Summary of Simulations with Summer Students at JLab

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EIC Collaboration Meeting
Washington, DC

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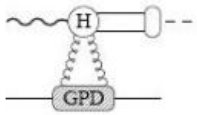
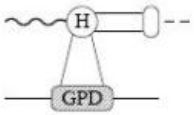
Activities of the Simulation Working Group

- Event Generators (standardized format)
  - Rate predictions including simulations of the detector restrictions
  - Input for detector design
    - Momentum and angular distributions for various particles
- Fast MC
  - Input: resolution function
- GEANT MC
  - Based on the CLAS12 simulation package GEMC
- Event Reconstruction/Tracking (for GEANT data)

Exclusive Event Generators

	"diffractive" (vacuum exchange)	"non-diffractive" (quantum number exchange)
Channel	$\gamma p,\ \rho^0 p,\ J/\psi\, p, \ldots$	$\pi^+ p,\ \pi^0 p,\ K\Lambda,\ \rho^+ n, \ldots$
GPDs	 gluon	 non-singlet quark
Cross section	rises with energy	drops with energy
Interest	gluon imaging of nucleon	spin/flavor structure of quark GPDs

Diffractive Channels

- Data experience from HERA, COMPASS
  - $\rho\ p$, φp, $J/\Psi p$
- DVCS simulations [A. Sandacz 06/07]

Non-diffractive Channels

- New territory for a collider!
- Much more demanding in luminosity
- Feasibility studies: $\pi^+ n$, $\pi\ p$, $K^+\Lambda$

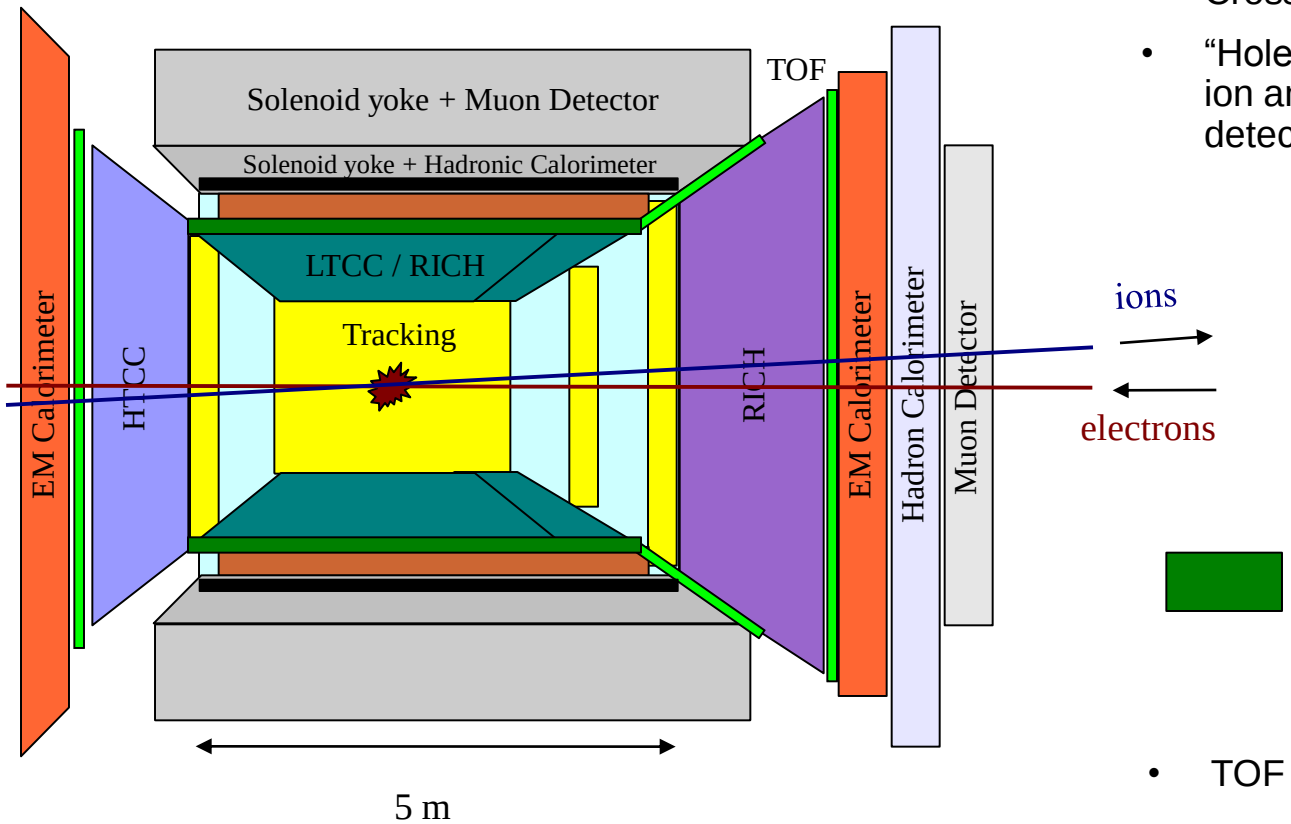
Exclusive Generators written for all of these channels – results shown in previous meetings

Detector Requirements

- Mainly driven by exclusive physics
  - Hermeticity (also for hadronic reconstruction methods in DIS)
  - Particle Identification (also SIDIS)
  - Momentum resolution (kinematic fitting to ensure exclusivity)
  - Forward detection of recoil baryons (also baryons from nuclei)
  - Muon detection (J/Ψ)
  - Photon detection (DVCS)

- But not only …
  - Very forward detection (spectator tagging, diffractive, coherent nuclear, etc.)
  - Vertex resolution (charm, strangeness)
  - Hadronic calorimetry (jet reconstruction)

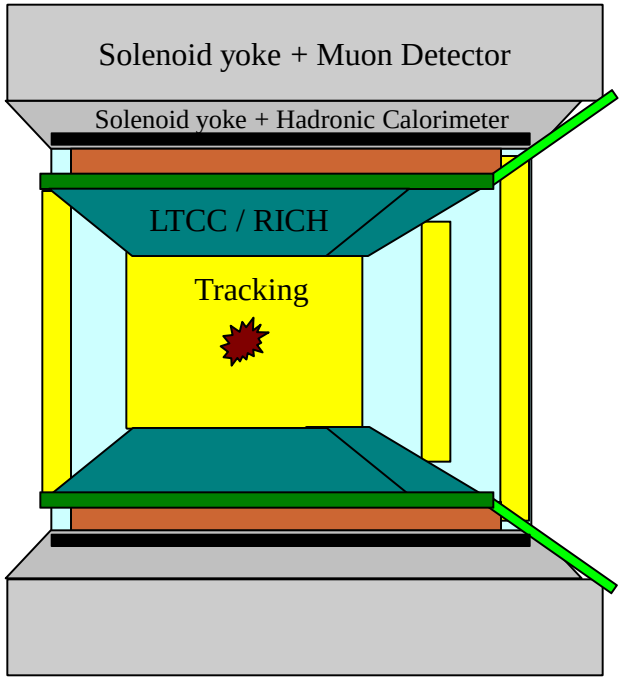
Central detector layout



- Crossing angle: 3 -5
- "Holes" for small-angle ion and electron detection not shown

- TOF +DIRC (5-10 cm)

Central Detector



Central Tracker

- Vertex Detector
- Small (GEM-based?) TPC
- Coarser-resolution tracking chambers

Solenoid Yoke, Hadron Calorimeter, Muons

- 3-4 T solenoid with about 4 m diameter
- Hadronic calorimeter and muon detector integrated with the return yoke (*c.f.* CMS)

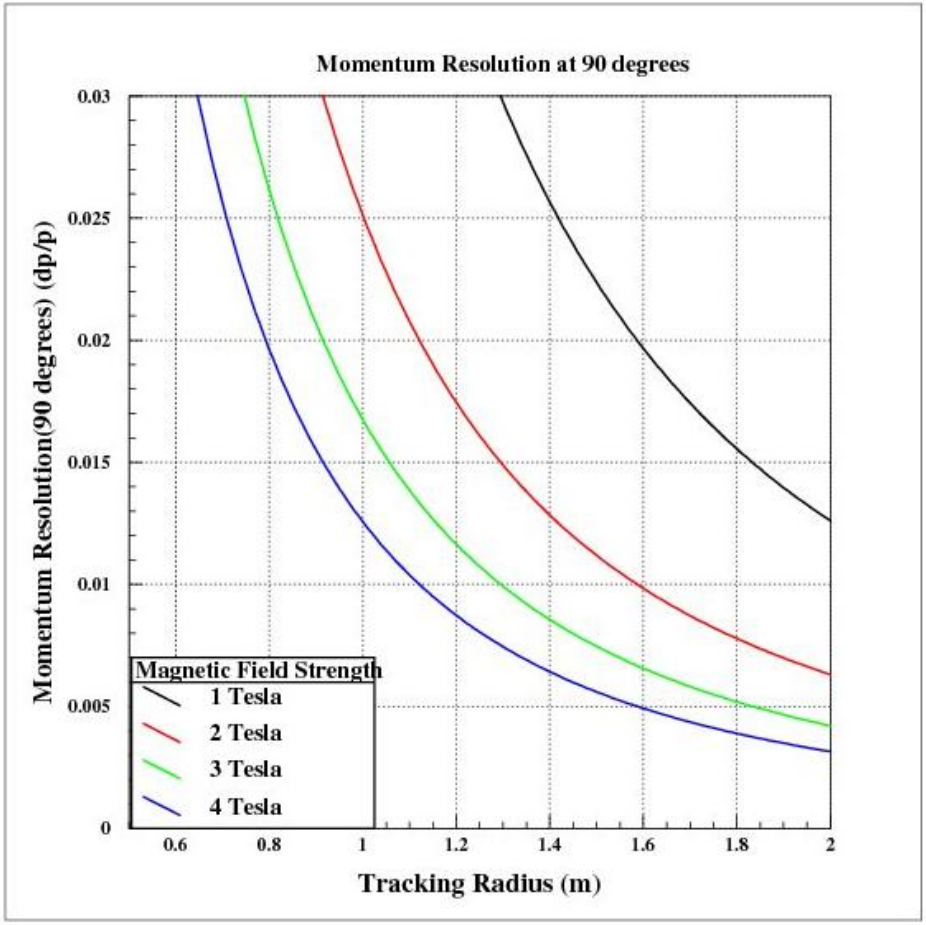
Particle Identification (in Central Detector)

- TOF for low momenta
- π/K separation options
  - DIRC up to 4 GeV
  - DIRC + LTCC up to 9 GeV
  - dual radiator RICH up to 8 GeV
- p/K separation options
  - DIRC up to 7 GeV
- e/π separation
  - LTCC (C_4F_8O) up to 3 (5) GeV
    - Very compact, 6% resolution

dp/p dependence on tracking radius

Broc Wursten, 2010

10 GeV pions, ideal field resolutions

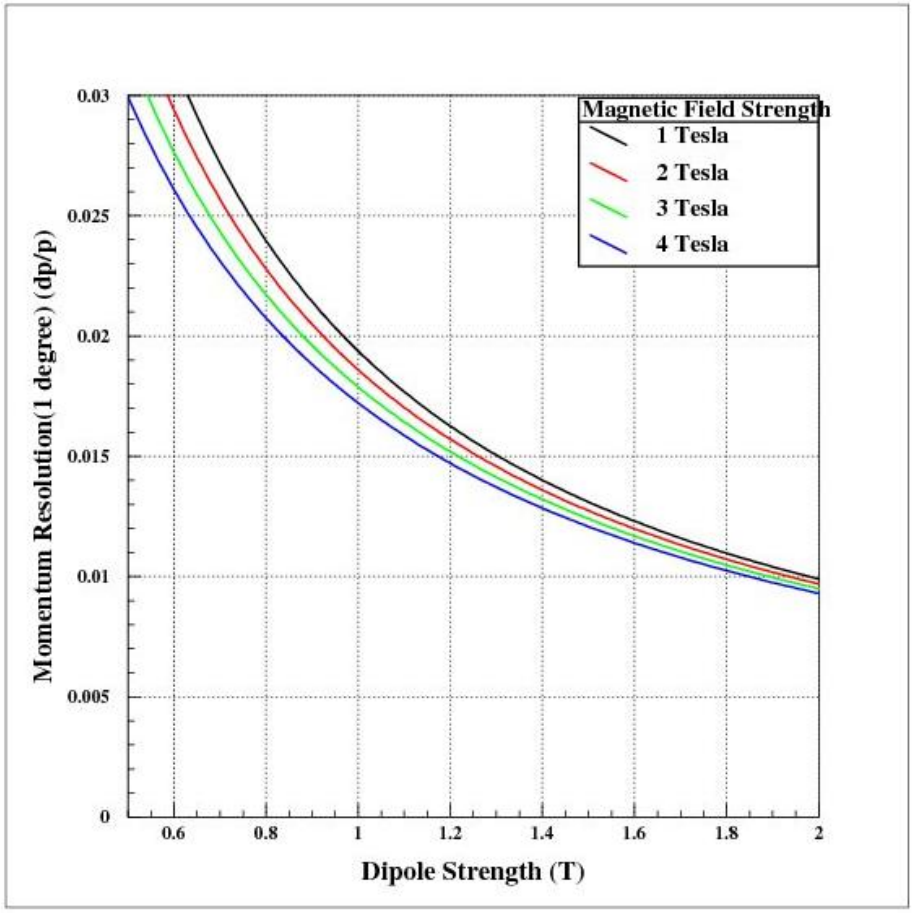


- The momentum resolution depends both on (solenoid) field strength and tracking radius
- Balance the solenoid field strength vs. the tracking radius
- Here plotted for pions of 10 GeV at *90 degree angles*
- Can get resolutions of ~1% for 10 GeV/c pions for say
  - 4 T & 1.1 m track length
  - 2 T & 1.6 m track length
- Are we better off with lower field but larger solenoid?

Include (1m long) dipole field

Broc Wursten, 2010

10 GeV pions at 1° scattering angle, ideal field resolutions



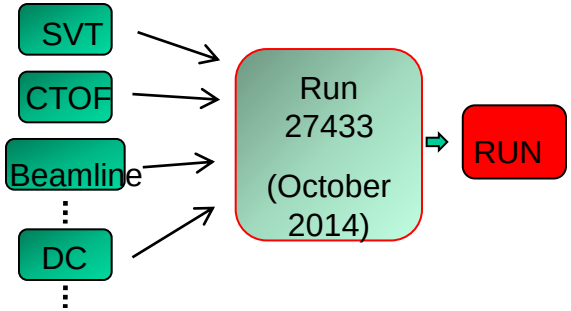
- Solenoid hardly has transverse field component at forward angle
  - effect due to crossing angle not included in this plot
- Momentum resolutions completely dominated by additional dipole field
  - 1% resolution requires only about 2 Tm dipole field
  - Probably good enough for resolution purposes
  - Spectator tagging for e-d and forward-angle tagging for e-A will require additional dipole, in MEIC design ~ 20 Tm at 20 meter from the IP

1 m long dipole → this is B.dl

GEMC (GEant4 MonteCarlo)

- EIC GEANT MC based on GEMC *[M. Ungaro]*
  - Cross section model based on a parameterization of NMC data

- GEMC can retain a very high degree of commonality between its CLAS12 and EIC implementations
  - Relies on external field map and geometry services implemented as queries to MySQL databases
  - The code could be maintained for both applications.



- Geometry server is accessed through a series of PERL scripts
  - Further information: https://eic.jlab.org/internal/images/f/f9/Gemc_overview_howto.pptx

GEMC Overview

Object Oriented Approach

- c++ classes, Standard Template Library containers

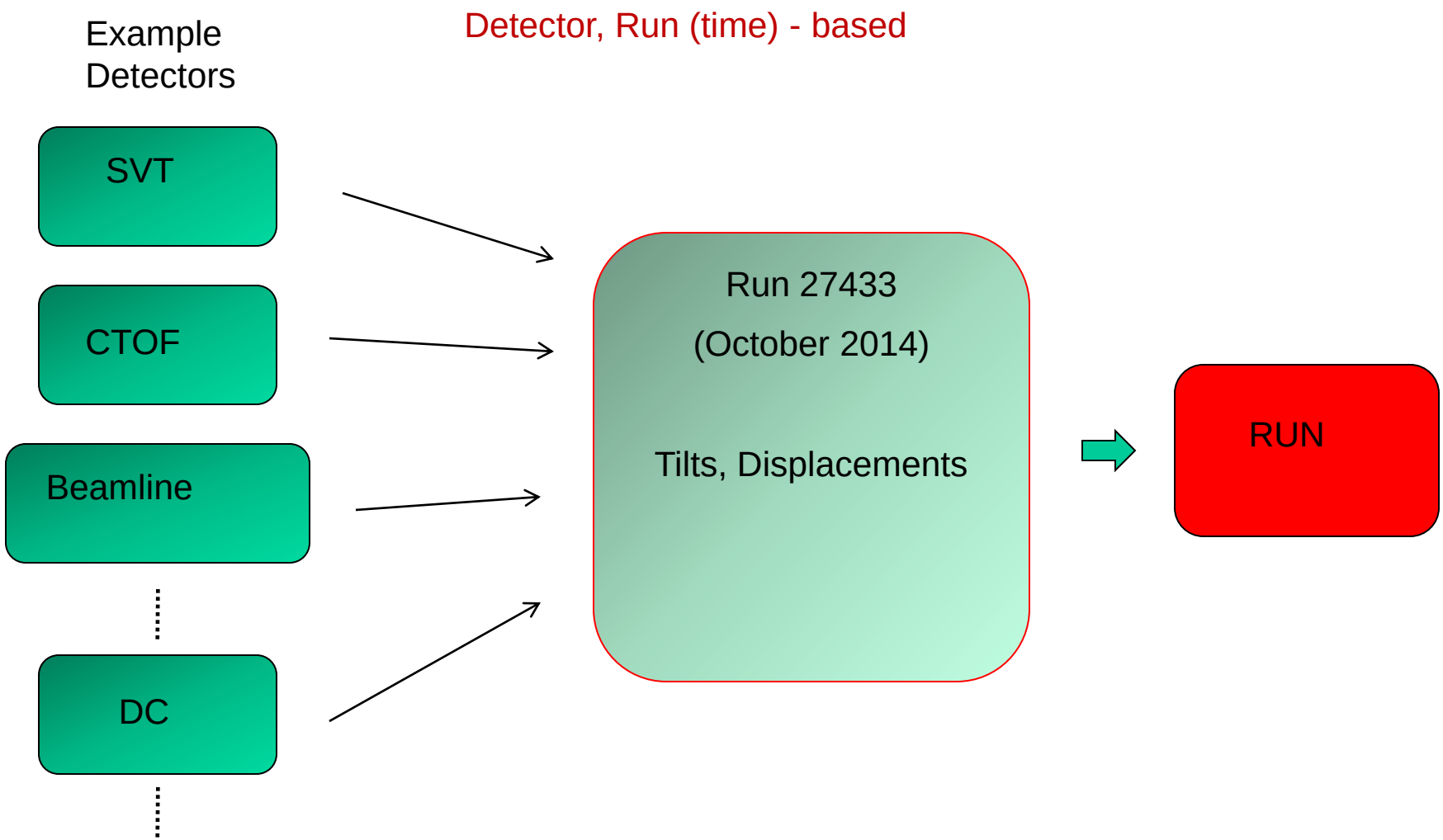
Simulation Parameters are External to Software

- Geometry, Materials, Fields, Banks stored in external database
- Run-Time user decisions on step sizes, Output Format, etc

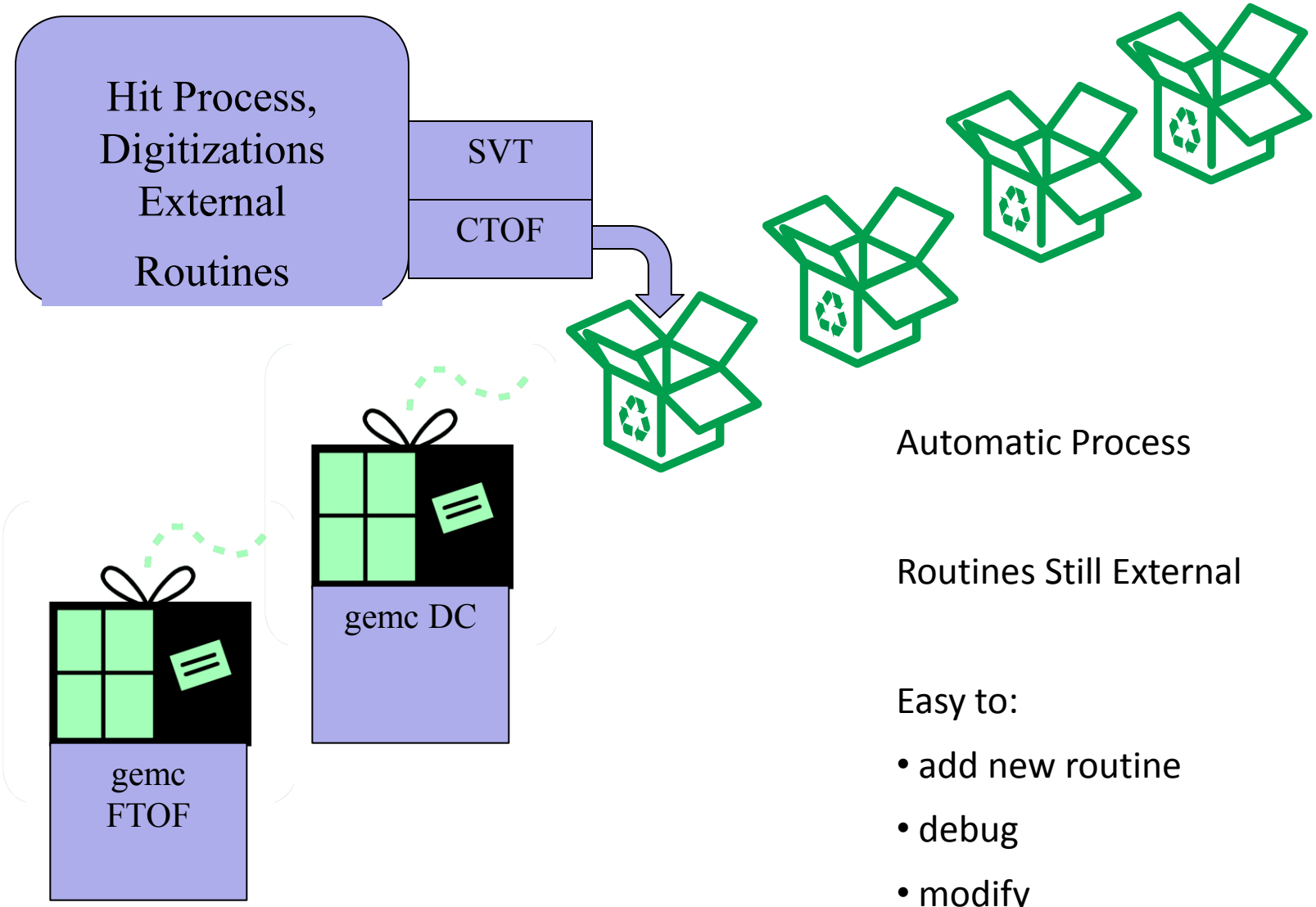
Factory Method

- Hit Process Routines, Digitization
- Input , Output Formats

Geometry Database



Factory Method for Hit Processes



Automatic Process

Routines Still External

Easy to:

- add new routine
- debug
- modify

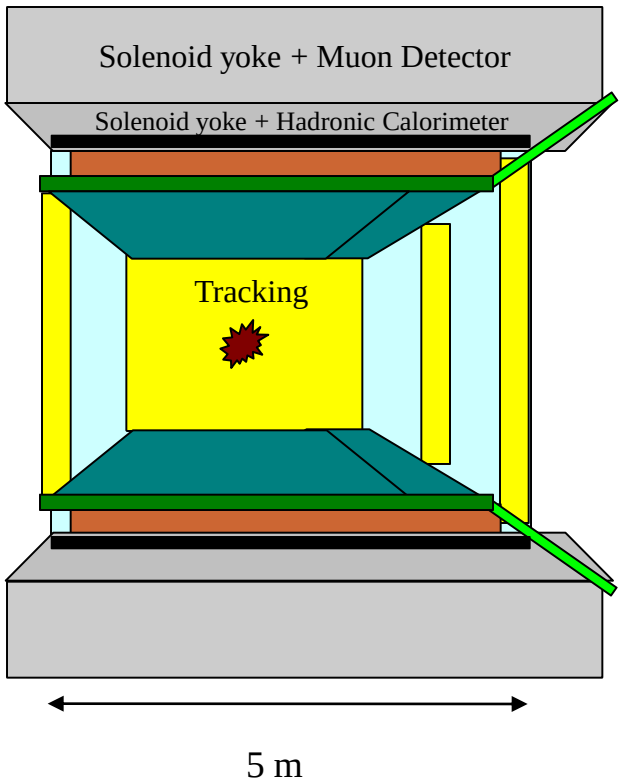
3 types of hits

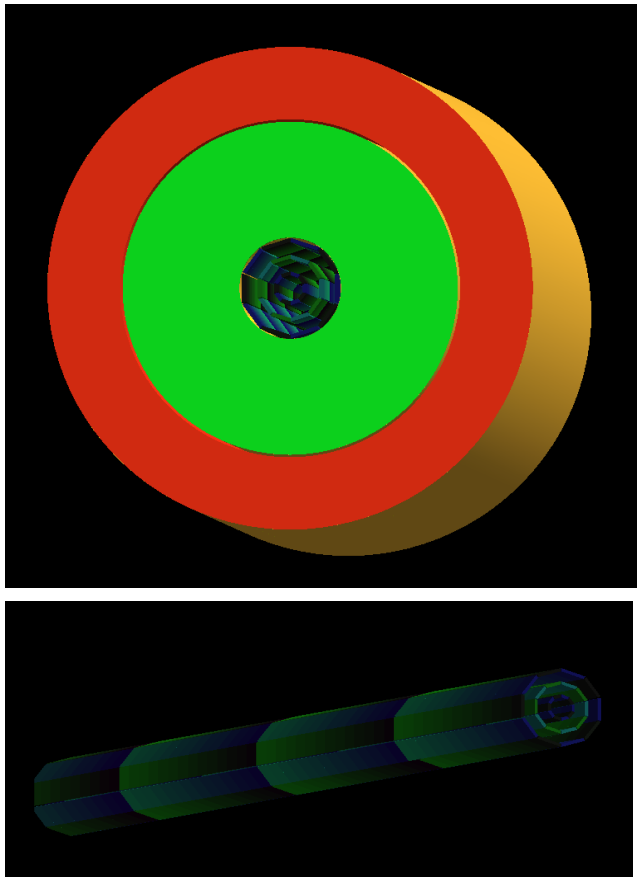
1) FLUX" type: every track has its own hit. Good for counting purposes (i.e. how many protons pass through a detector, etc)

2) Time Window ADC: all hits (separate tracks too) in the same time window for a particular detector will be added to give a ADC

3) Time Window TDC: the first hit within the detector time window will give the TDC.

EIC GEANT MC



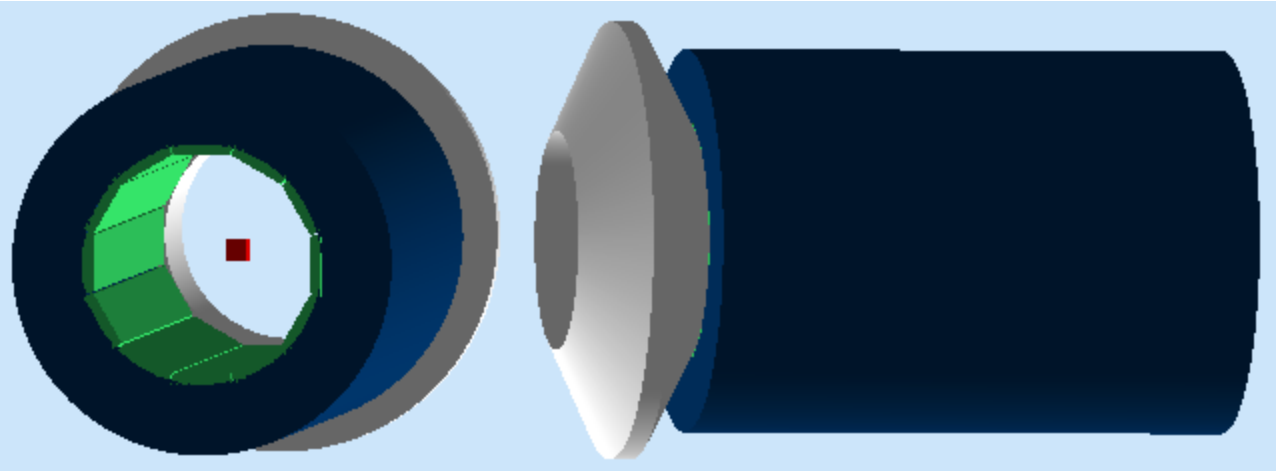


Thoth Gunter: GEMC Tracking, 2010

- Implementation will be done in several steps with increasing levels of sophistication
  - Cartoon serves as guideline for the implementation
- First iteration: understand rate distributions in various parts of the detector
  - Compare with simple background studies *[Jacob Castilow 09]*

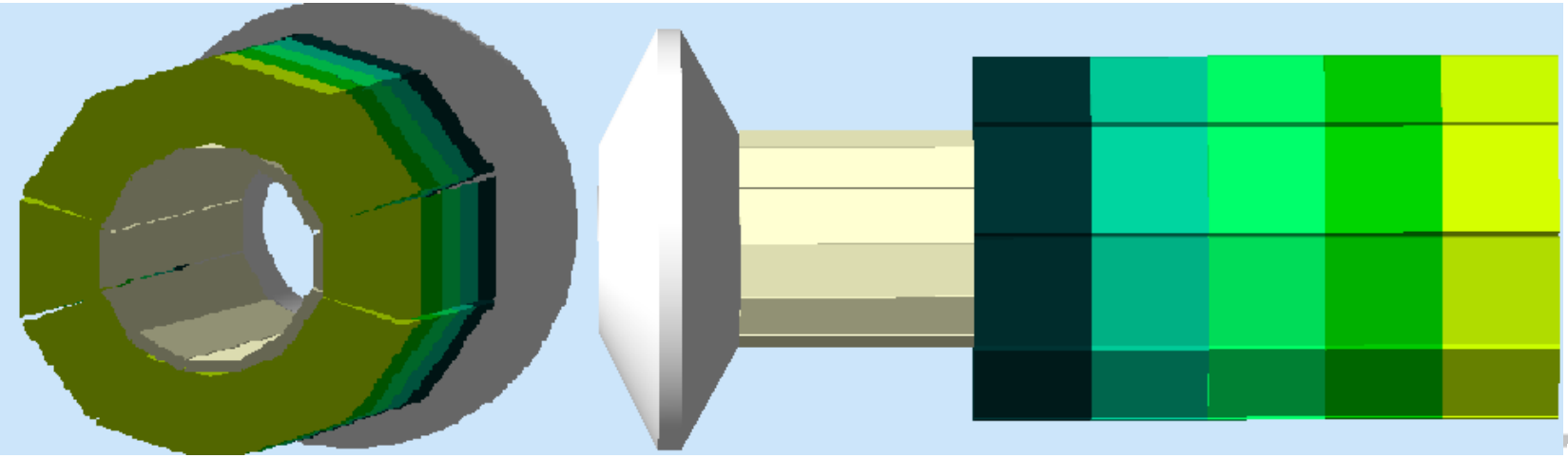
EIC GEANT MC

Joe Olson: GEMC implementation of Particle Identification, 2010

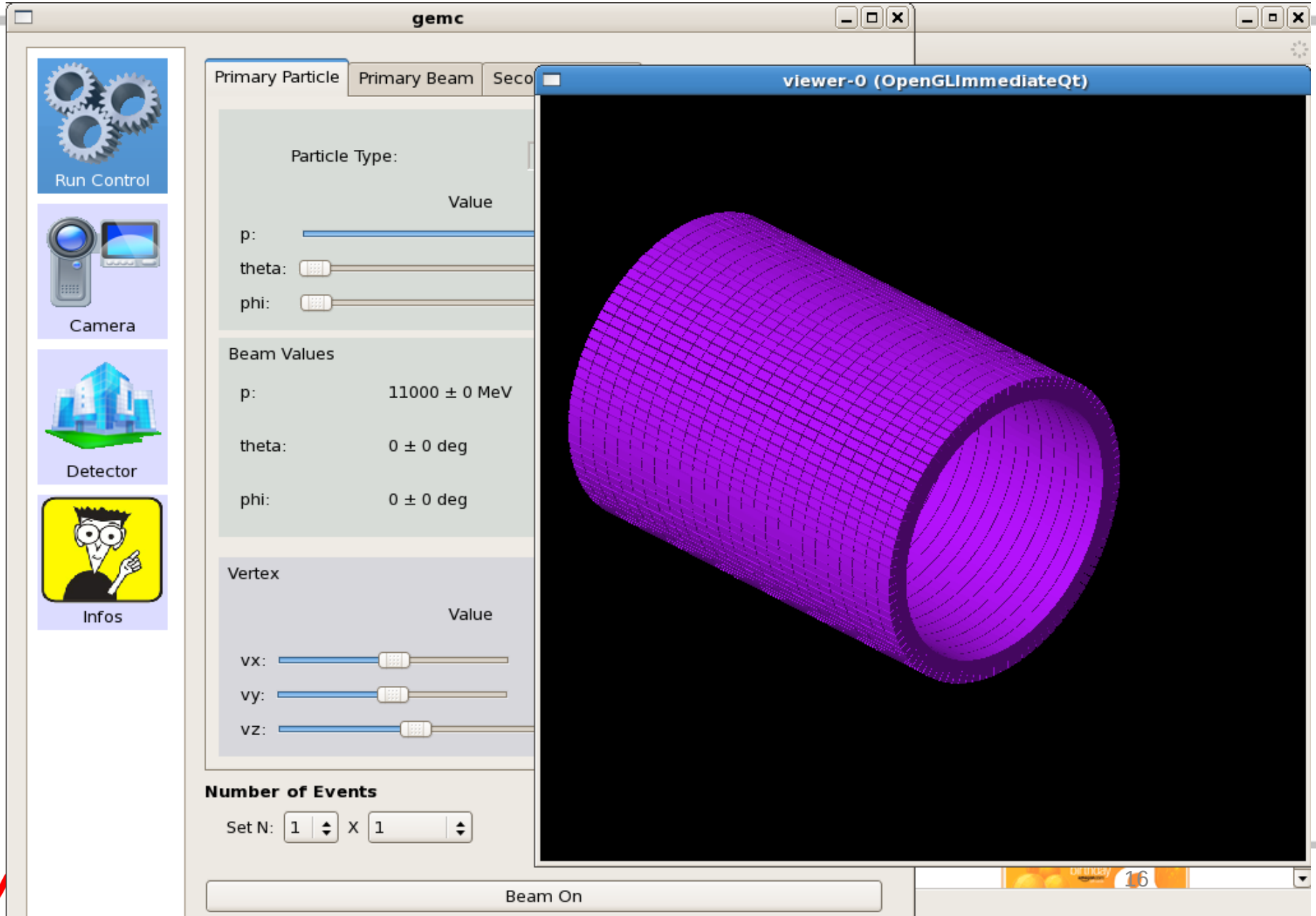


First Design of DIRC and LTCC

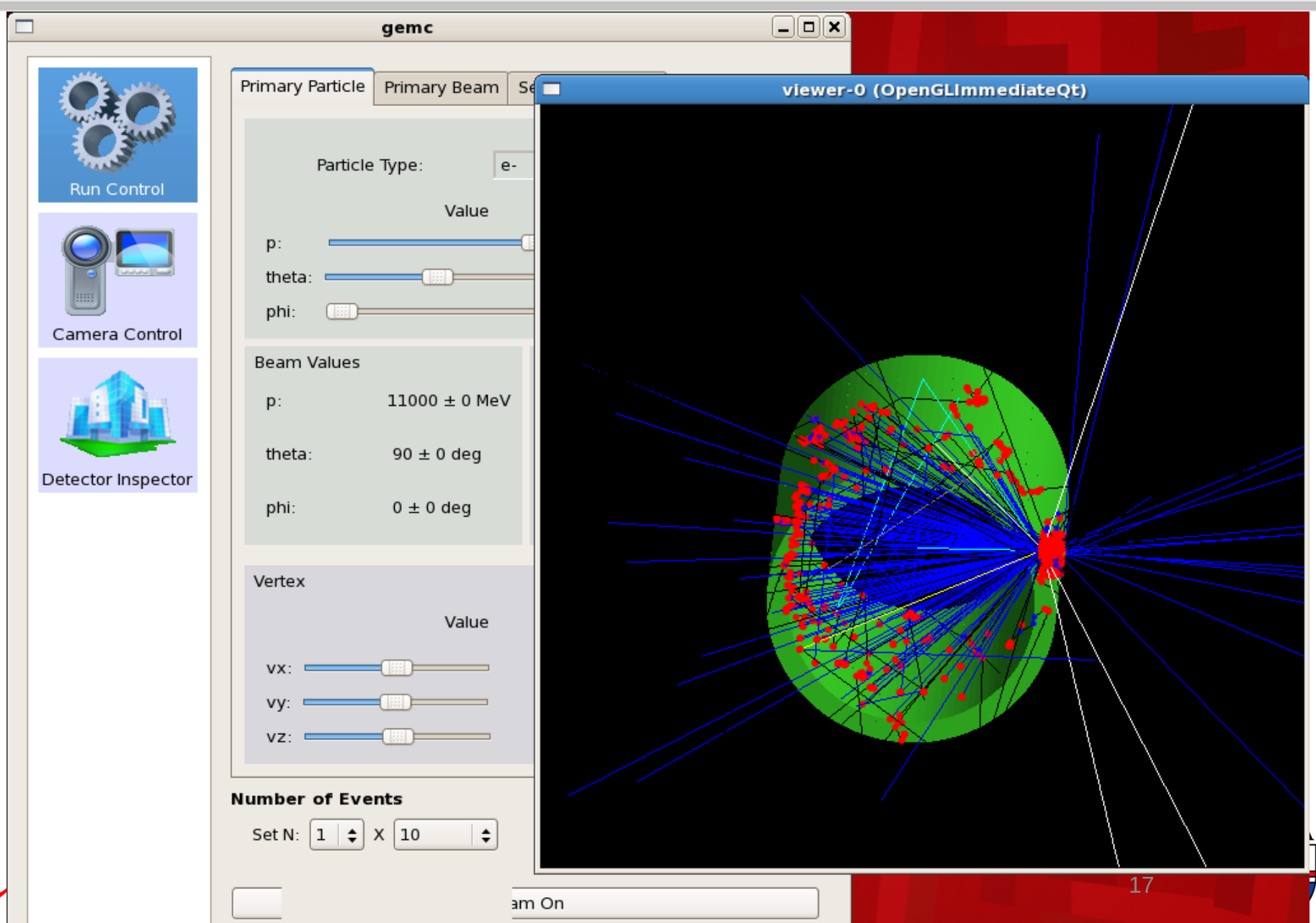
(Present thoughts for central detector hadron PId are a DIRC and C4F8O LTCC combination)



Angela Spence: GEMC implementation of EM Calorimeter, 2010



EIC GEANT MC Interface



Check out the EIC GEANT MC

Check out gemc

```
svn co https://clas12svn.jlab.org/repos/trunk/clas12/gemc/production gemc
cd gemc
setenv GEMC `pwd`
```

Add $GEMC/database_io to your bin path

You're now ready to use the gemc scripts

Example:

database_io/eic/geo/cnd/

./go_table user_geomety

- GEMC is easy to use
- Very flexible software that can be used for any detector

gemc installation

Mac OSX

Fedora 11 64 bit

Fedora 8 32 bit

Red Hat Enterprise Linux 5.3 32 bit

Scientific Linux 4.5 64 bit

CentOS 5.3 64 bit

http://clasweb.jlab.org/wiki/index.php/Yum_installation_for_various_Linux_distro

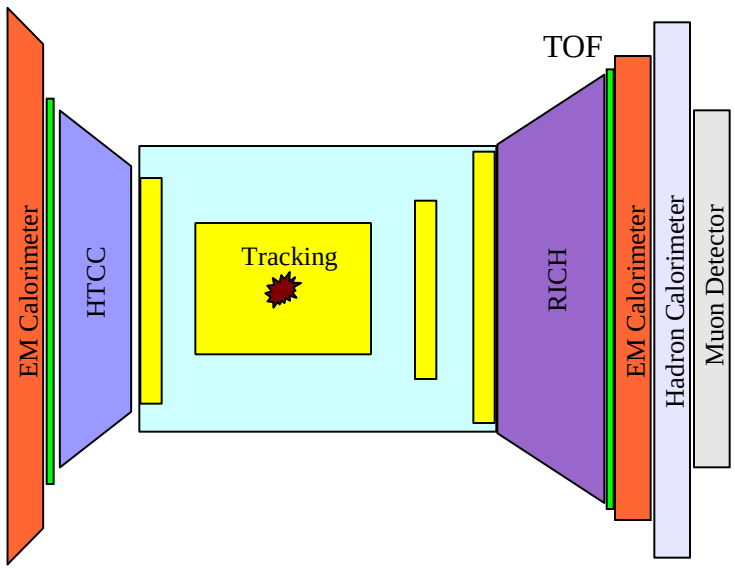
http://clasweb.jlab.org/wiki/index.php/Mac_OS_X_gemc_installation_with_Fink

EIC@JLab Simulation and Reconstruction Working Group

- The main goals of the simulation working group is to provide
  - Event generators for various processes
  - Fast Monte Carlo to explore acceptance and resolution requirements
  - GEANT4 based Monte Carlo to study detector resolution and acceptance
  - Event Reconstruction for GEANT based MC

- GEANT4 MC will use the standard CLAS12 engine, GEMC.
  - Flexible design uses external, implementation independent field map and detector geometry servers.
  - Support for digitizations, etc provides data that can be used for full event reconstruction.
  - Package will be maintained and developed together with CLAS12.

Detector Endcaps



Electron side (left)

- Bore angle: ~45 (line-of-sight from IP)
- High-Threshold Cerenkov
- Time-of-Flight Detectors
- Electromagnetic Calorimeter

Ion side (right)

- Bore angle: 30-40 (line-of-sight from IP)
- Ring-Imaging Cerenkov (RICH)
- Time-of-Flight Detectors
- Electromagnetic Calorimeter
- Hadronic Calorimeter
- Muon detector (at least at small angles)
  - Important for J/Ψ photoproduction

Tracking

- Forward / Backward
  - IP shifted to electron side (2+3 m)
  - Vertical planes in central tracker
  - Drift chambers on either side

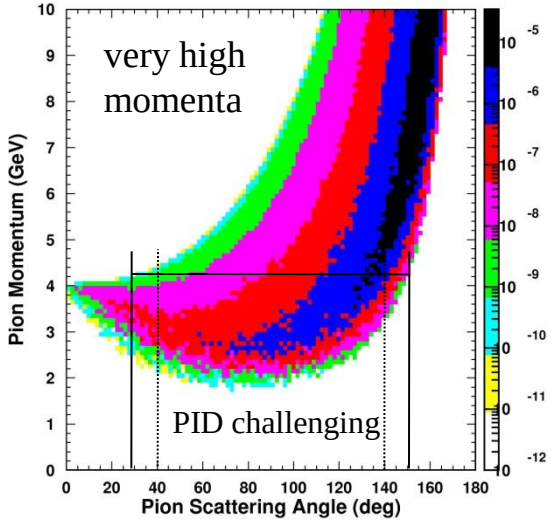
Exclusive light meson kinematics

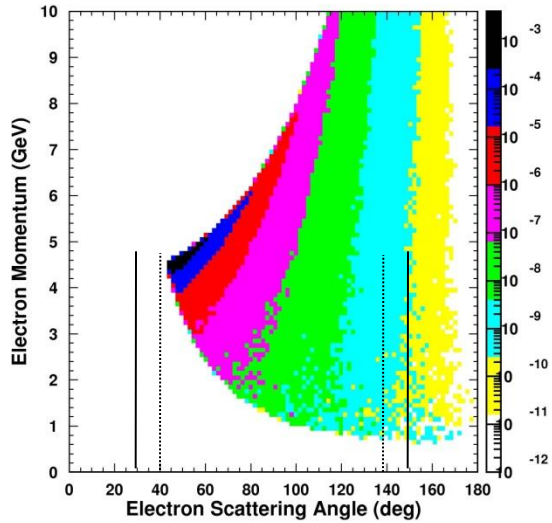
$ep \rightarrow e'\pi^+ n$

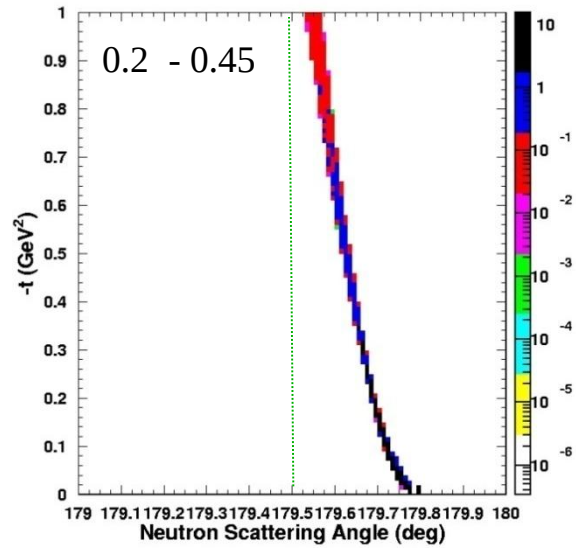
mesons | scattered electrons | recoil baryons

Horn 08+

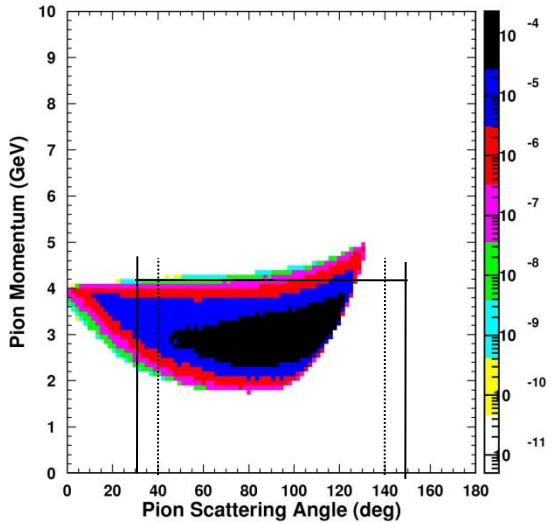
4 on 250 GeV

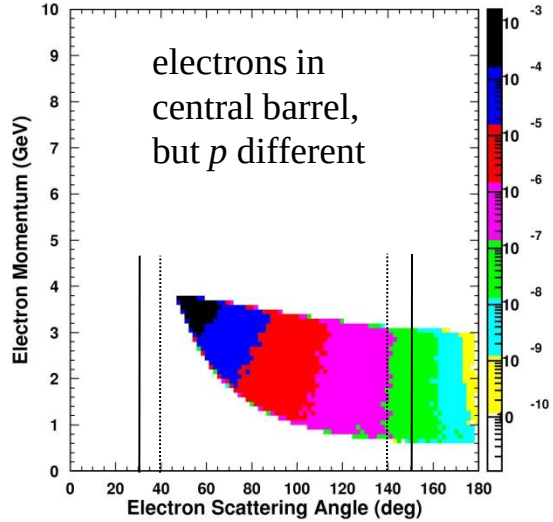


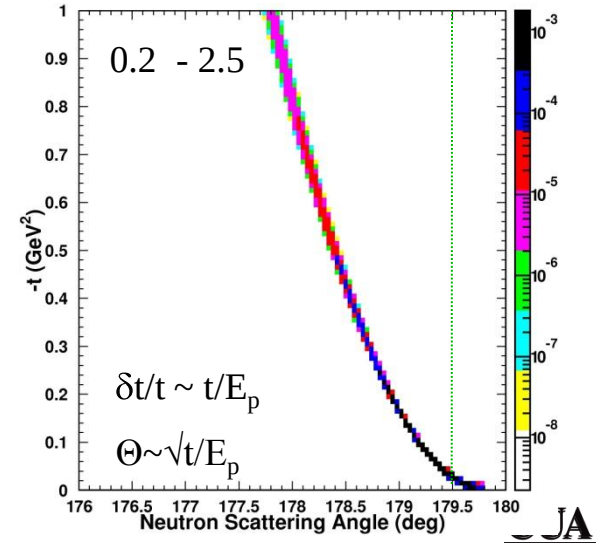




4 on 30 GeV







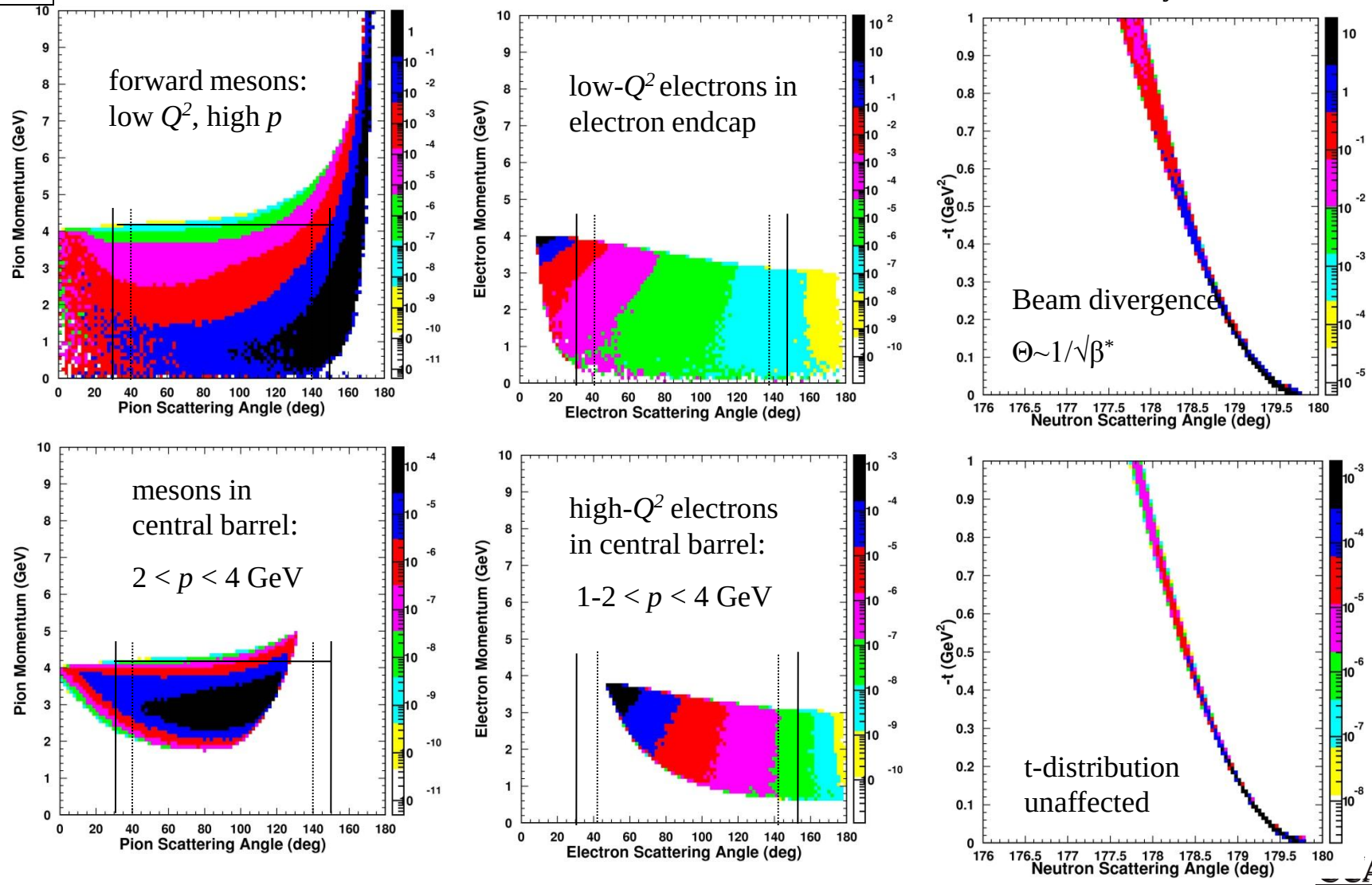
Photoproduction vs. high Q^2 (light mesons) – 4 on 30

$ep \rightarrow e'\pi^+n$

mesons | scattered electrons | recoil baryons | *Horn 08+*

no Q^2 cut

$Q^2 > 10$ GeV^2



EIC@JLAB – further info

- EIC@JLAB webpage: http://eic.jlab.org
  - Overview and general information

- EIC@JLAB WIKI: https://eic.jlab.org/wiki
  - Ongoing project information
  - Working groups

- Weekly project meetings at JLab
  - Fridays at 9:30am in ARC724 or F324/25

- Series of Workshops at the INT, Seattle
  - Info: http://www.int.washington.edu/PROGRAMS/10-3/