EIC_NET General Meeting

MC studies and Physics Performance

A. Mastroserio, S. Fazio

Montecarlo Simulations - Ongoing Activities

- Bi-weekly meetings
- EIC_NET - Simulation activities:
  - **Tracking perfomances**
  - **dRICH**
  - **Physics simulations**
- News for EIC SWG : final decision available!

EIC Software decision

- **1. Code repository**:
  - Decision: "We will implement a hybrid solution that uses GitHub as the primary repository, while using the eicweb GitLab instance for CI/CD." Endorsement at https://docs.google.com/document/d/1jT8CXj1cS9FEa0MbpJBV5jBA0T_vu2UdNDX93IJSo9c/
- **2.Geometry Description and Detector Interface**
  - Decision: "We will implement the geometry description and detector interface using DD4hep." Endorsement at https://docs.google.com/document/d/16dQ-u2u5CdJIN3_slvcI79vTWJYnQytoQclMu2e-TpY/
- **3. Data Model**
  - Decision: "We will adopt PODIO as the tool for managing the EDM. We will adopt the EDM4hep Data model as the initial Data Model." Endorsement at https://docs.google.com/document/d/1seWDXQr570Tv_yJijUCKgXhla6u5HAV-ibO82PR43Xk/
- **4. Reconstruction Framework**
  - Decision: "The working group conveners recommend JANA2 as the reconstruction framework." Endorsement at https://docs.google.com/document/d/1lomak02ztchkwQB2d_f-58gabBOQF9WaPaQhf8kTvfY/edit

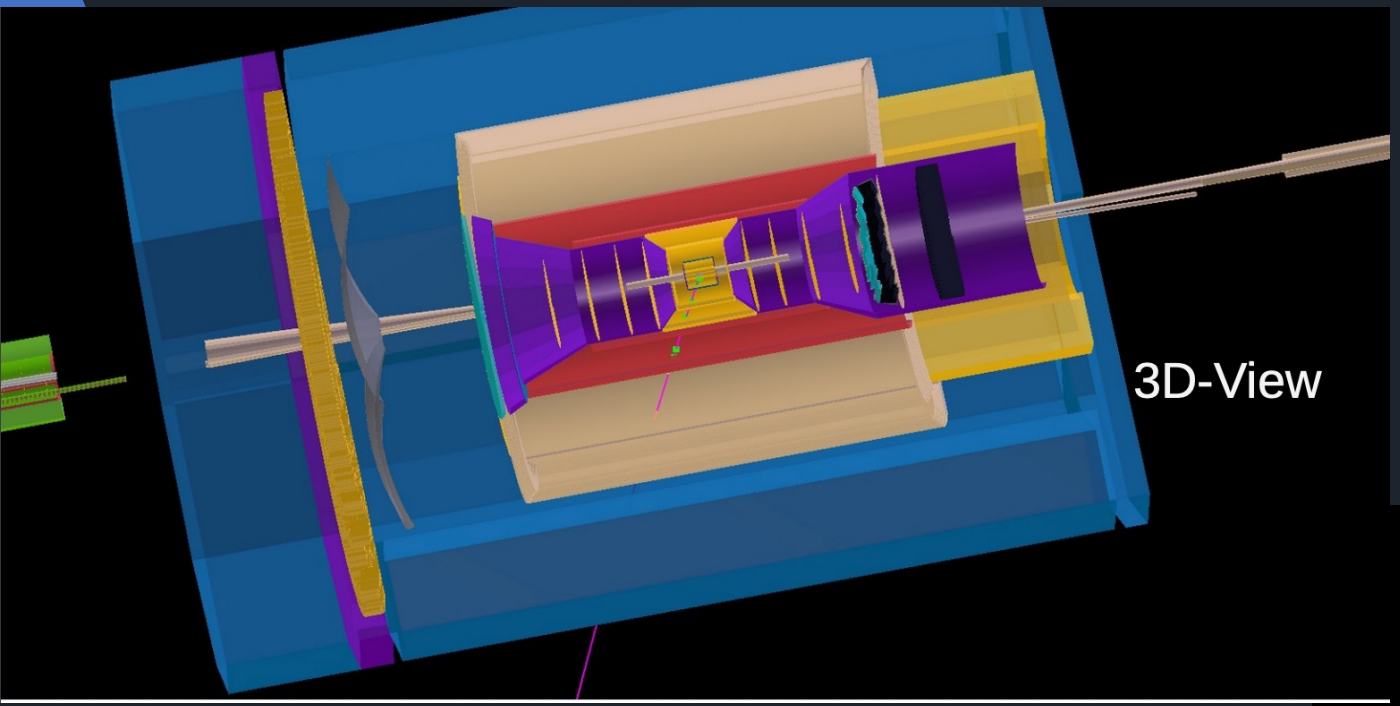
Tutorials are available here

- Tracking performance studies

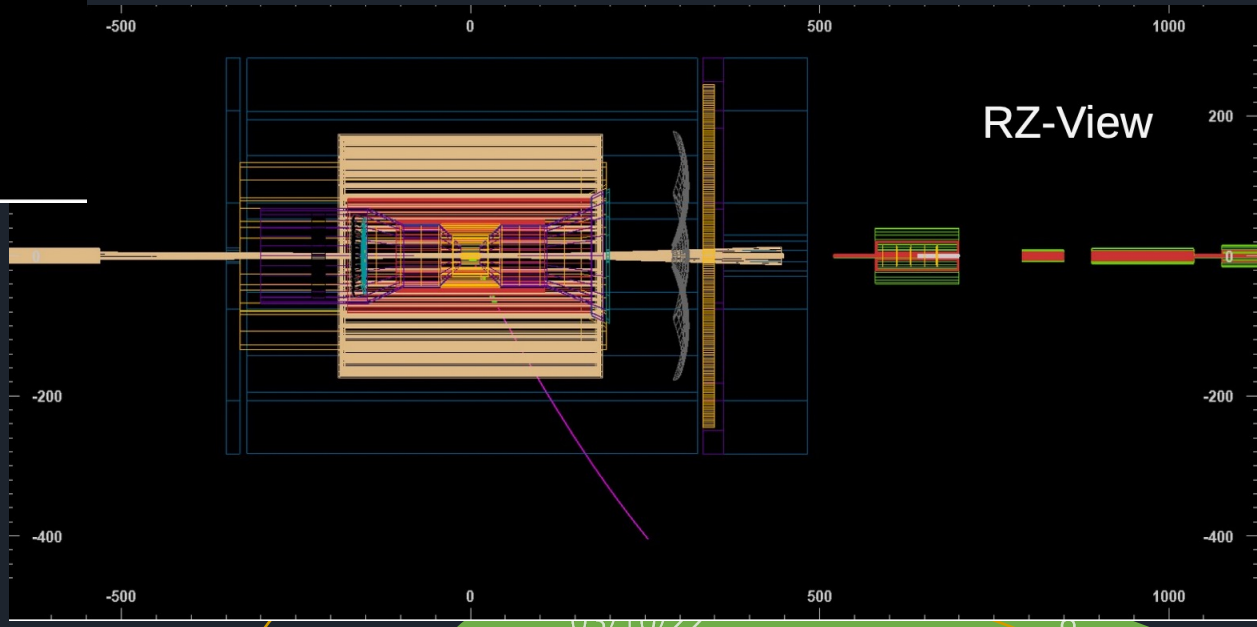
Tracking performance

- Geometry studies
  - Event display
  - Volumes
- Material budget maps as a function of η
- Initial studies on reconstructed tracks
  - Tracking efficiency
  - Pointing resolution
  - Momentum resolution

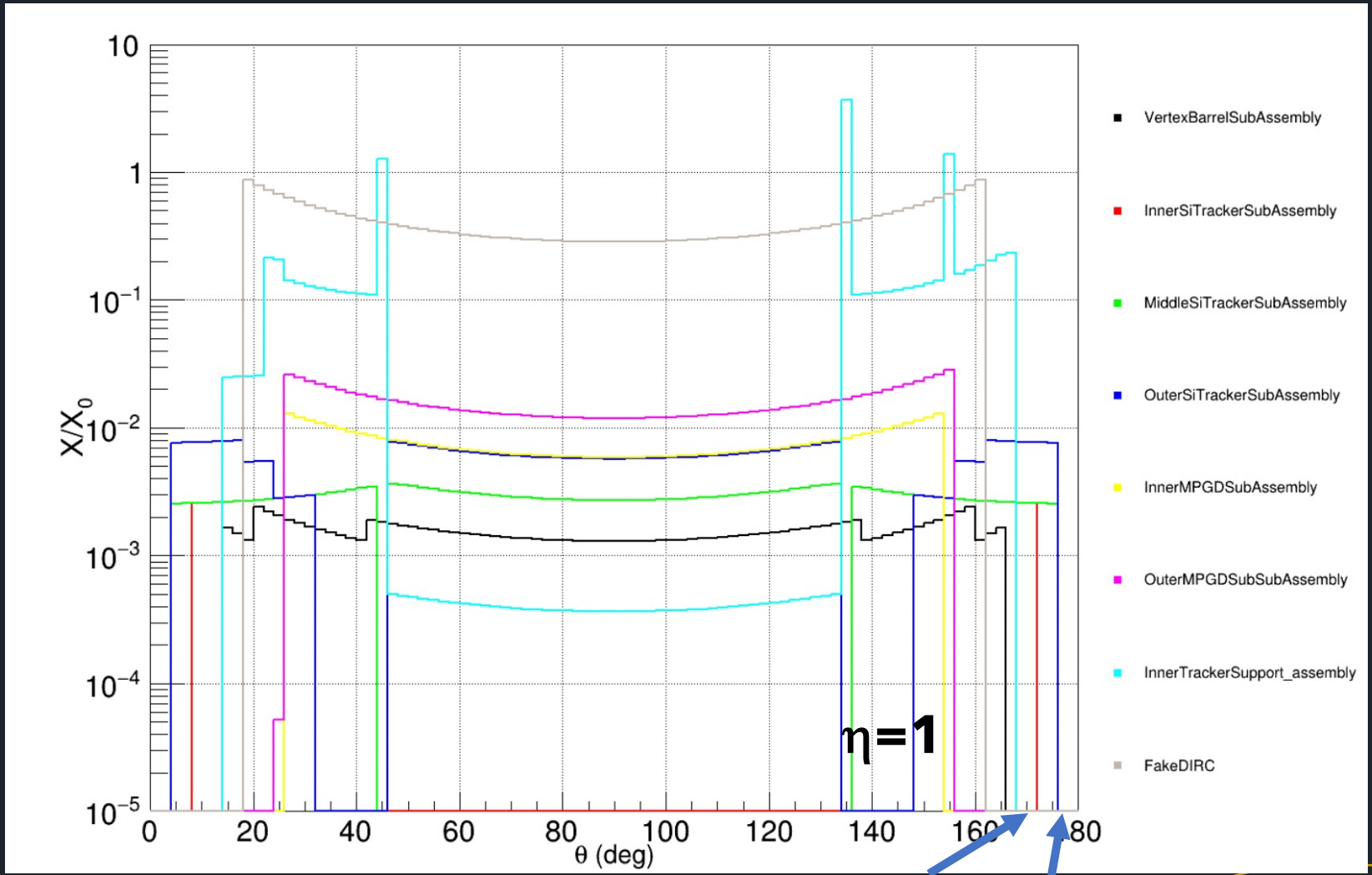
ePIC Geometry in DD4HEP



Shyam Kumar



Material budget /acceptance studies



Shyam Kumar

Vertex:
3 x 0.05 % X/X0= 0.15%

Tracking layers OK

Tracking efficiency

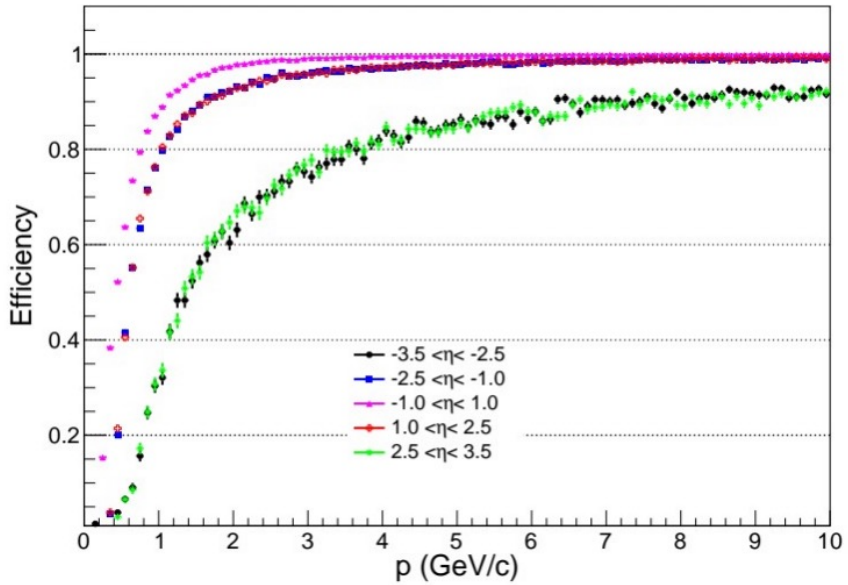
https://agenda.infn.it/event/32684/contributions/180271/attachments/97093/134022/Infn_meeting_Shyam.pdf

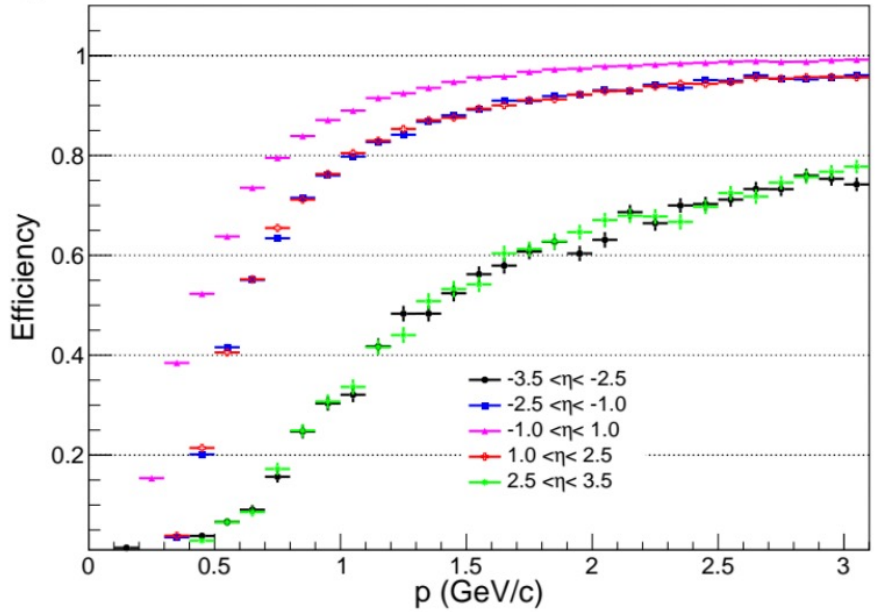
Efficiency

https://arxiv.org/pdf/2103.05419.pdf

Min p_T (barrel) : 400 MeV/c

3 M Pi+ using particle gun





No Material budget included in tracking

Limited information stored in the reconstructed tracks

e.g.: MC track ID not available (-→ fix available in ≈ 1 month)

Next steps

- Recompute tracking efficiency
  - New tracking results with material budget included
  - MC id selection
- Momentum resolution
- Pointing resolution
- Look at the D^0 reconstruction efficiency

•dRICH

dRICH studies

Chadradoy Chatterjee

- **Simulation chain is working!**
- We can run dd4hep, juggler and evaluation script to characterize dRICH
- There have several debugging and intermediate refactoring steps to reach to the current config

```
Detector       INFO  +++ Patching names of anonymous shapes....
DDG4           INFO +++ Imported 358 global values to namespace:DDG4
Geant4Kernel         OutputLevel:  2
Geant4Kernel         UI:           UI
Geant4Kernel         NumEvents:    10
Geant4Kernel         NumThreads:   0
DDG4           INFO +++  List of sensitive detectors:
DDG4           INFO +++  DRICH                    type:tracker      -->Sensitive type: ('Geant4TrackerWeightedAction', {'HitPositionCombination': 2, 'CollectSingleDe
False})
Geant4UI       INFO  +++ UI> Install Geant4 control directory:/ddg4/UI/
Geant4Kernel   INFO  ++ Registered global action UI of type dd4hep::sim::Geant4UIManager
Geant4UI       INFO  +++ MagFieldTrackingSetup> Install Geant4 control directory:/ddg4/MagFieldTrackingSetup/
Geant4Kernel   INFO  ++ Registered global action RunInit of type dd4hep::sim::Test::Geant4TestRunAction
Geant4UI       INFO  +++ RunAction> Install Geant4 control directory:/ddg4/RunAction/
Geant4UI       INFO  +++ EventAction> Install Geant4 control directory:/ddg4/EventAction/
Geant4Output2EDM4hep INFO  instantiated...
Geant4UI       INFO  +++ EDM4hepOutput> Install Geant4 control directory:/ddg4/EDM4hepOutput/
DDSim          INFO ++++ Adding DD4hep ParticleGun ++++
DDSim          INFO Enabling the PrimaryHandler
Geant4UI       INFO  +++ GeneratorAction> Install Geant4 control directory:/ddg4/GeneratorAction/
Geant4UI       INFO  +++ Gun> Install Geant4 control directory:/ddg4/Gun/
Geant4UI       INFO  +++ hepmc4> Install Geant4 control directory:/ddg4/hepmc4/
Geant4UI       INFO  +++ InteractionMerger> Install Geant4 control directory:/ddg4/InteractionMerger/
Geant4UI       INFO  +++ PrimaryHandler> Install Geant4 control directory:/ddg4/PrimaryHandler/
Geant4UI       INFO  +++ TrackingAction> Install Geant4 control directory:/ddg4/TrackingAction/
Geant4UI       INFO  +++ SteppingAction> Install Geant4 control directory:/ddg4/SteppingAction/
Geant4UI       INFO  +++ ParticleHandler> Install Geant4 control directory:/ddg4/ParticleHandler/
DDSim.Helper.Filter INFO ReqFilt {'opticalphotons', 'edep0'}
DDSim          INFO getDetectorLists - found active detector DRICH type: tracker
DDSim          INFO Setting up SD for DRICH
DDSim          INFO       replace default action with : Geant4OpticalTrackerAction
Geant4UI       INFO  +++ DRICH> Install Geant4 control directory:/ddg4/DRICH/
Geant4UI       INFO  +++ DRICHHandler> Install Geant4 control directory:/ddg4/DRICHHandler/
DDSim.Helper.Filter INFO Adding filter 'opticalphotons' matched with 'DRICH' to sensitive detector for 'DRICH'
Geant4UI       INFO  +++ PhysicsList> Install Geant4 control directory:/ddg4/PhysicsList/
PhysicsList          +++ Dump of physics list component(s)
PhysicsList          +++ Extension name      FTFP_BERT
PhysicsList          +++ Transportation flag: 0
PhysicsList          +++ Program decays:     0
PhysicsList          +++ RangeCut:           0.700000
Geant4UI       INFO  +++ GlobalRangeCut> Install Geant4 control directory:/ddg4/GlobalRangeCut/
Geant4UI       INFO  +++ CerenkovPhys> Install Geant4 control directory:/ddg4/CerenkovPhys/
Geant4UI       INFO  +++ OpticalGammaPhys> Install Geant4 control directory:/ddg4/OpticalGammaPhys/
FieldSetup     INFO Geant4 magnetic field tracking configured.
FieldSetup     INFO G4MagIntegratorStepper:ClassicalRK4 G4Mag_EqRhs:Mag_UsualEqRhs
FieldSetup     INFO Epsilon:[min:0.000050 mm max:0.001000 mm]
FieldSetup     INFO Delta:[chord:0.250000 1-step:0.010000 intersect:0.001000] LargestStep 10000.000000 mm
```

Updates on simulation

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The only step can be of interest (and probably discussion in future?)

- During the ATHENA proposal we had been using PhotonCounter class to describe the photon interaction property and filling the collection class. This has been changed substantially in the later phase. Now SiPMs are like SiPM tracker. That was causing loss of photons entering into the Collection Class.
- The remedy was to add the Geant4 option fStopandKill to kill the (!photon) as soon as it arrives at the sensor active material and not to propagate it any further.
- After that description also the sensor surface definition became compatible.

IRT bug fix

A bug in the IRT algorithm while porting from athena to epic framework. The bug caused a eta dependency of the reconstructed Cherenkov angles. The bug is fixed now we are compatible with situation in ATHENA

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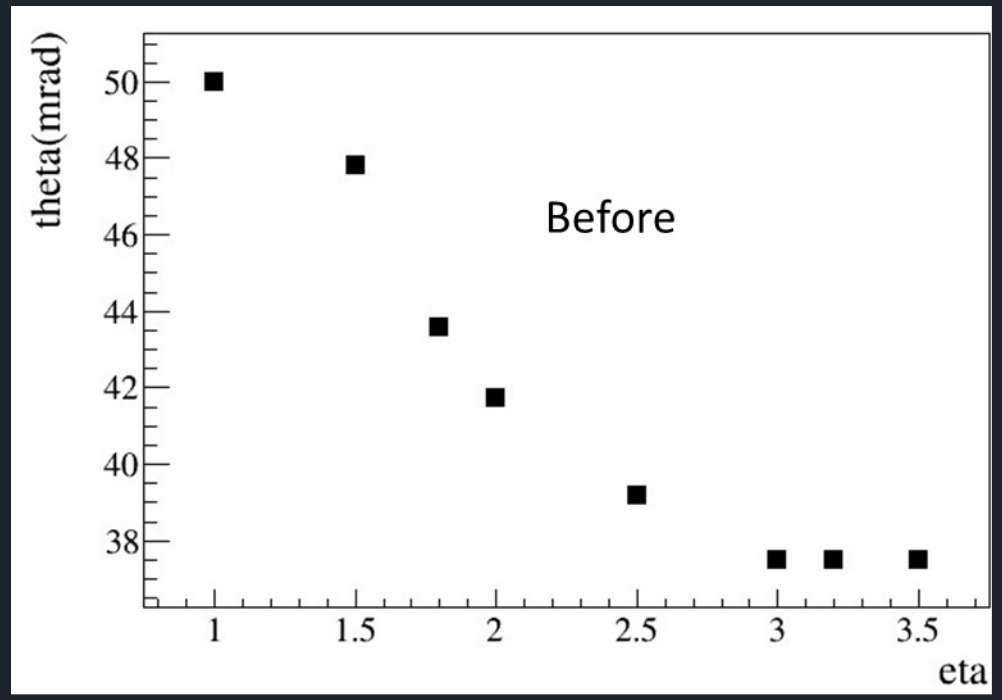

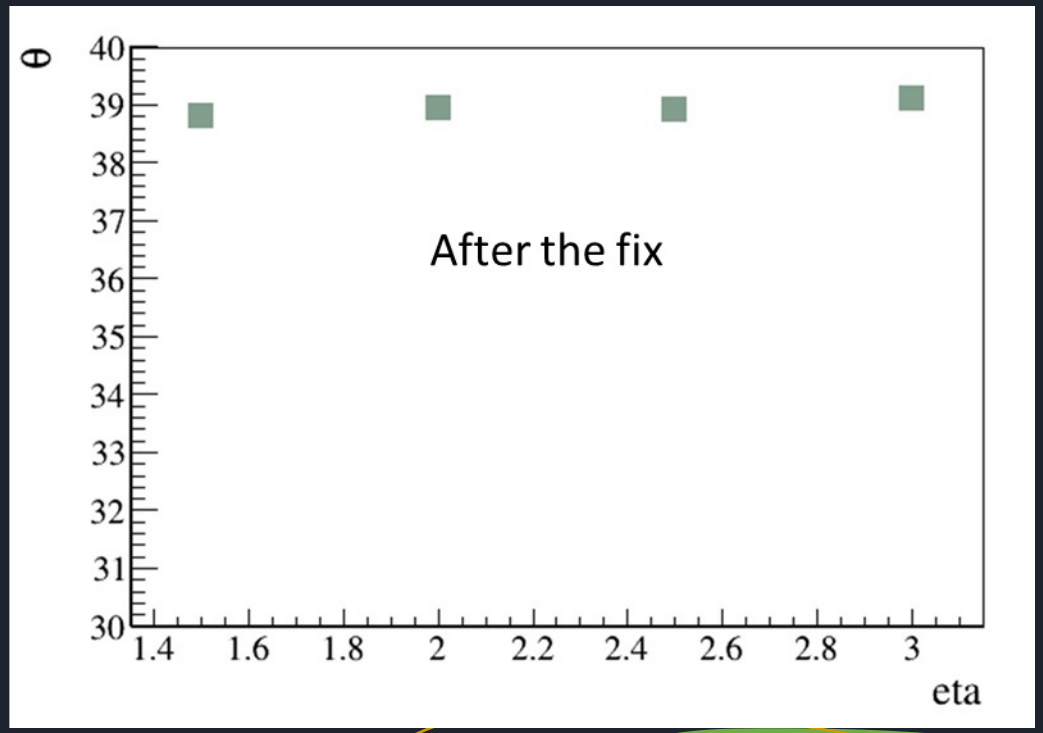

Reconstructed Cherenkov angle

Consistent with theoretical expectations (solid lines). The results use full EPIC software chain. Currently we are throwing single MC particle. Reconstructed particles are soon to be added

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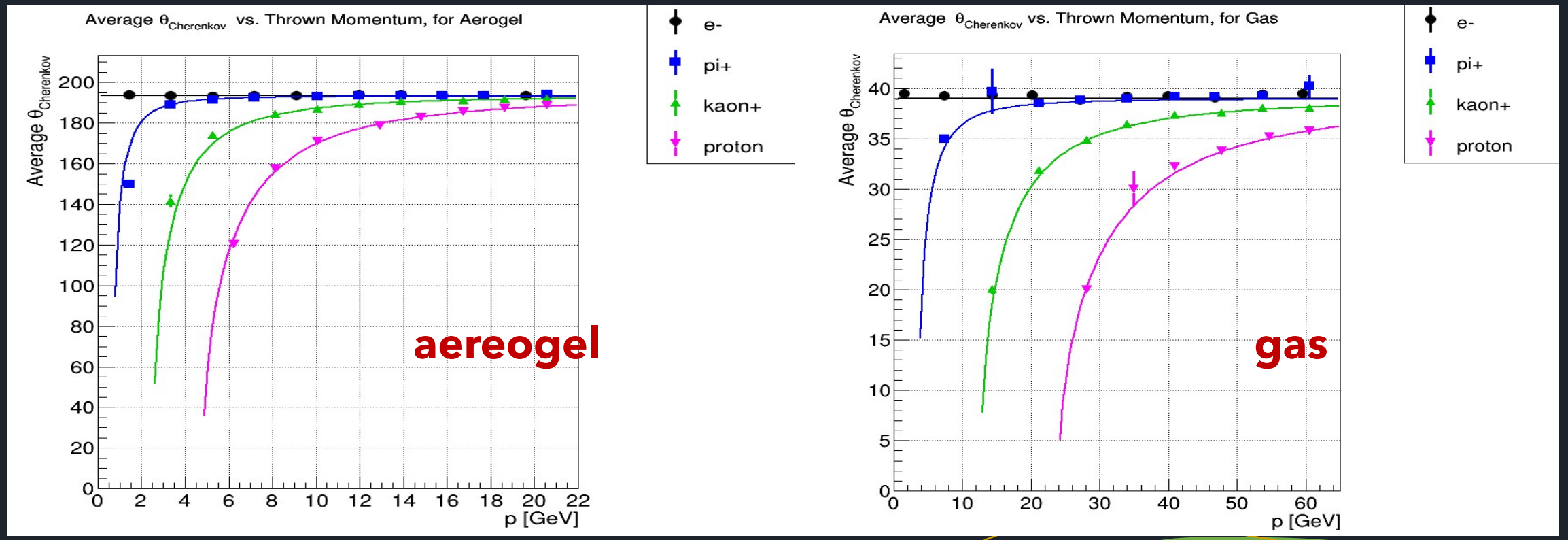
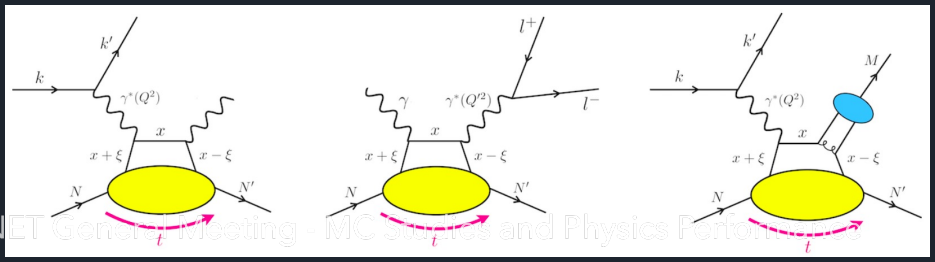


•Physics Simulations

The EpIC generator

- **EpIC:** an event generator for exclusive reactions
  - Named after EIC and the philosopher *Epicurus*
  - Note: we inspired the name for EIC detecor-1 ☺
- EpIC uses the PARTONS framework (http://partons.cea.fr), takes advantage of:
  - two state-of-art GPD models (GK, KM20)
  - flexibility for adding new models
- Multiple channels: DVCS, TCS, π^0
  - Initial and final state radiative corrections are implemented based on the collinear approximation
  - flexibility for adding all exclusive mesons



Salvatore Fazio

87 [hep-ph] 3 May 2022

EpIC: novel Monte Carlo generator for exclusive processes

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Received: date / Accepted: date

Abstract We present the EpIC Monte Carlo event generator for exclusive processes sensitive to generalised parton distributions. EpIC utilises the PARTONS framework, which provides a flexible software architecture and a variety of modelling options for the partonic description of the nucleon. The generator offers a comprehensive set of features, including multi-channel capabilities and radiative corrections. It may be used both in analyses of experimental data, as well as in impact studies, especially for future electron-ion colliders.

like separations. In case there is no momentum transfer to the nucleon, *i.e.* in the forward limit, certain GPDs become equivalent to PDFs. Additionally, the first Mellin moments of GPDs are related to elastic form factors. In this regard, GPDs may be viewed as a unified concept of elastic form factors studied via elastic scattering processes and one-dimensional parton distribution functions studied via (semi-) inclusive scattering processes. Another key aspect of GPDs is their relation to nucleon tomography. The Fourier transform of GPDs are related to the impact parameter space distri-

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Radiative Corrections – a first look

- Pure DVCS with 10 GeV electron and 100 GeV proton
- Kinematic cuts:

$0.0001 < xB < 0.63$

$1\ GeV^2 < Q^2 < 100\ GeV^2$

$0.04 < |t| < 1.3\ GeV^2$

$0.01 < y < 0.6$

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No cut on $\sum E - Pz$ & $\epsilon = 10^{-6}$

DVCS - 10 GeV x 100 GeV Simulated with EpIC

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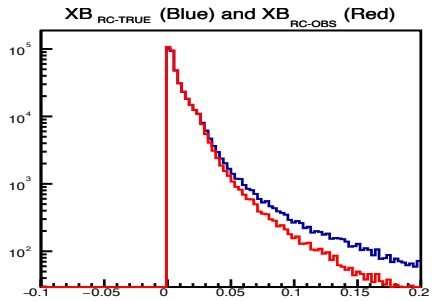

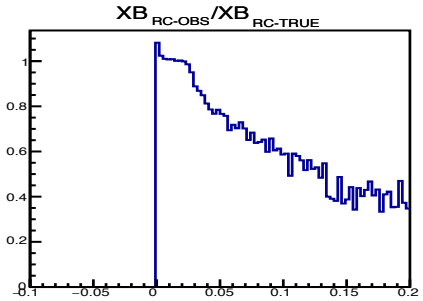

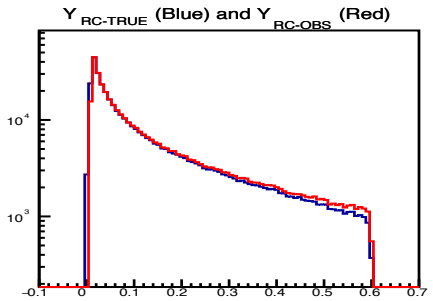

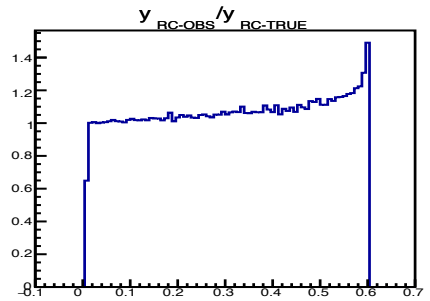

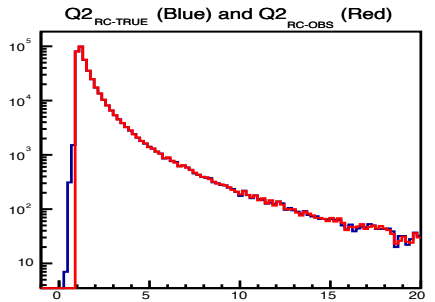

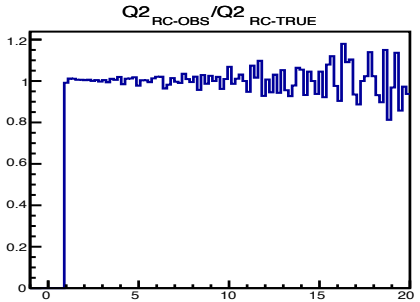

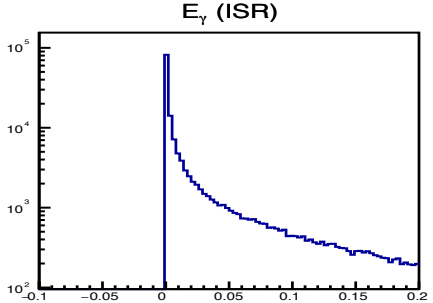

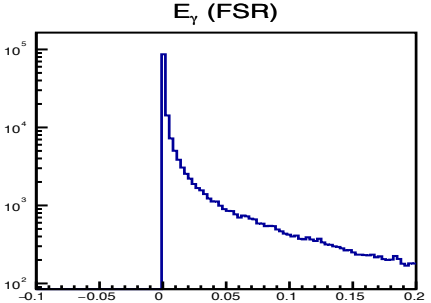

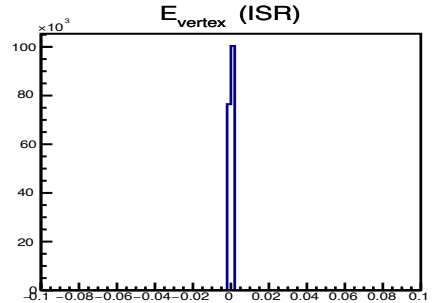

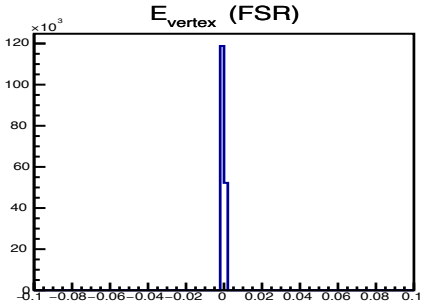

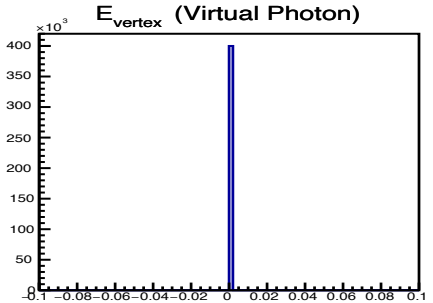

$\sum E - Pz > 17$ GeV & $\epsilon = 10^{-6}$

DVCS - 10 GeV x 100 GeV Simulated with EpIC

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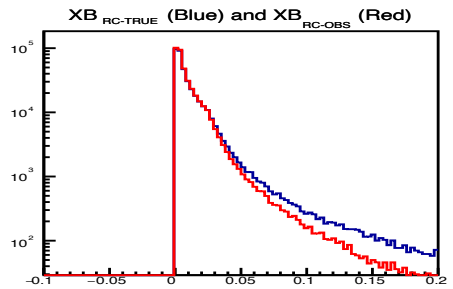

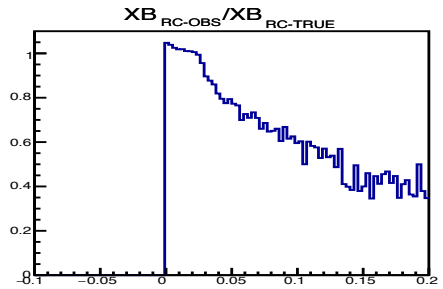

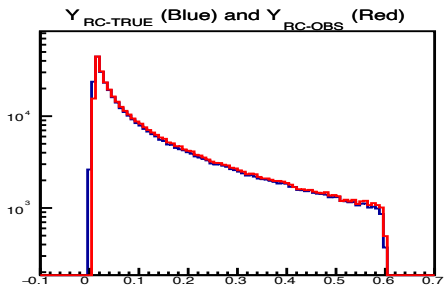

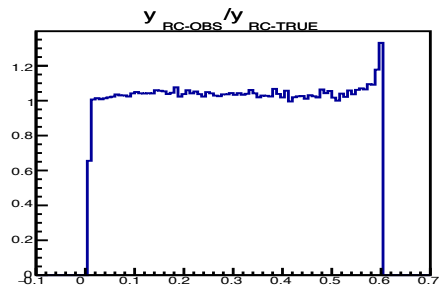

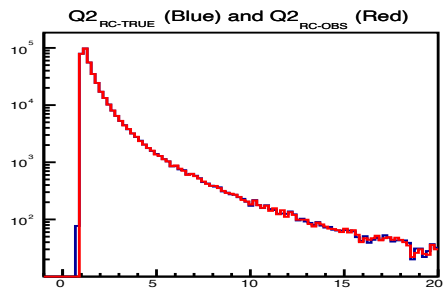

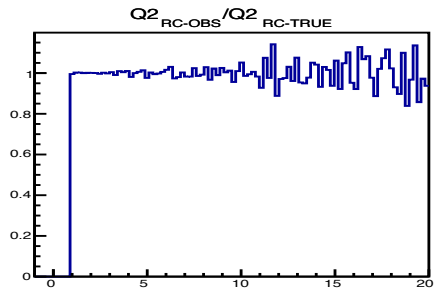

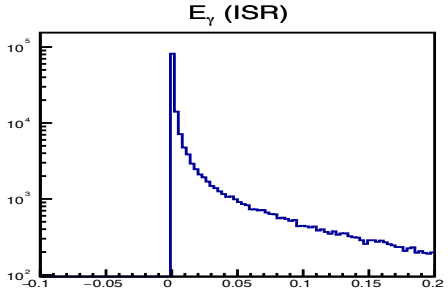

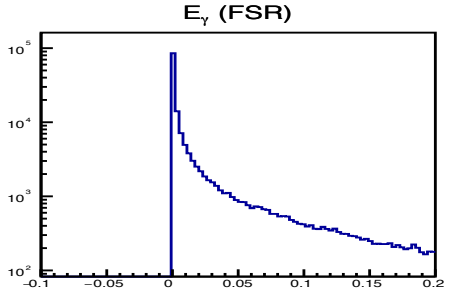

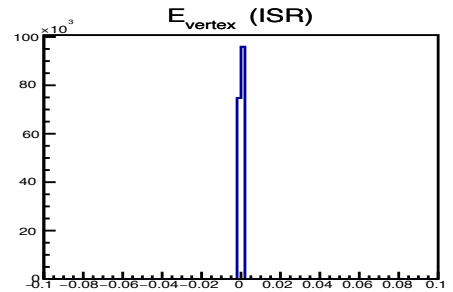

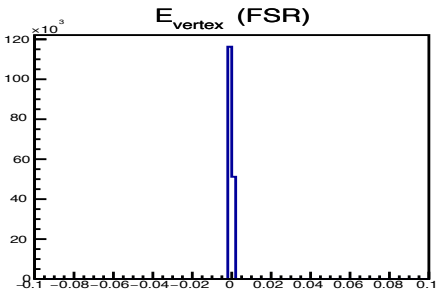

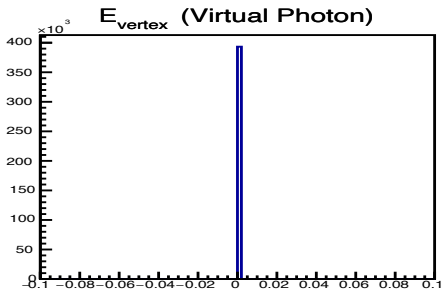

$\sum E - Pz > 19$ GeV & $\epsilon = 10^{-6}$

DVCS - 10 GeV x 100 GeV Simulated with EpIC

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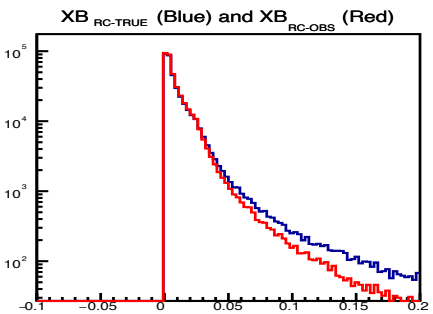
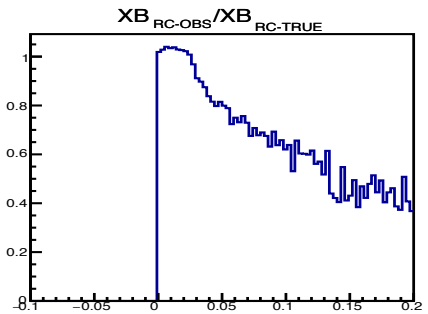
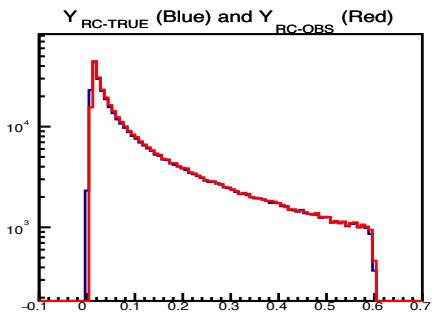
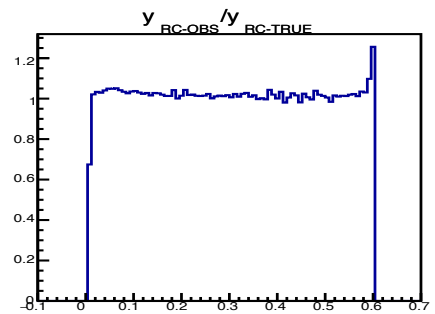
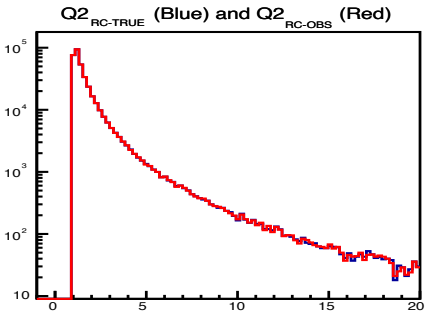
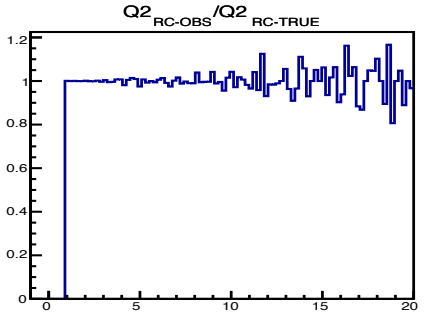


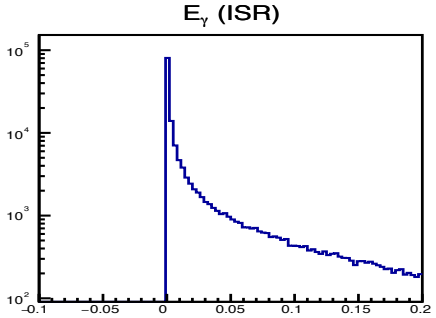


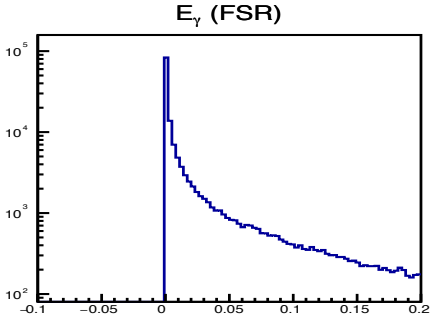


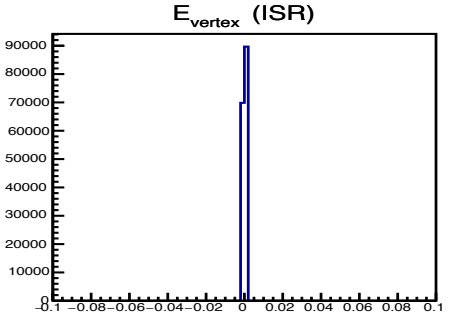


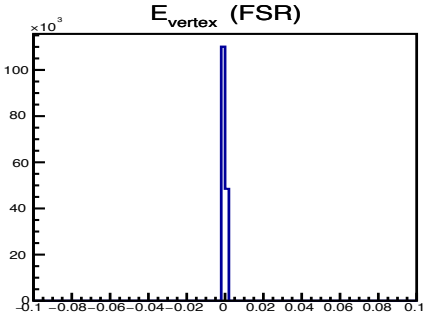


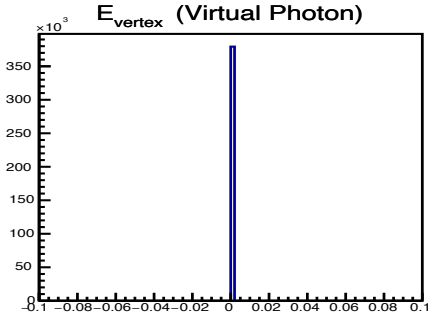








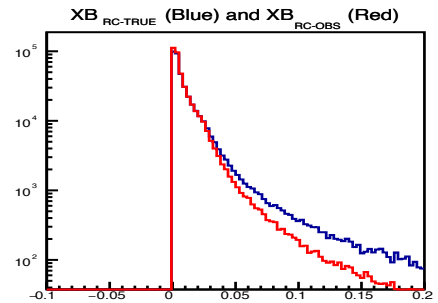


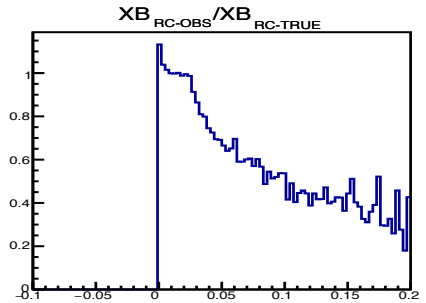


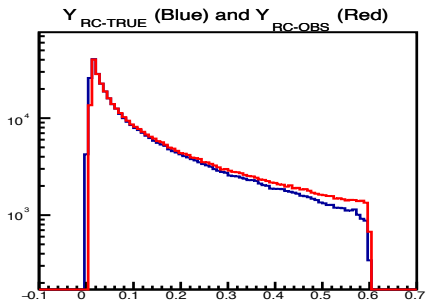
No cut on $\sum E - Pz$ & $\epsilon = 10^{-8}$

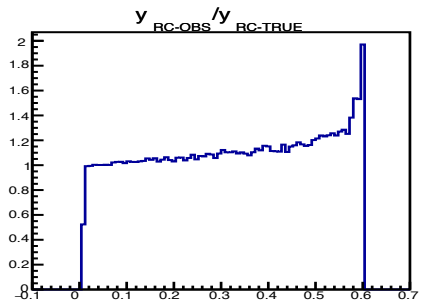
DVCS - 10 GeV x 100 GeV Simulated with EpIC

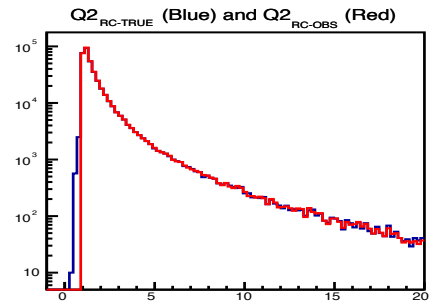
Salvatore Fazio

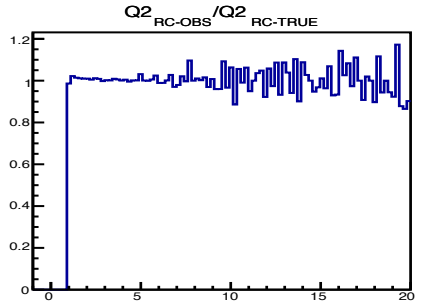


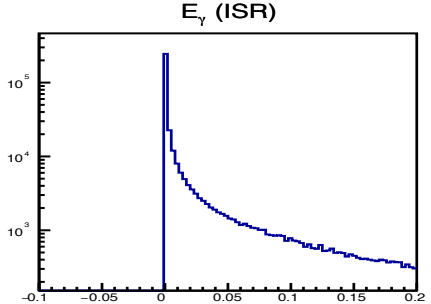


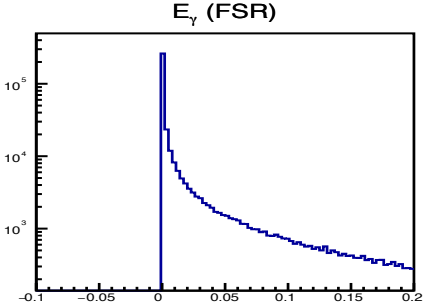


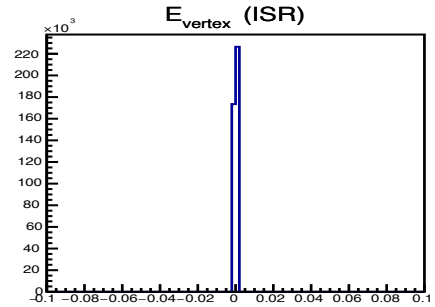


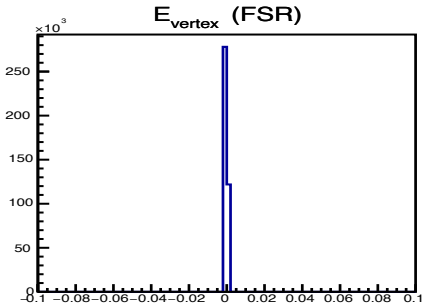


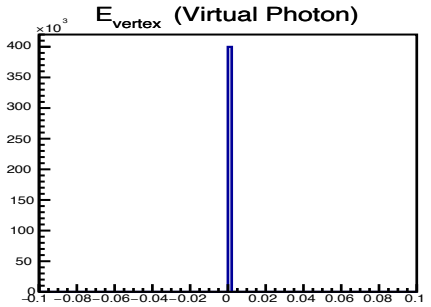








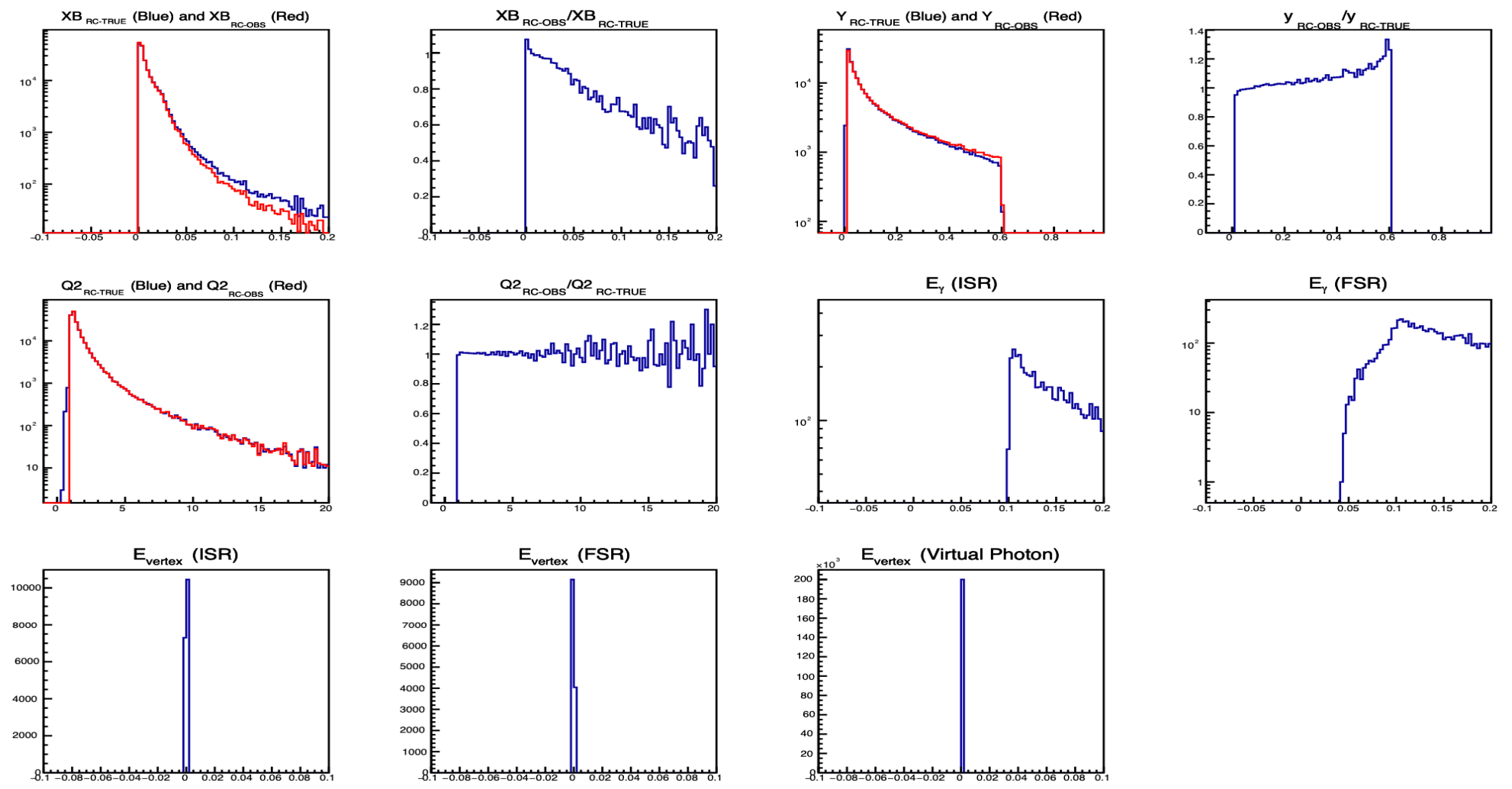




No cut on $\sum$E -Pz & $\epsilon = 10^{-2}$

DVCS - 10 GeV x 100 GeV Simulated with EpIC

Salvatore Fazio

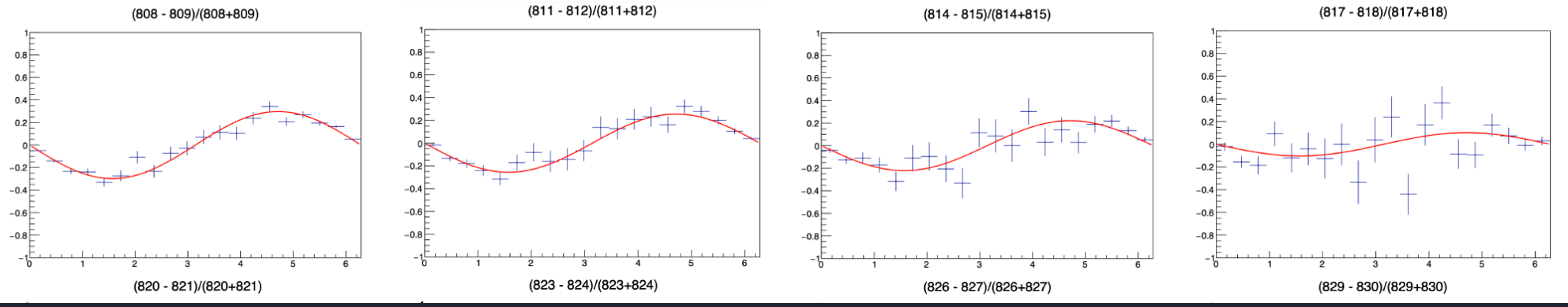


Transverse spin asymmetry – A_{UT}

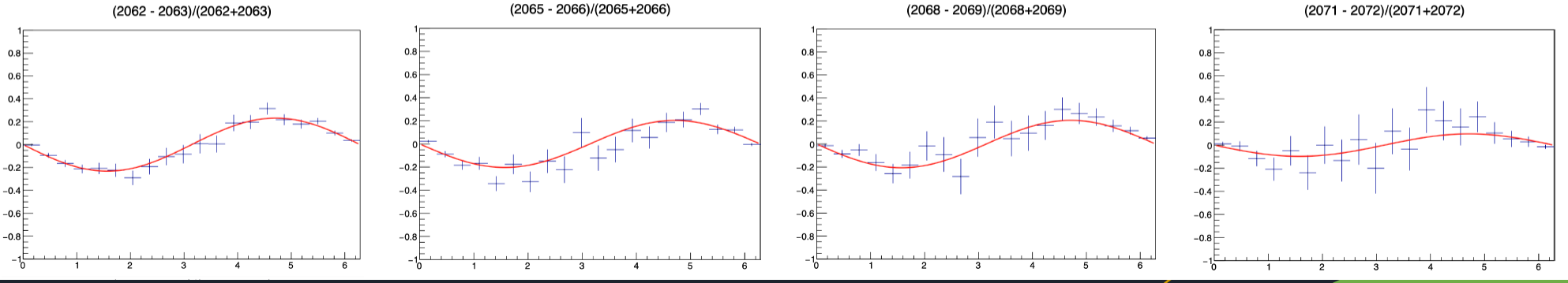
DVCS+BH+INT - 10 GeV x 100 Ge
Simulated with EpIC

Salvatore Fazio

Bin: $0.000251189 \leq xB < 0.000398107, \quad 1 \leq Q2 < 1.77828$



Bin: $0.001 \leq xB < 0.00158489, \quad 3.16228 \leq Q2 < 5.62341$



Next step: EIC impact studies!

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- We aim at performing new impact studies for extracting GPDs, similarly to what was done for the W.P. [E.C. Aschenauer, S.F., K. Kumericki, D. Mueller - JHEP09(2013)093], now with:
  - geant-4 simulation of the detector-1 response and realistic event reconstruction
  - state-of-art radiative effects implemented in the E*p*IC generator
  - BH and π^0 background subtraction
  - state of art models (GK and KM20)
- INFN people with longstanding experience in the field of partonic imaging: ZEUS@HERA, STAR@RHIC, EIC physics case and the EIC Yellow Report initiative
- People involved:
  - Simulation & analysis: E. Aschenauer, **S.F.**, A. Jentsch, P. Sznajder (+ student), K. Tezgin
  - Theory guidance and global fits: K. & K.P. Kumericki, H. Spiesberger, H. Moutarde
- **We would like to welcome new people from EIC_net!**
- We aim at a first publication in 2023 (extraction of CFFs)

Spatial 3D imaging – our goals!

✓ Milestone y21-22 release a novel, unique, Monte Carlo generator for hard exclusive processes based on available and upcoming GPD models, featuring first and second order initial- and final-state radiative effects

Milestone y23 extract GPDs by performing global NLO fits of various models in order to quantify the impact of the future Electron-Ion Collider at BNL in constraining CFFs and GPDs, from DVCS and TCS measurements

Future Goal 1 assess the feasibility of extracting the energy-momentum tensor, through which gravity couples to matter and generates fundamental properties such as mass and spin

Future Goal 2 include HEMP into the generator and explore the possibility of disentangling the contribution to GPDs from different partonic flavor

Salvatore Fazio

Longer term perspectives:

- Seed future topical collaborations
- Guide future executive decisions on the EIC second experimental apparatus

Diffractive PDFs

Slides by Marta Ruspa

- **Proton DPDFs not yet exploited for the EIC!**
  - good constrain on the gluon densities though scaling violation
- **A DPDF fit releasing the assumption or Regge factorization was never done**
  - though the HERA data might suggest a breaking.
- **PLAN: Evaluate the impact of the EIC to disentangle to which extent Regge factorization holds**
  - Understand the detector acceptance for inclusive diffractive processes
  - Full Monte Carlo chain generation-detector-reconstruction
  - Generation of pseudodata to be used in DPDF fit
  - Additional inclusion of the HERA data to evaluate the impact
- **Room to collaborate for EIC_net people → please ~~contact~~** us!

Summary

Several activities ongoing from the detector simulations to the physics simulations

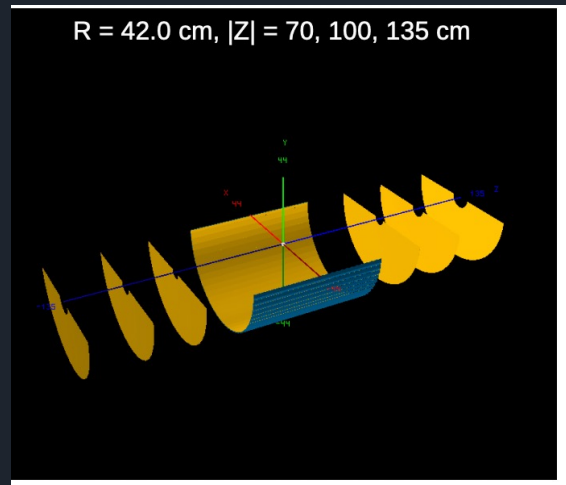
- Tracking : initial studies done, a lot of work to be done
  - ACTS available -> check perfomances
  - No kinks ,No fake tracks flags, etc,
  - Etc.

- dRICH: several issues met at the beginning solved!!! Simulation works. A lot of work to be done

- Physics simulations: very good results from EpIC. A lot of work to be done.

Open to anybody interested in simulations (hardware and physics).
Do not hesitate to contact us for further information

Backup



Barrel:

	r [mm]	l [mm]	X/X0 %
Layer 1	36	270	0.05
Layer 2	48	270	0.05
Layer 3	120	270	0.05
Layer 4	270	540	0.25
Layer 5	420	840	0.55