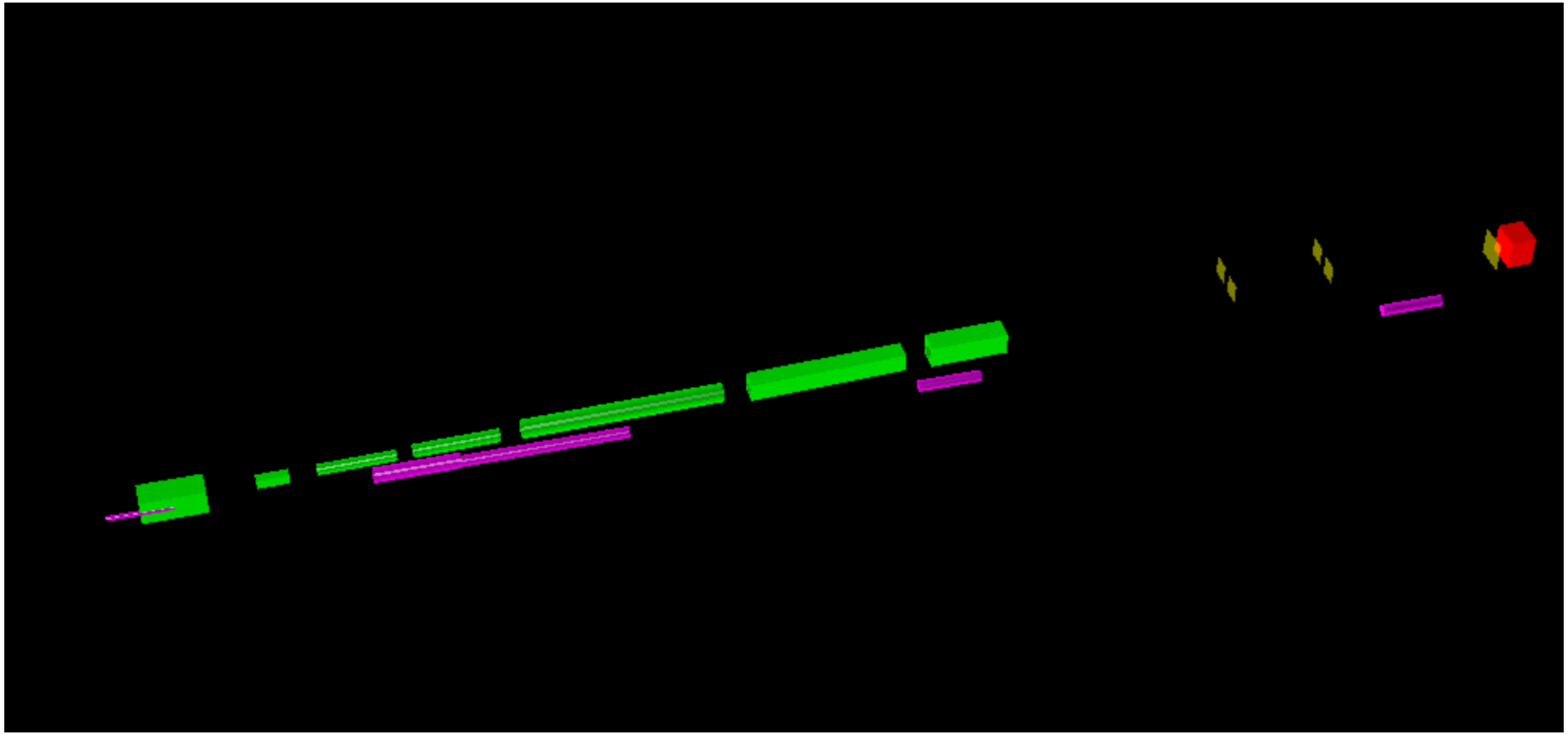
- PYTHIA
- RAPGAP
- PEPSI
- DJANGOH
- MILOU
- BeAGLE
- Sartre
- DPMJet
- gmc_trans

Full Forward Interaction Region (IR) Simulation

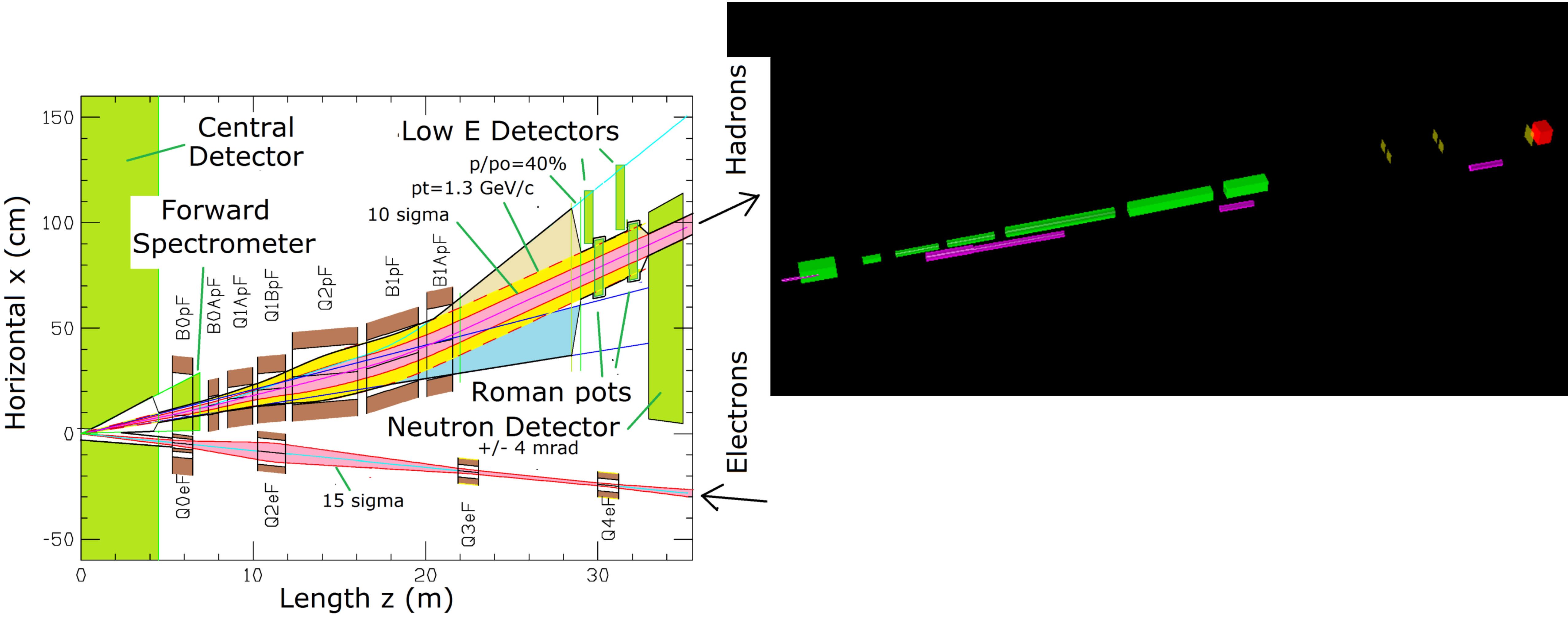


EIC Forward IR Layout

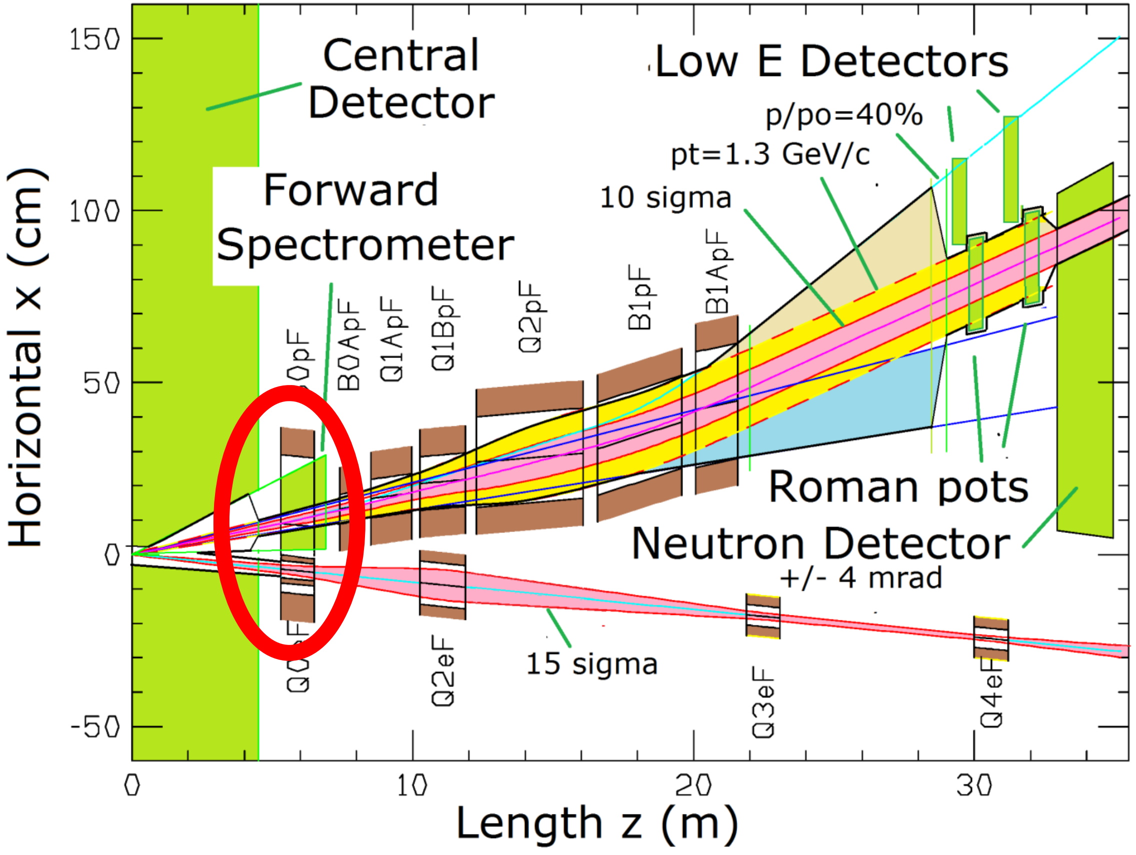
If we look at the *Geant3* (4?) event display for the forward IR, we see the following:

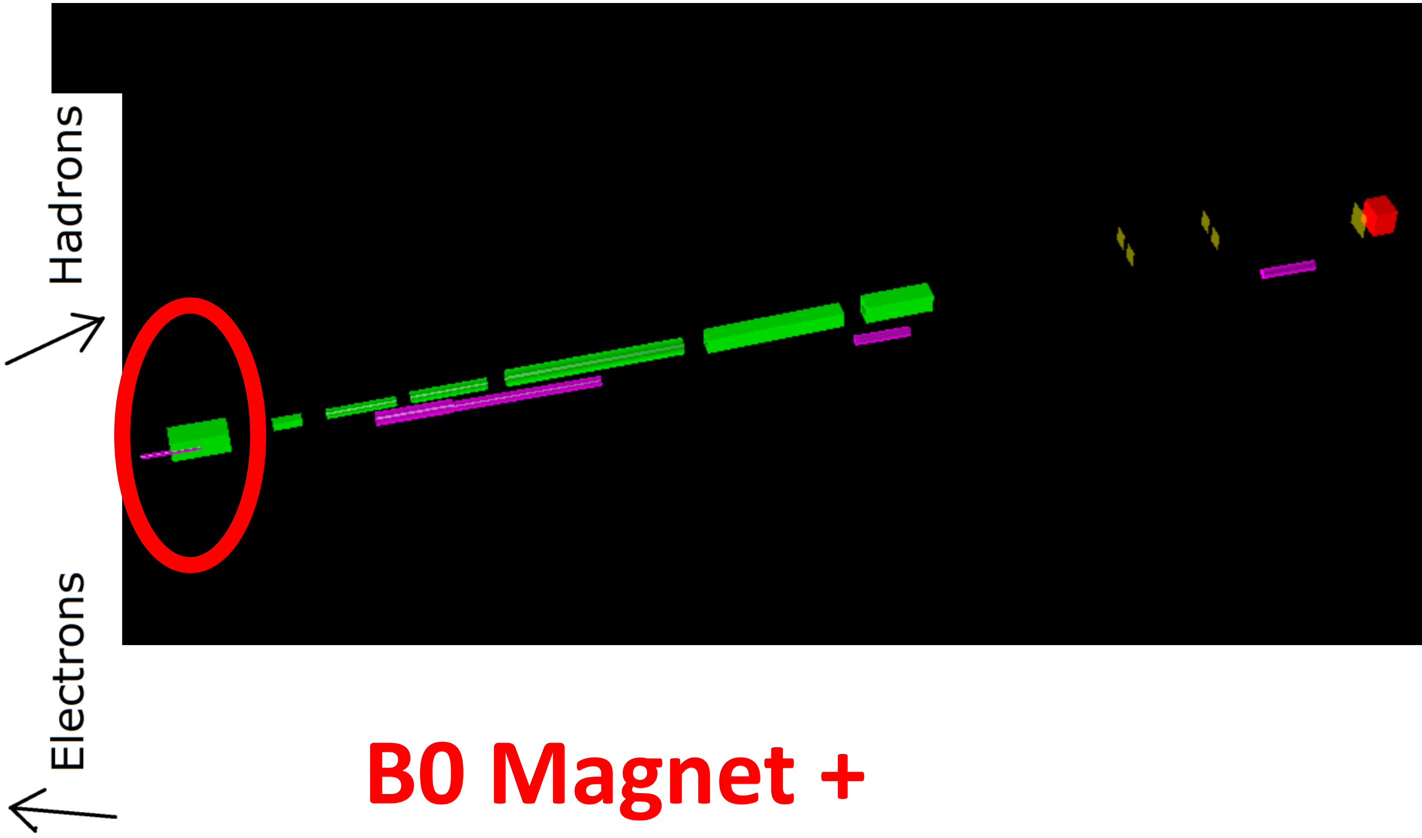


EIC Forward IR Layout



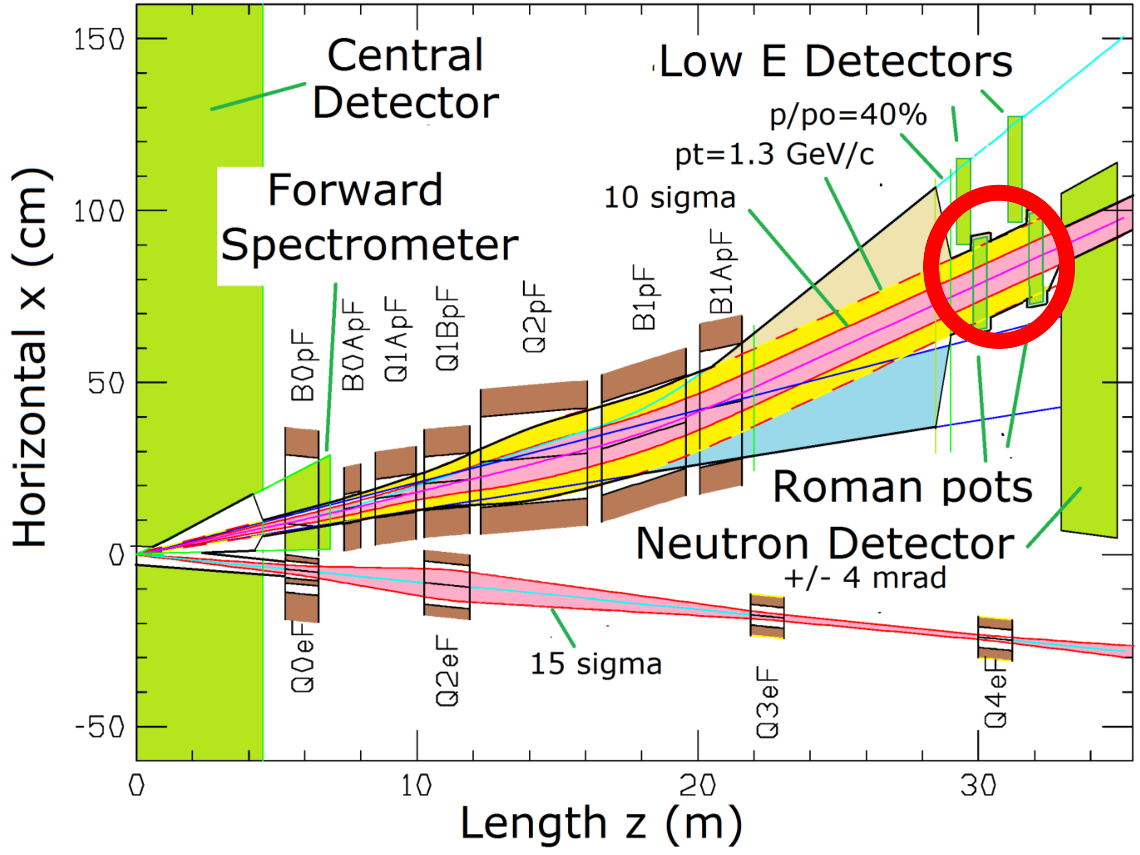
EIC Forward IR Layout

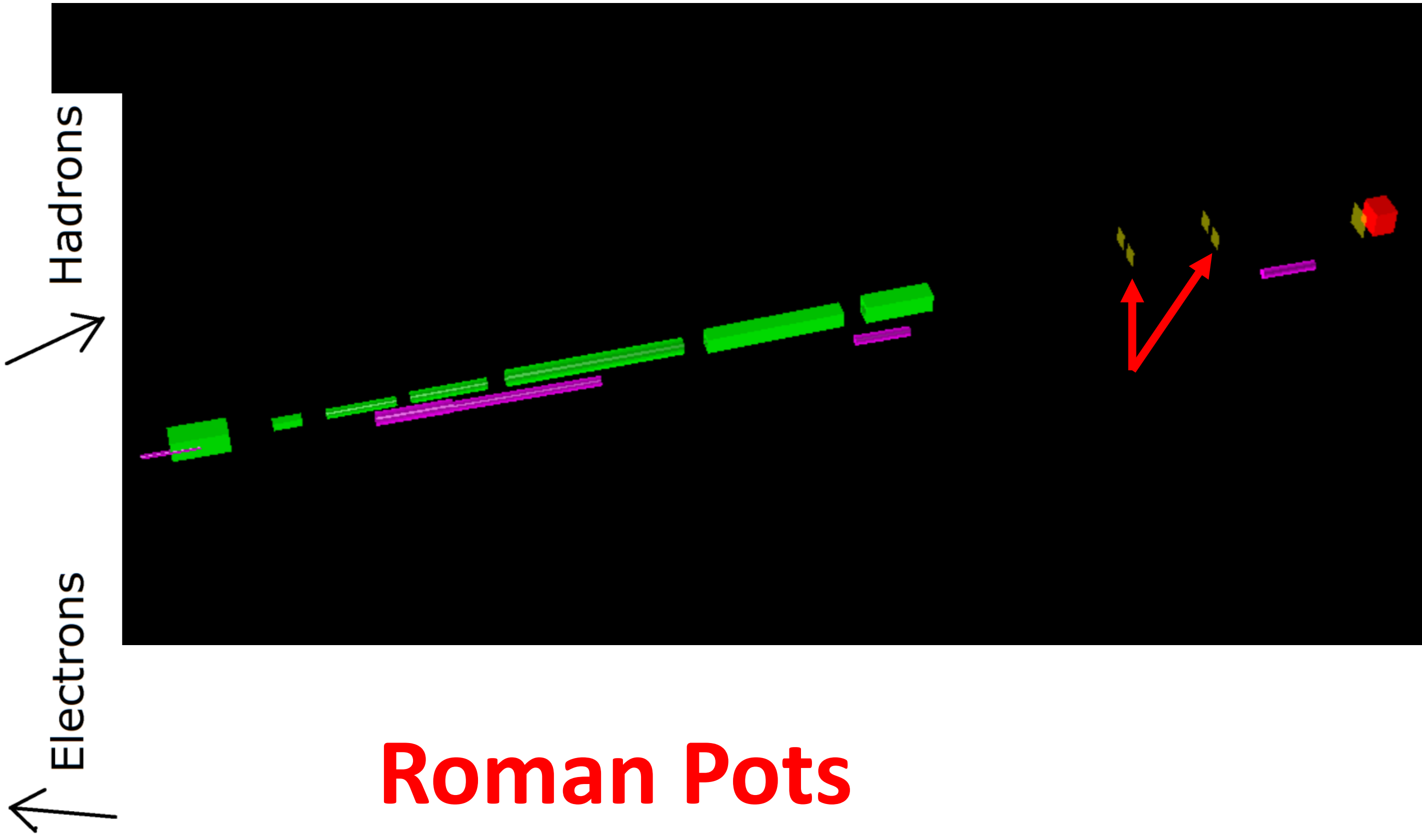




B0 Magnet + Detector

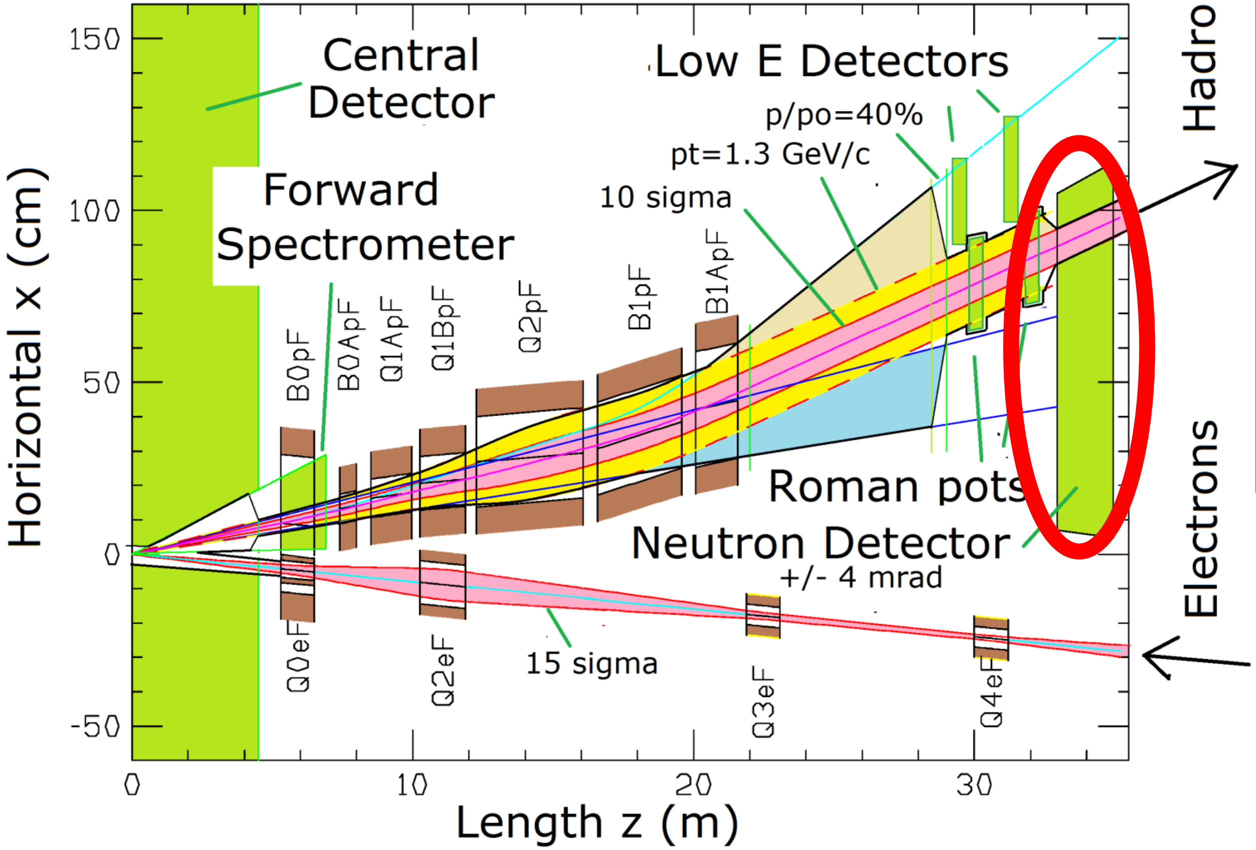
EIC Forward IR Layout

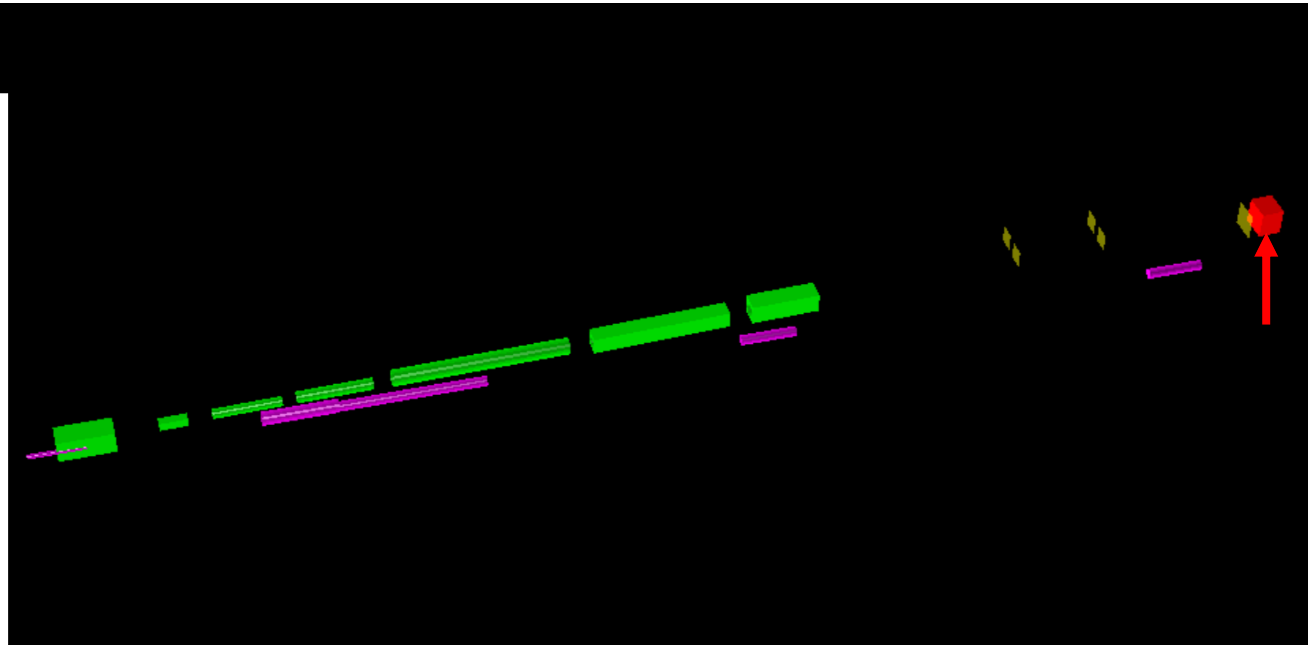




Roman Pots

EIC Forward IR Layout

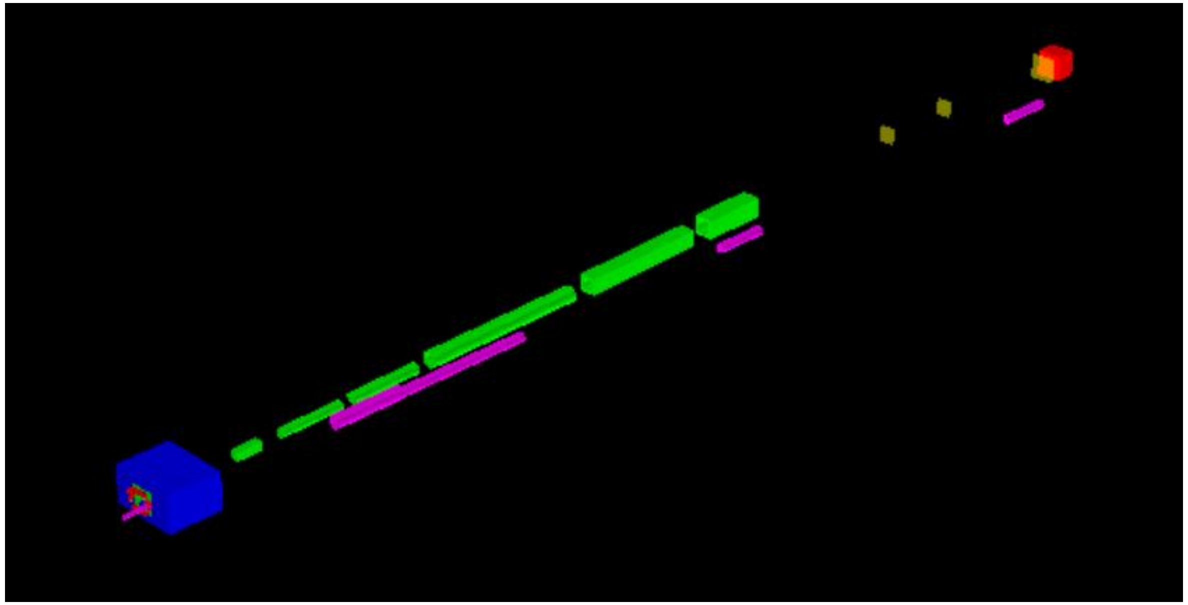


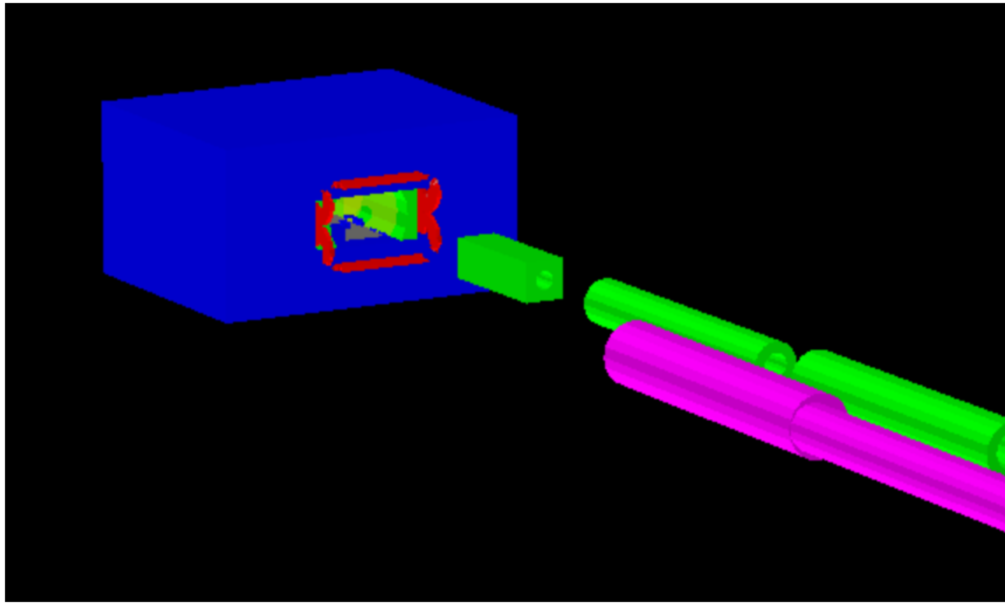


ZDC

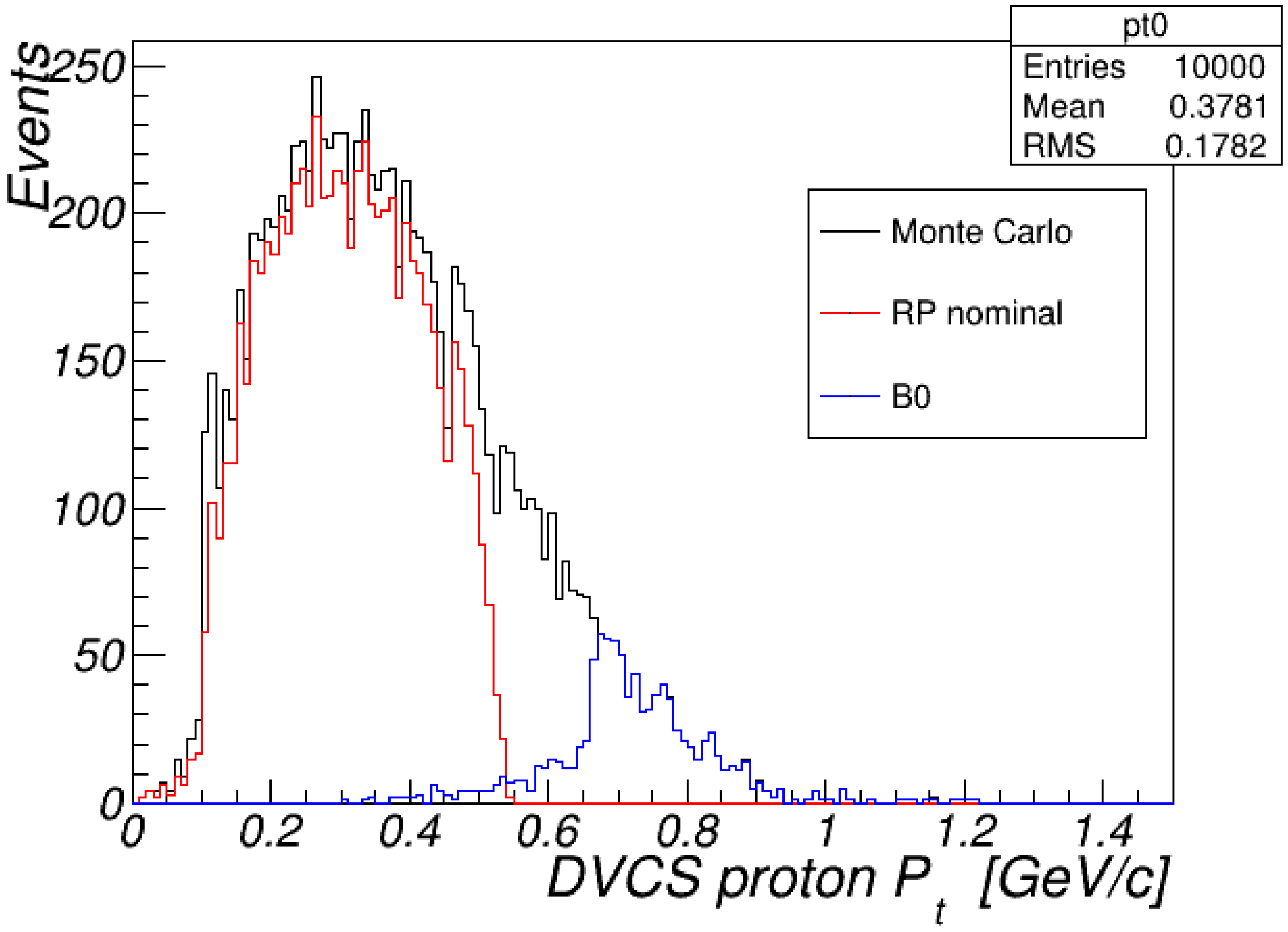
EIC Forward IR Layout

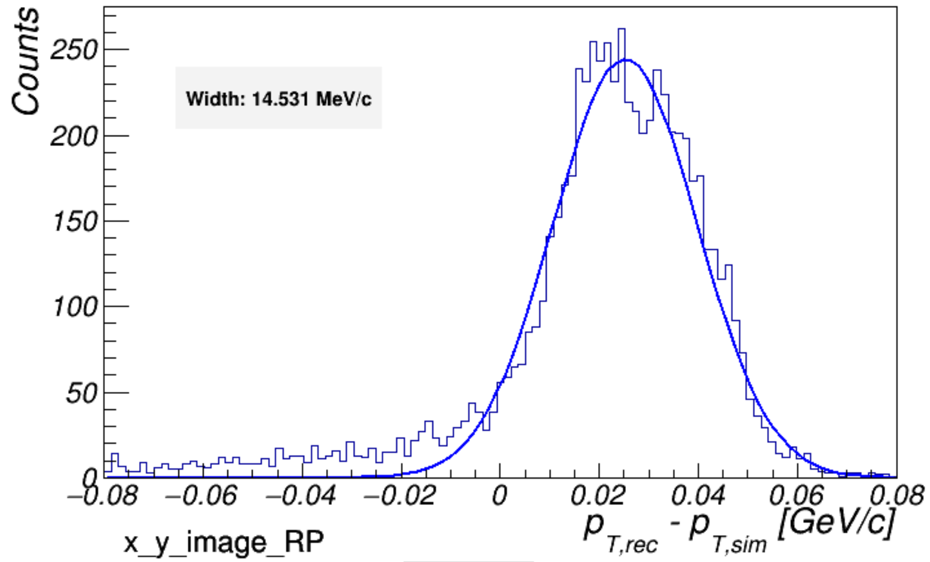
We can also include other parts of the forward IR, if we want. For example, we include the B0 magnet material (and remove the low-E detectors) in the setup below. Adding the B0 magnet material will slow down the simulation running time, and (I think) it is only necessary to include if we are doing the background studies.

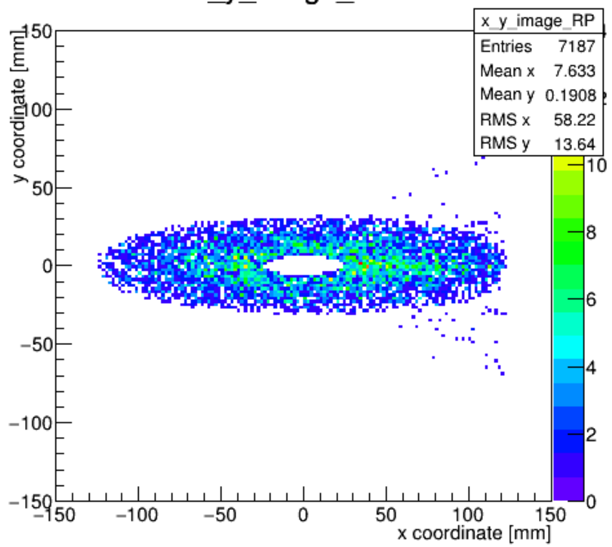




EIC Forward IR Simulation Results







Final Summary

- We have generated large amounts of our signal events (in *Sartre*) and background events (in *Pythia6*) at *EIC* energies.
- We have run those generated events simultaneously through the fast simulation (*eic-smear*) and the forward simulation (*EicRoot*). We need to check that we are using the most-up-to-date version of the forward spectrometer.
- The next steps are to look at kinematic reconstruction for the elastic events and the vetoing of the background.
- The longer-term goal would be to consider these same questions for J/ψ production in electron-nucleus scattering.