Simulation tools and eRHIC detector geometry for EIC VMP studies

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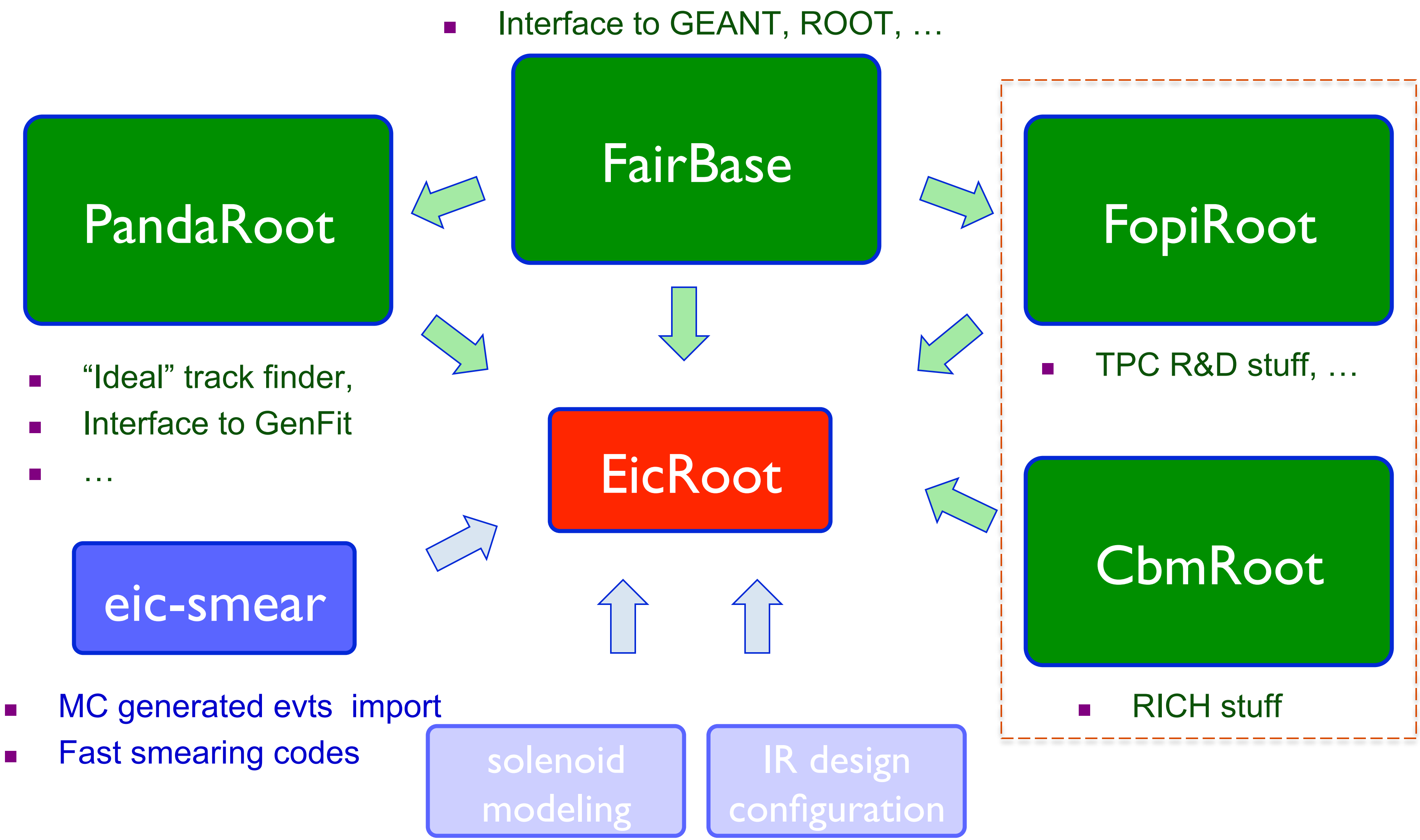
Outline

- BeAST main detector geometry and modeling tools
- eRHIC Interaction Region (IR) modeling environment ...
- ... and a couple of selected results
- Outlook

EicRoot framework in one slide



Available functionality

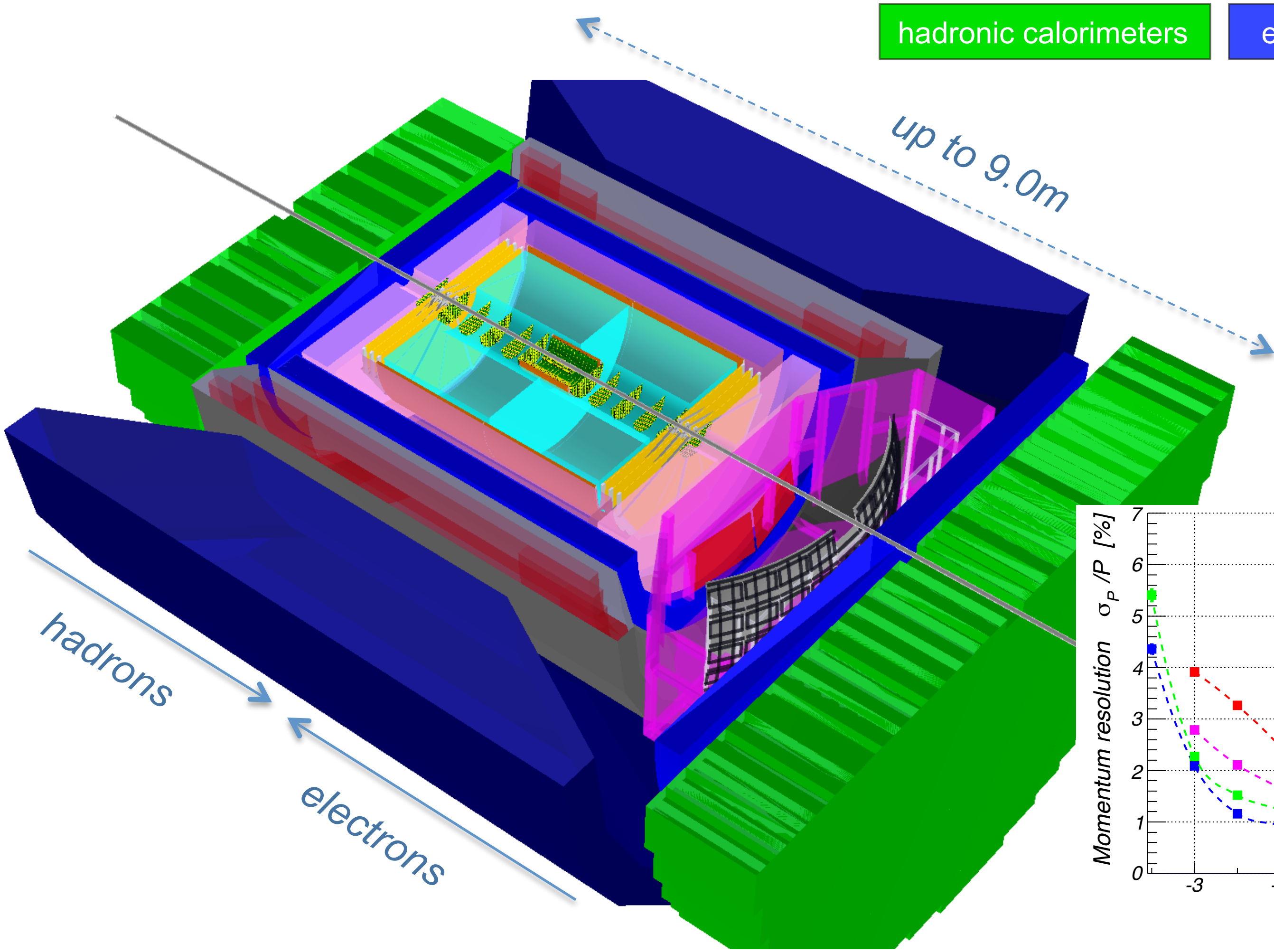
- Flexible MC event import
  - Various generator ASCII output files (MILOU, PYTHIA, ...), binary formats: (TPythia, ...)
  - Vertex smearing, kinematics adjustment (22mrad crossing angle), ...
- Modular geometry
- Reasonably good track reconstruction ...
- ... and much less functional calorimetry codes

- Several advances in the IR description
- Main detector and forward-acceptance detectors are treated *at once*
  - Recoil proton goes to B0 silicon tracker or to the RPs
  - Scattered electron (& say $\pi^+\pi^-$ pair) - to the main detector

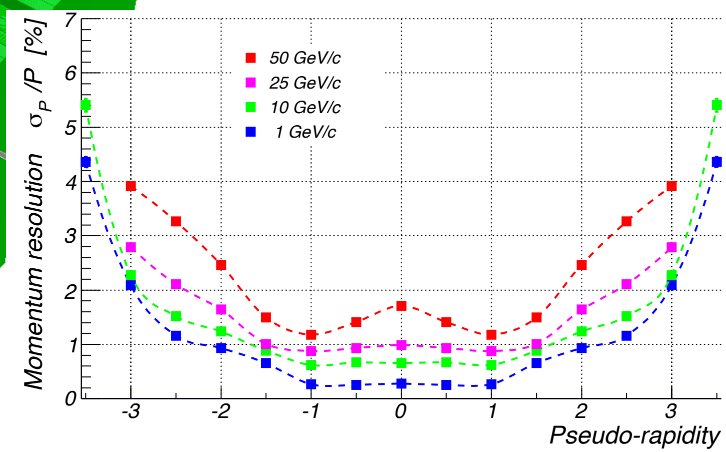
BeAST model detector in EicRoot

-3.5 < η < 3.5: Tracking & e/m Calorimetry (hermetic coverage)

hadronic calorimeters | e/m calorimeters | RICH detectors



Momentum resolution

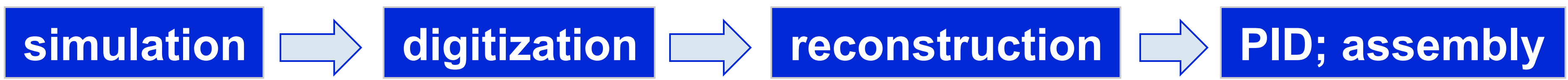


silicon trackers | TPC | GEM trackers | Micromegas barrels | 3T solenoid cryostat | magnet yoke

An update incorporating IR vacuum system design is in progress

Simulation usage options

1) Download & compile EicRoot from scratch
2) Download pre-packaged EicRoot Docker container



-> MC points   -> Hits   -> Tracks, clusters   -> Events

3) Wait until "EIC Sandbox" framework grand-unification environment is set up

-> first version as early as June this year?

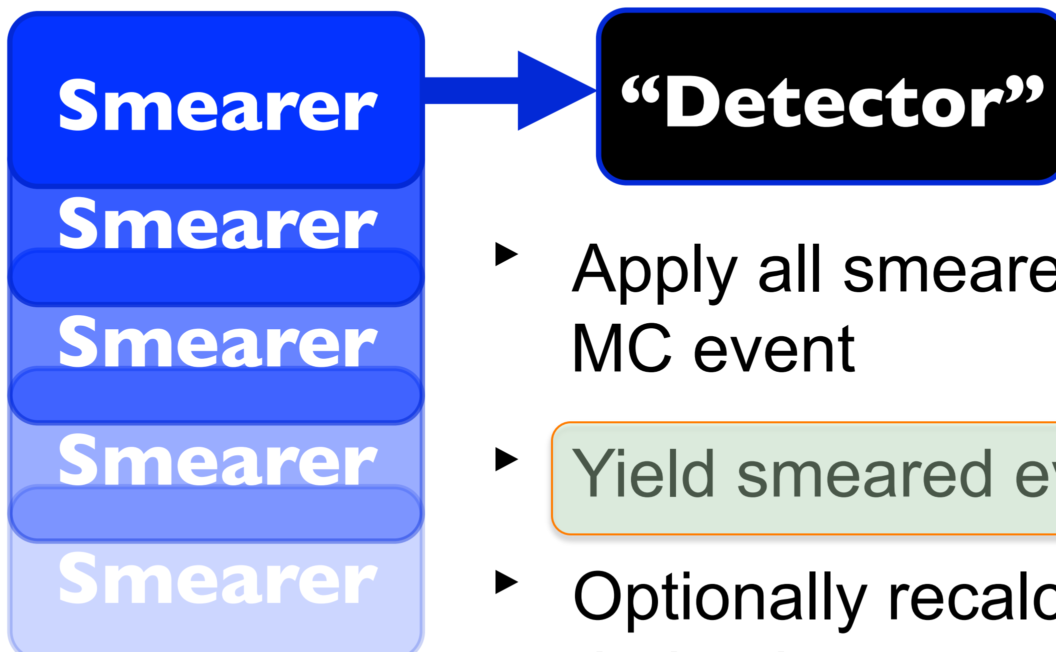
4) Use EIC smearing generator package (*eic-smear*) instead?

EIC smearing generator

"Smearer" defines some element of performance + acceptance

- Built-in standard smearers provided with eic-smear
- Users can define own smearers using inheritance

NOT a "physical detector": represents the **overall performance** in measuring a quantity.



- Apply all smearers to an MC event
- Yield smeared event
- Optionally recalculate derived values e.g x, Q^2

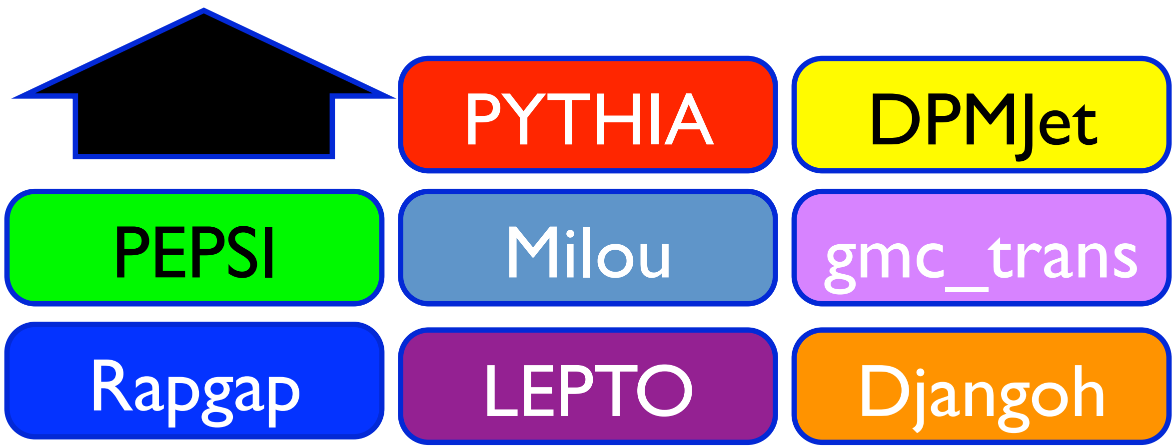
→ Think of it as a parametric filter, which acts on imported MC events

EIC smearing generator

- Easy to install & use
- No external dependencies other than ROOT
- ASCII generator file import is readily available

- The main idea: once detector acceptance regions and resolutions of kinematic variables are determined via complete GEANT simulation & subsequent reconstruction (*by somebody else*), for rough basic estimates it may suffice to use a collection of “parameterized detectors” rather than running the full simulations

EIC smearing generator

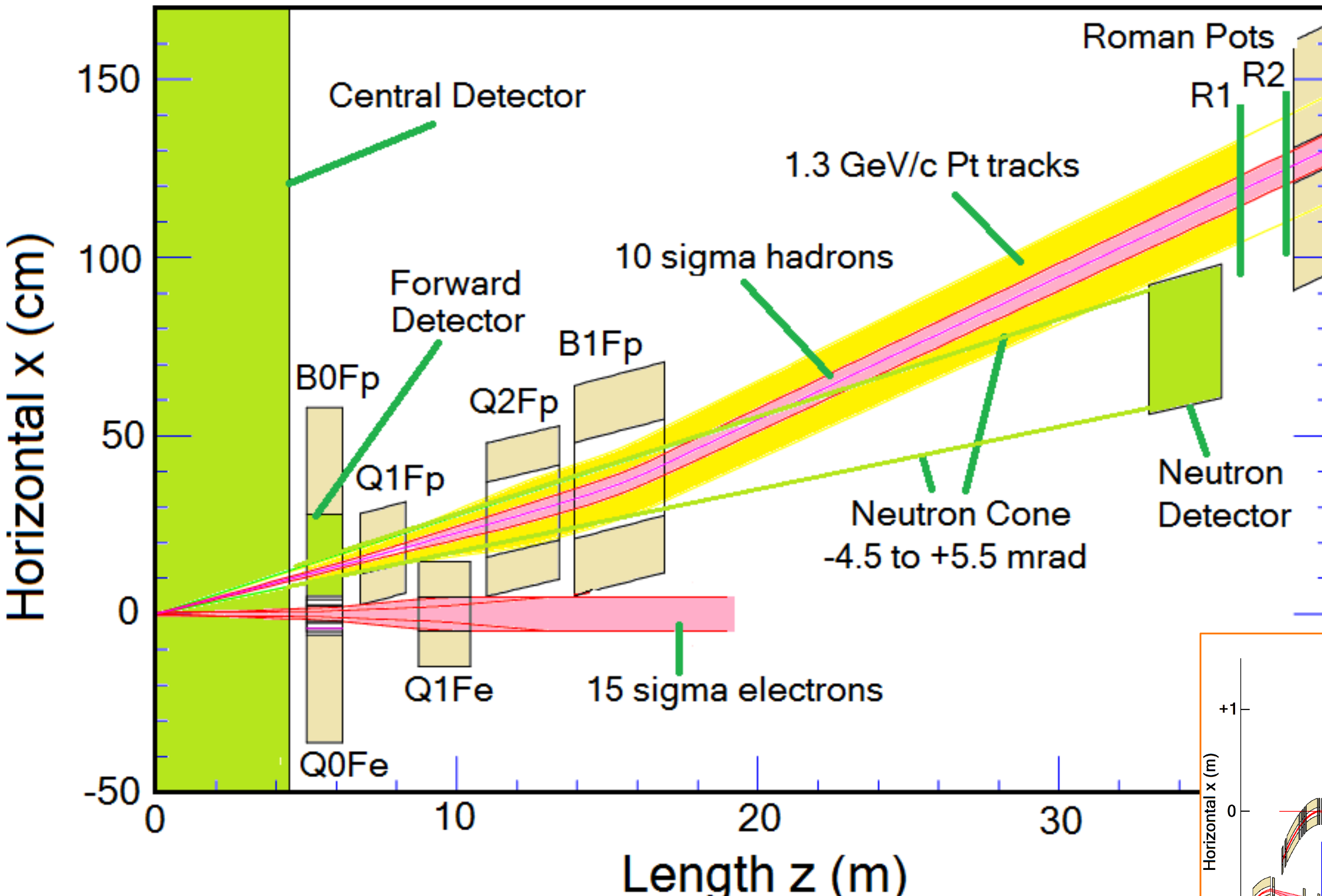


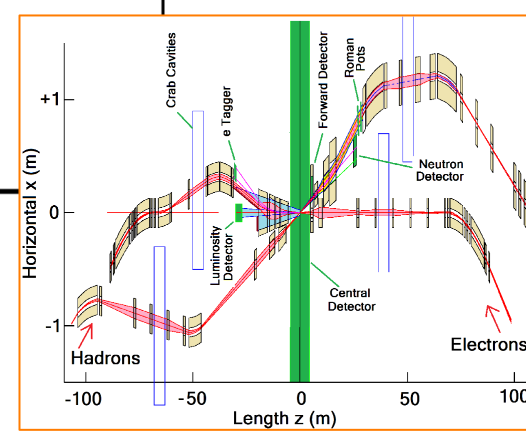
Large number of EIC Monte Carlo generators with standard ASCII format

- NB: both event import and smearing functionality is supported in EicRoot

eRHIC IR hadron-going direction

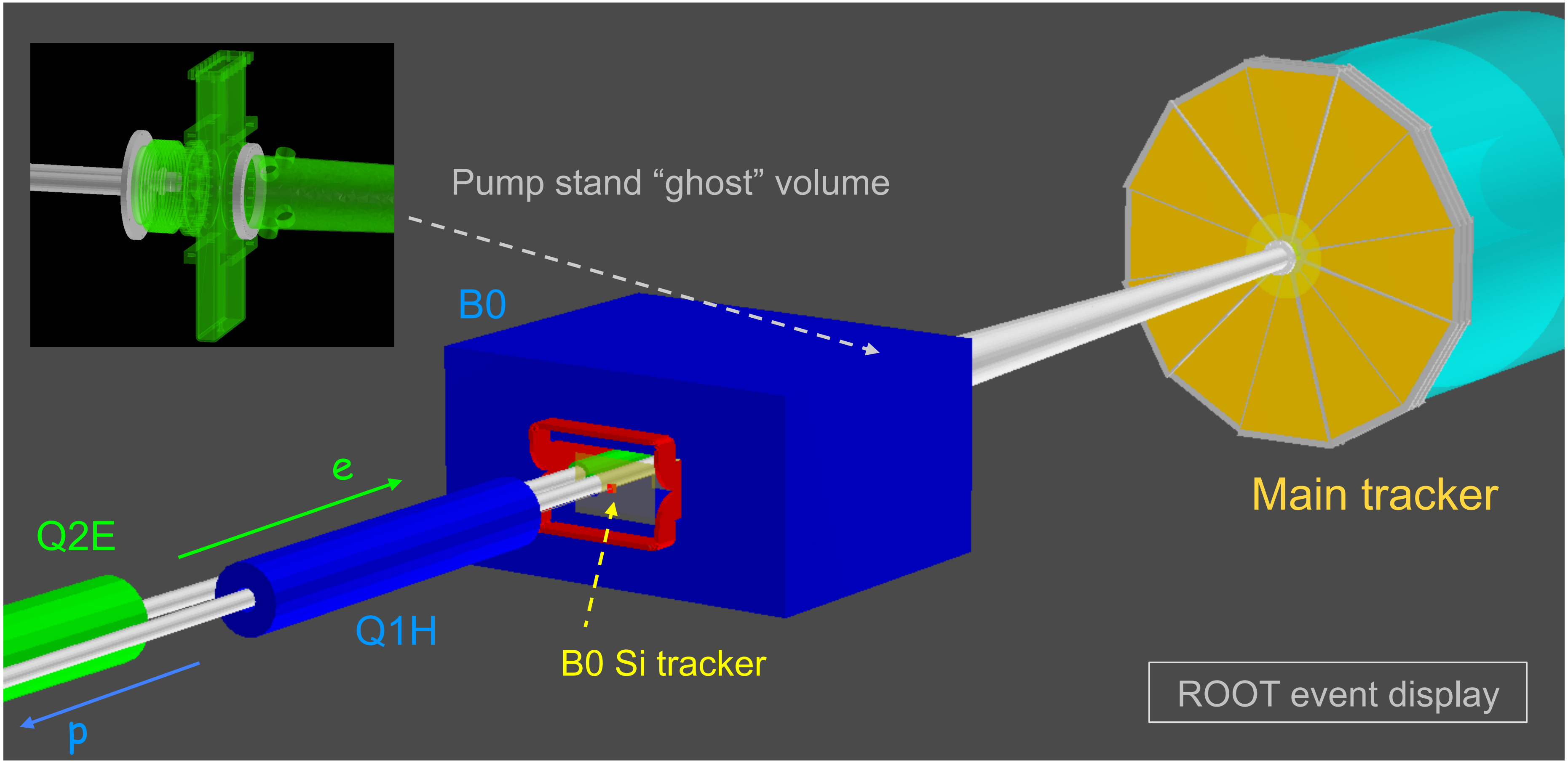
→ Back to the full GEANT simulations





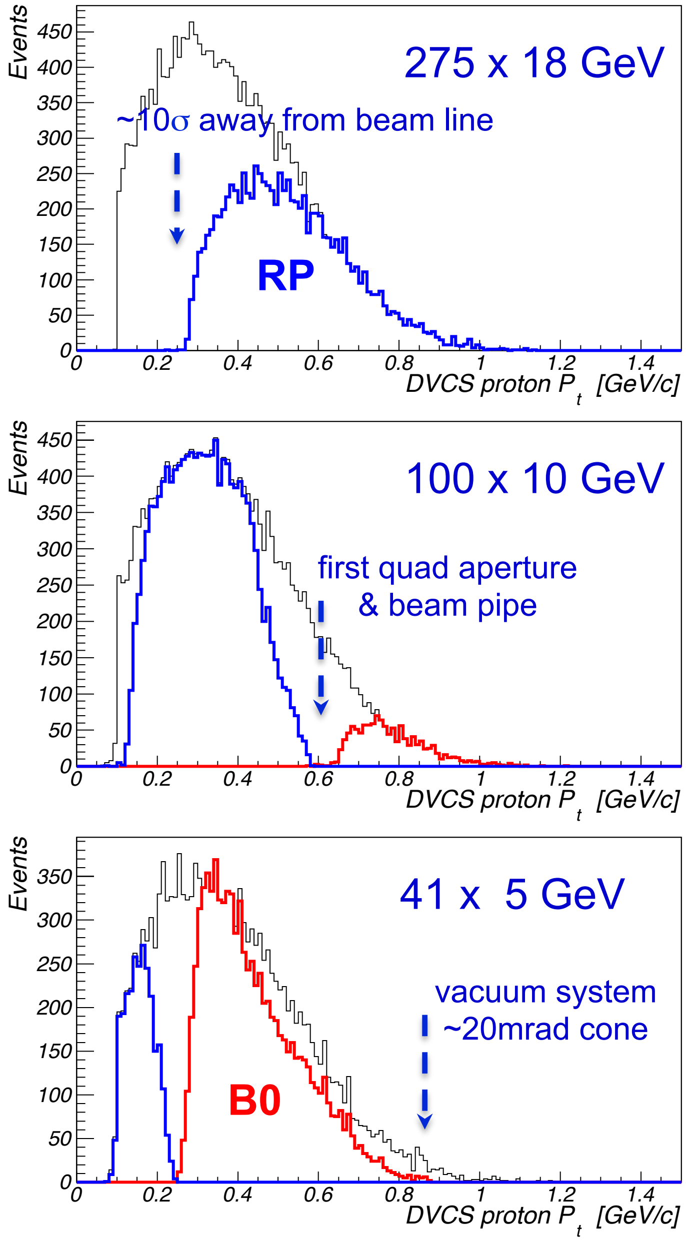
→ Will focus on B0 magnet, RPs & ZDC

eRHIC IR simulation environment

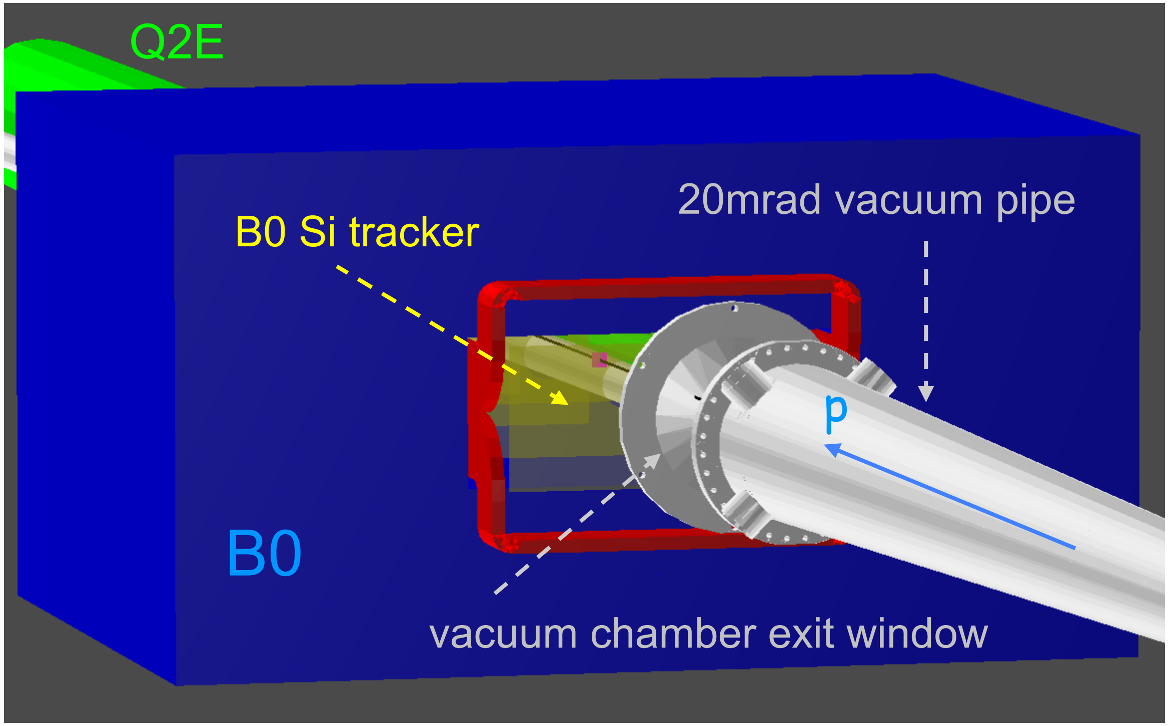


- → Beam line element apertures and magnetic fields (.madx files)
- → Vacuum system engineering drawings (ground CAD .stp import)
  - → Either boolean decomposition or STL->tetrahedrons dump or just a "ghost" shape
- → B0 large-acceptance dipole design (COMSOL .mphtxt import)

P_t acceptance for DVCS protons



→ Plots: HD (high divergence) case



→ Gap between **RP** and **B0** will be further optimized

→ Low-P_t part can be filled in with HA-running

achieve at least 0.3 GeV < p_t < 1.3 GeV range

Angular acceptance for charged tracks

- ~[0 .. 5] mrad: Roman Pots
- ~[5 .. 7] mrad: "gray zone"
- ~[7 .. 20] mrad: B0 forward large-acceptance spectrometer
- ~[20 .. 50] mrad: "gray zone"
- From ~50 mrad or so ($\eta \sim 3.5$): main tracker

P_t resolution for recoil protons

- B0 magnet [100 GeV/c beam energy @ p_t ~ 1.3 GeV/c (worst case)]

  (~1.3T field, ~1.2m long; 4 Si stations with ~20μm resolution; Kalman fIlter)

  - ~30 MeV/c without IP vertex constraint
  - ~15 MeV/c with reasonable assumptions about beam envelope size at the IP

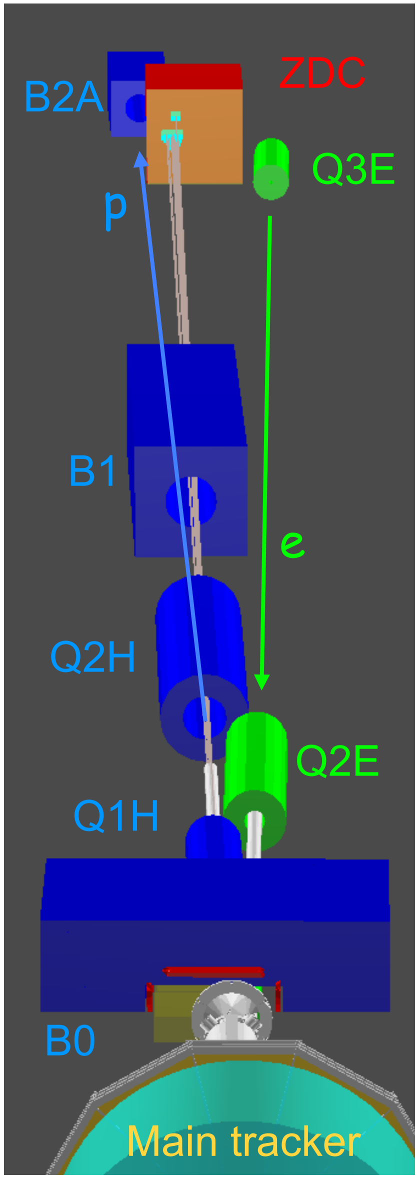
- Roman Pots [275 GeV/c beam energy]

  (2 stations ~30m from IP, 20cm apart, ~20μm resolution; matrix transport)

  - ~20 MeV/c at ϕ ~ 0 degrees (recoil in horizontal plane)
  - ~10 MeV/c at ϕ ~ 90 degrees (recoil in vertical plane)

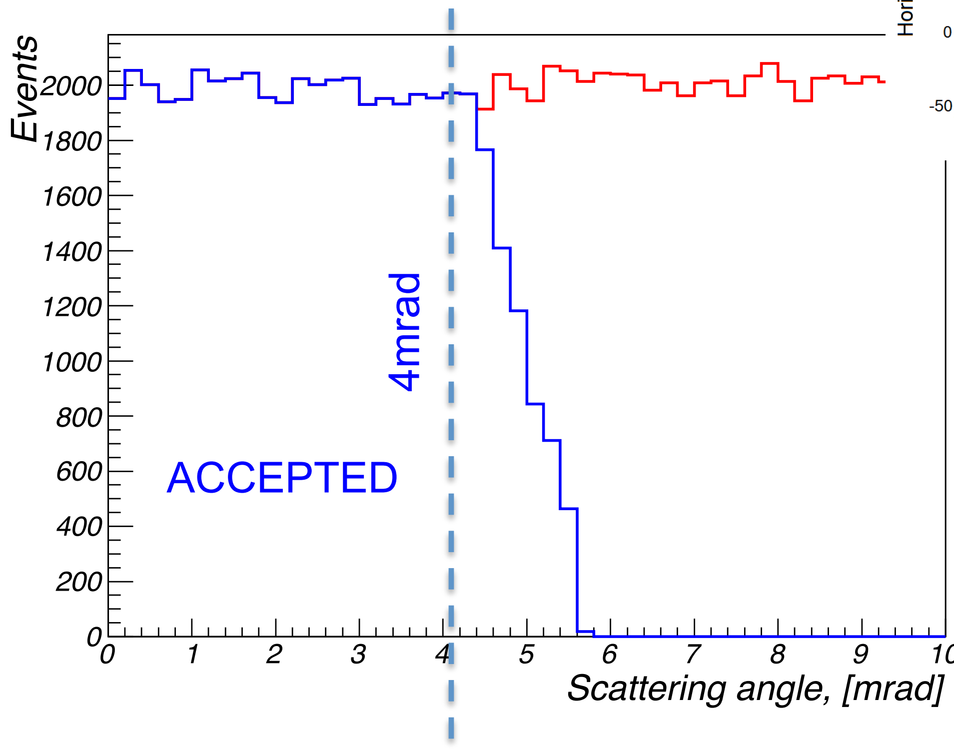
NB: these estimates do not include beam divergence at the IP

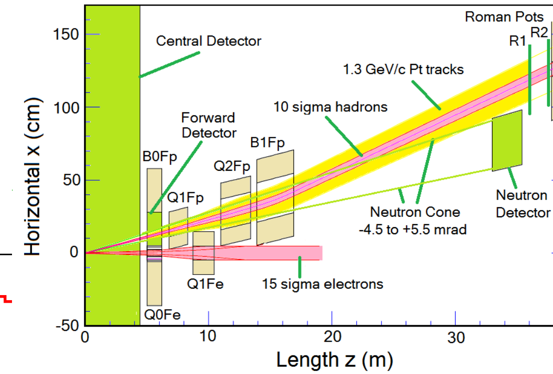
Angular acceptance for neutrons



→ NB: here particles generated flat in θ

→ ZDC is handled as a "black hole" volume





→ NB: space for ZDC needs to be increased for better hadronic shower containment

Achieve the 4 mrad acceptance requirement

Summary & Outlook

- Main detector geometry and IR geometry bits a pieces (basic vacuum chamber blocks, quad & dipole volumes, simplified magnetic fields, etc) can be imported in a full GEANT environment and used *at once ...*
- ... otherwise smearing generator fast simulation tool is available
- Recently the GEANT codes were used for eRHIC IR design validation
- Eventually: use *unique source* of geometry & other input info for
  - Physics simulations
  - Detector performance benchmarks
  - Beam-gas machine background studies
  - Synchrotron background studies
  - Neutron flux and radiation dose estimates