LOW-Q^2 TAGGER ACTIVITIES

EIC UK meeting, Birmingham

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18th November 2024

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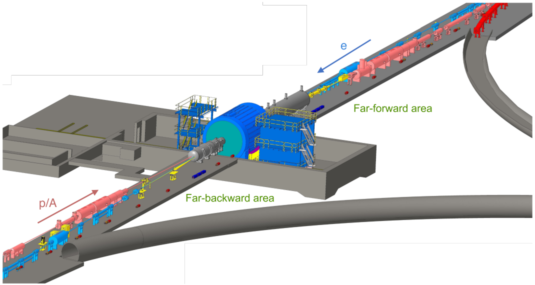
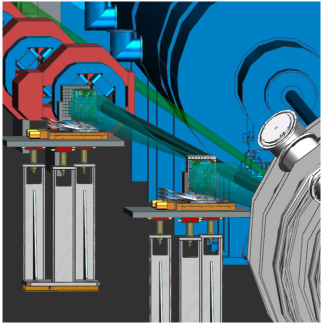




INTERNATIONAL AND GLASGOW WORKFORCE

INTERNATIONAL TEAM - EIC PROJECT SUPPORT

WBS 6.10 EIC Detector														
WBS-Item:	**WBS 6.10.01 Detector Management**	**WBS 6.10.02 Detect. R&D & Physics Design**	**WBS 6.10.03 Tracking**	**WBS 6.10.04 Particle Identification**	**WBS 6.10.05 Electromagnetic Calorimetry**	**WBS 6.10.06 Hadronic Calorimetry**	**WBS 6.10.07 Magnets**	**WBS 6.10.08 Electronics**	**WBS 6.10.09 DAQ/Computing**	**WBS 6.10.10 Detector Infrastructure**	**WBS 6.10.11 Integration & Auxiliary Detectors**	**WBS 6.10.12 Detector Pre-Ops & Commissioning**	**WBS 6.10.13 Detector #2 Development**	**WBS 6.10.14 Polarimetry and Luminosity**
CAMs:	Rolf Ent (JLab) & Elke-Caroline Aschenauer (BNL)	Thomas Ullrich (BNL) & Rolf Ent (JLab)	Rolf Ent (JLab) Interim	Beni Zihlmann (JLab)	Alexander Bazilevsky (BNL)	Oleg Eyser (BNL)	Renuka Rajput-Ghoshal (JLab)	Fernando Barbosa (JLab)	David Abbott (JLab) & Jeff Landgraf (BNL)	Rahul Sharma (BNL)	Yulia Furletova (JLab)	E.C. Aschenauer (BNL)	E.C. Aschenauer (BNL) & Rolf Ent (JLab)	Frank Rathmann (BNL)

Figure 1: Organization of the EIC project CAMs

Yulia Furletova - FF/FB CAM

Andrii Natocii - Geant4 Synchrotron simulation

LOW-Q^2 DSC

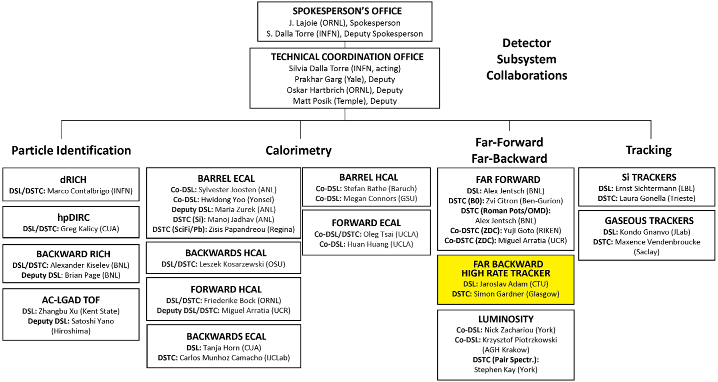


Figure 2: Organisation of the ePIC collaboration DSCs

Jarda (Jaroslav Adam) - DSC Lead

Simon Gardner - DSC Technical Lead

UK WP2 TEAM

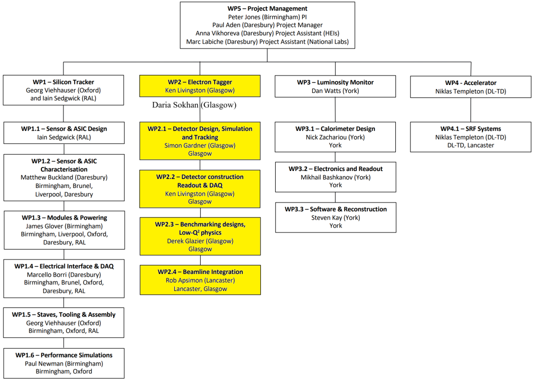


Figure 3: Organisation of the UK WP2

Ken Livingston

Daria Sokhan

Rob Apsimon

Simon Gardner

Derek Glazier

GLASGOW EXTRA-CURRICULAR ACTIVITIES

Physics

Rachel Montgomery - Ex-Exclusive PWG Convener

Gary Penman - Helium DVCS, PhD Student?

Oliver Jevons - DVCS

No Picture Found

Hao Jiang - DVMP

Photon Sensors for Cherenkov Detectors

Rachel Montgomery

Andrew Cheyne - PhD Student

EPIC LOW-Q^2 TAGGER - INTRODUCTION

ePIC Low-Q^2 Tagger

- For precise measurements of photoproduction and vector mesons.
- The ePIC Low-Q^2 Tagger extends the reach of the central detector down to effectively Q^2=0.
- Located after the first group of beamline steering and focusing magnets.
- Scattered electrons follow a unique path through the magnetic optics, resulting in a unique measured electron vector.
- Electrons with reduced energy are steered away from the main beam.
- Transforming the vector back through the magnetic optics accesses the original scattered vector.
- 4-momentum of the virtual photon interaction can be inferred.

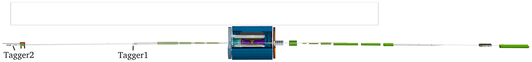


Figure 4: ePIC Low-Q^2 Tagger in Far Backward region.

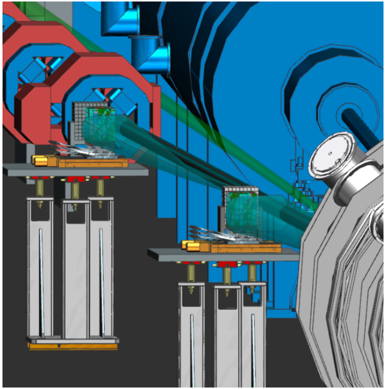
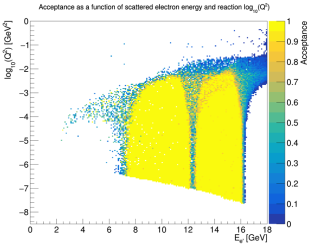
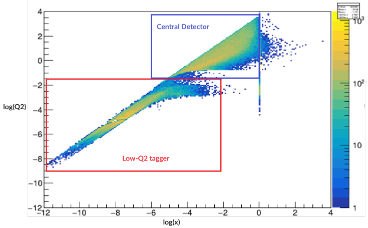


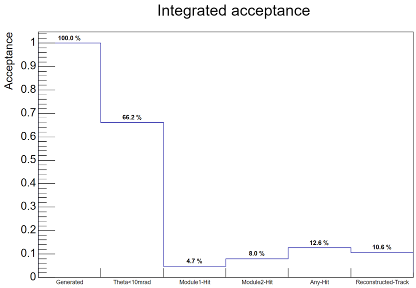
Figure 5: 2 Low-Q^2 Tagger stations placed beside the outgoing electron beamline.



Acceptance of reconstructed low-Q2 tagger electrons as a function of energy and Q^2



x-Q^2 acceptance showing central and low-Q^2 tagger.



Limitations

- Integrated acceptance or Quasi-real photoproduction events.
- Most events are produced at the highest energy, too close to the electron beam.
- Low energy lost in beamline magnets.
- Q^2 gap between central detector due to beamline magnet configuration.

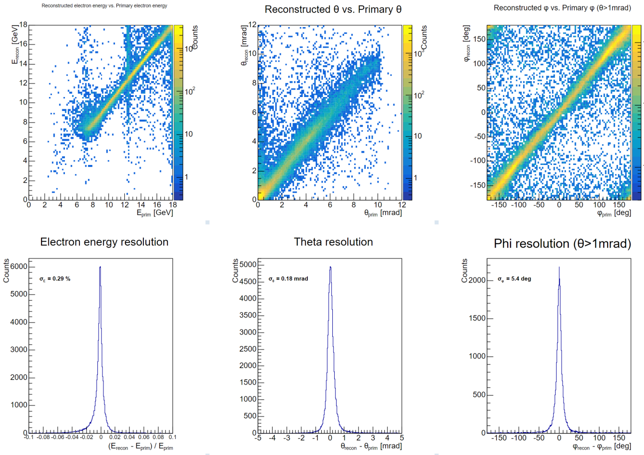


Figure 6: Reconstructed kinematics and resolution of Quasi-Real photoproduction electrons. ϕ has been limited to where θ>1 mrad

Limitations

- Fundamentally limited by the beam divergence.
- ϕ can never be extracted below the beam divergence limit.
- Limited acceptance where polarization observables will be possible.

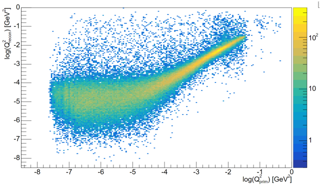


Figure 7: Reconstruction of Q^2

DESIGN

Tagger Design

- Two tagger stations covering different energy ranges.
- Tracker consisting of 4 layers of Timepix4 detectors.
- Detector layer consisting of tiled Timepix4 ASICs using TSV.
- SPIDR4 readout
- Calorimeter based on the luminosity systems design for high rates.

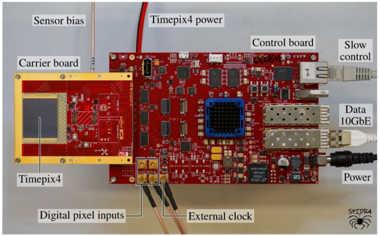


Figure 8: SPIDR4 readout - K. Heijhoff et al 2022 JINST 17 P07006

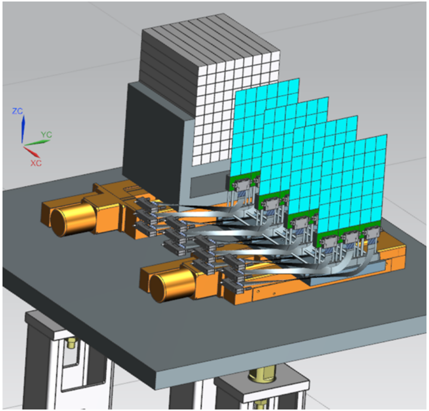
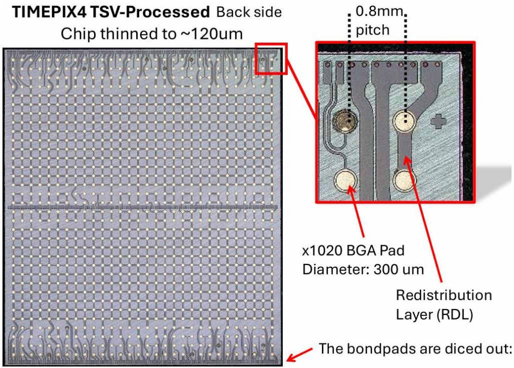
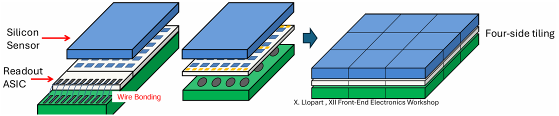


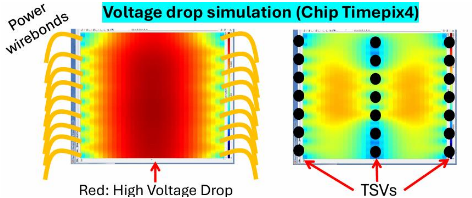
Figure 9: CAD model of a tagger station

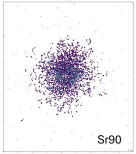
Hardware and Tests

- **Medipix4 collaboration** progress on Through-Silicon-Vias
  - 4 side buttable
  - Improved power distribution
  - Impedance of wire bonds smaller allowing faster readout.
  - Successful tests demonstrating improvements in readout
  - TSV processing technique being fine-tuned.









First result with radioactive source

Images from:

TWEPP 2024: Francisco Piernas, 3D Integration of Pixel Readout Chips using Through-Silicon-Vias

CHALLENGES

Challanges

- EIC integration
- Data Rate
- Background Rejection
- Momentum Reconstruction

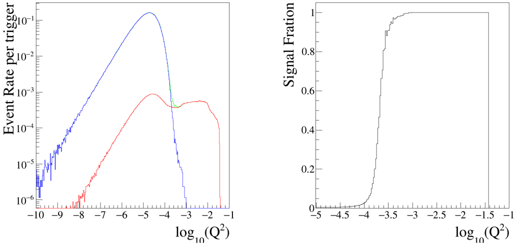


Figure 10: Left - Distribution of Bremsstrahlung (blue) and signal Quasi-real (red) events across Q^2. Right - Fraction of signal

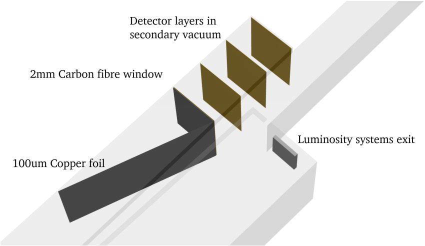


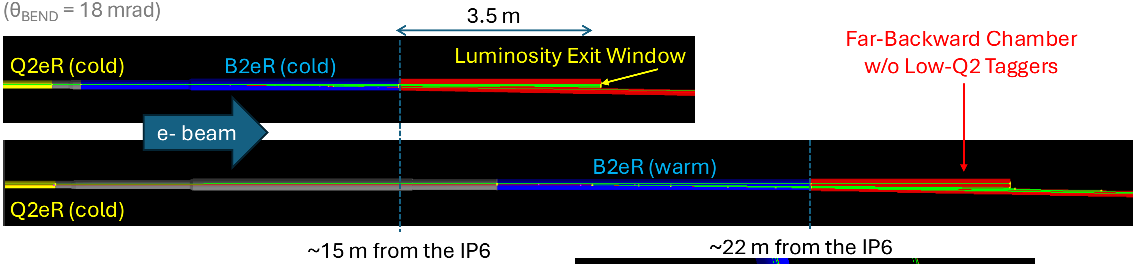
Figure 11: Design of tagger station. Carbon fibre vacuum exit window perpendicular to the beam to minimize material. Sloped copper foil to minimize beam impedance.

UPDATES - BEAMLINE INTEGRATION

New B2eR configuration

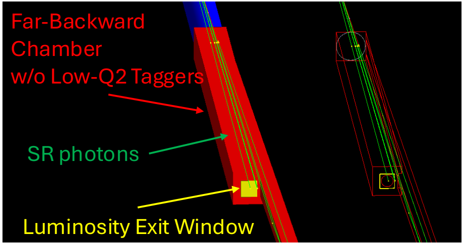
Lattice file v6.2: Cold B2eR

(θ_{BEND} = 18 mrad)

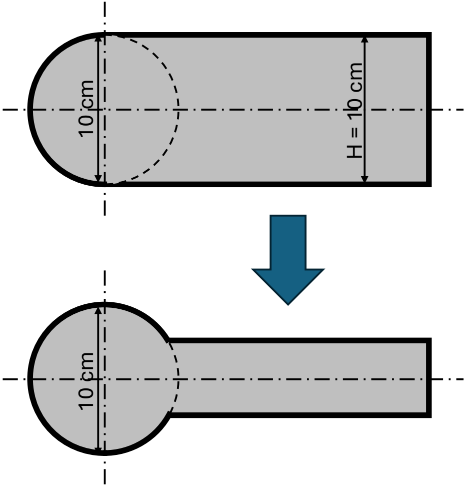


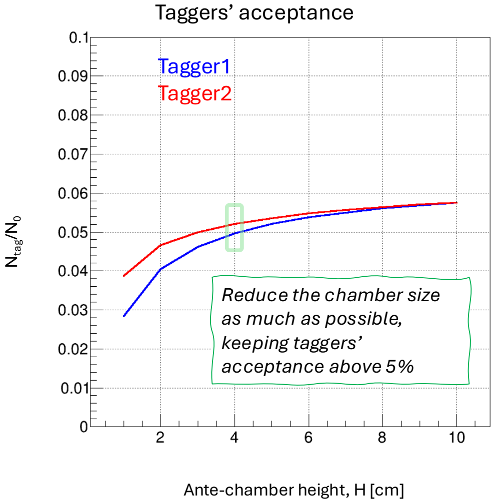
Lattice file v6.3: Warm B2eR

(θ_{BEND} = 20 mrad)

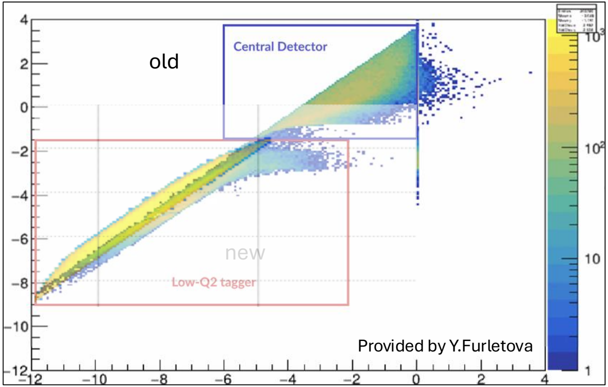


Step 2: Ante-chamber height scan

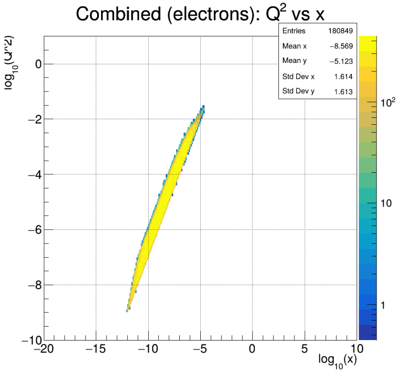




Old vs New inconsistency

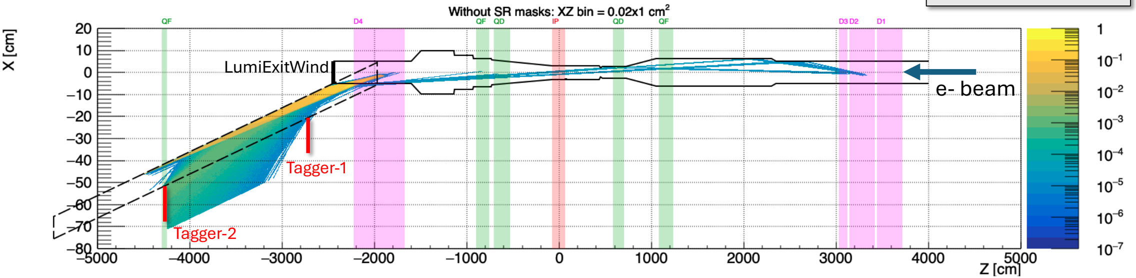


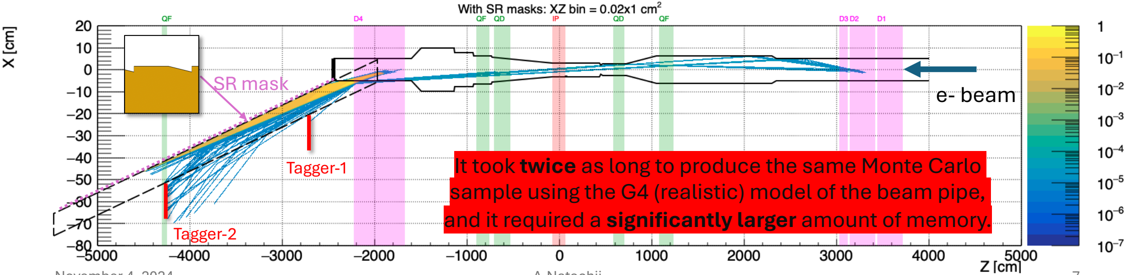
new (combined distribution)



Beam Core

Draw X-ray tracks for:
$E_\gamma > 10$ keV
$Z \in (-45;-25)$m

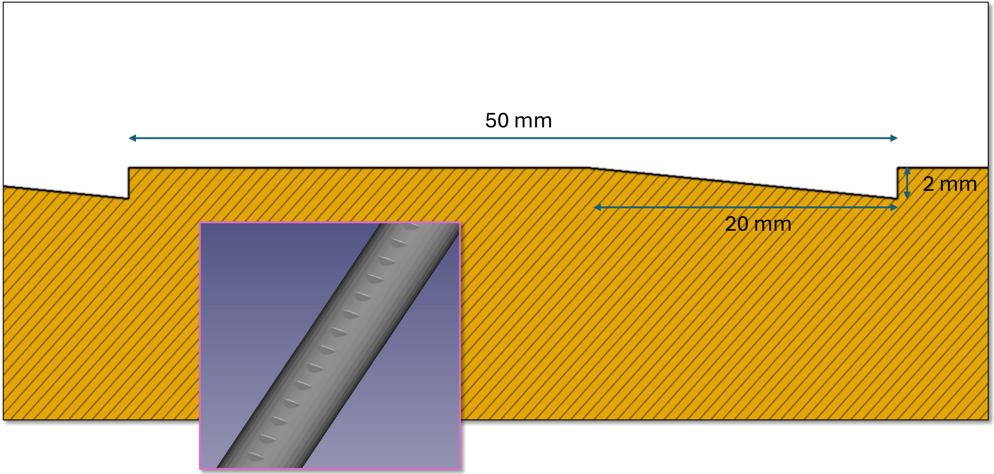




It took **twice** as long to produce the same Monte Carlo sample using the G4 (realistic) model of the beam pipe, and it required a **significantly larger** amount of memory.

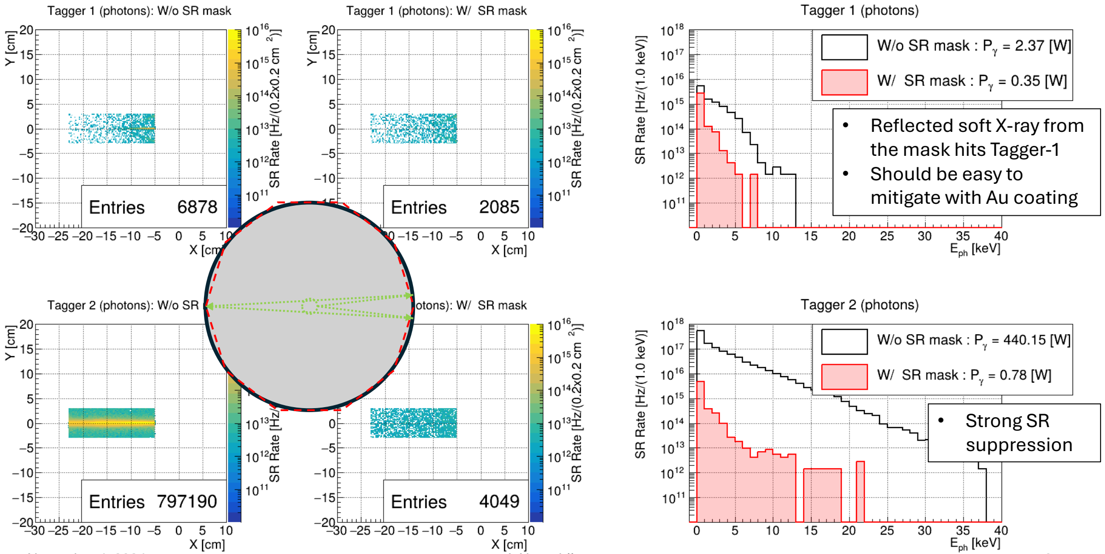
Beam Core: SR Rate on Taggers

G4 (realistic) model of the beam pipe with the SR saw-tooth mask



Beam Core: SR Rate on Taggers

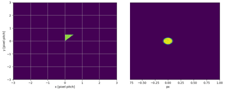
G4 (realistic) model of the beam pipe



UPDATES - DATA MANAGEMENT

Remove Bias

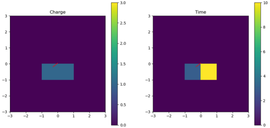
- Need latent space to be orthogonal to conditions
- Train adversarial network to try and identify conditions from latent space coordinates
- Loss subtracted from main training so bias is removed.

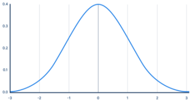


Training

Input 6x6 array of pixel ToA and ToT

Data transformed into normal distributions in N dimensional latent space





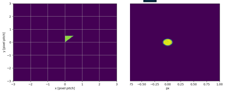
x N

Output 6x6 array of pixel ToA and ToT

Randomly sample from latent space normal distributions

Problem:
Probably bias between conditions and latent space normal distribution

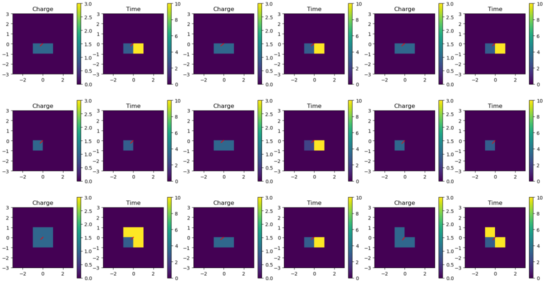
Inference

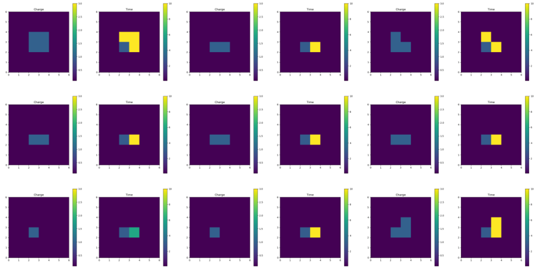


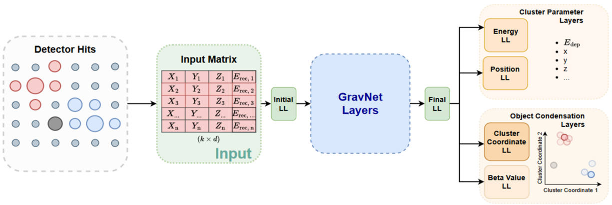
x-0.0_y-0.0_px--0.05_py--0.05

Input

Predicted







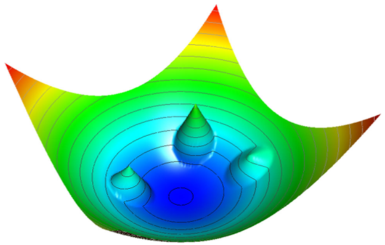


Fig. 1 Illustration of the effective potential that is affecting a vertex belonging to the condensation point of the object in the centre, in the presence of three other condensation points around it

- Object Condensation method presented by Jan Kieseler 2020[1].
- Graph network architecture taking each hit as a node.
- GravNet layers pass messages between closest neighbours in learned space[2].
- After passing through the graph layers, every node now has the information encoded for a track.
- A single hit per track is identified as a ”condensation point”, should provide the best estimate of track properties.
- Hits from the same track are clustered around the the condensation point.
- Classification and regression can additionally be carried out on the encoded information.
- Recent study on simulations for Charged Particle Tracking at the High Luminosity LHC[3].

Is this a sledgehammer to crack a nut for the Low-Q^2 tagger? -Maybe... But the unknown backgrounds are expected to be high.

[1] Object condensation: one-stage grid-free multi-object reconstruction in physics detectors, graph, and image data
[2] Learning representations of irregular particle-detector geometry with distance-weighted graph networks
[3] An Object Condensation Pipeline for Charged Particle Tracking at the High Luminosity LHC

ADDING ARTIFICIAL NOISE

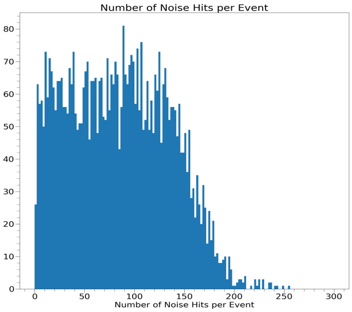


Figure 7: Distribution of artificial noise hits added to event.

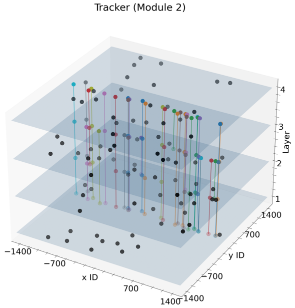


Figure 8: Sample event showing tracks identified in module 2 with inefficiencies and noise added

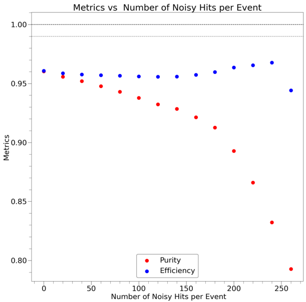


Figure 9: Efficiency and purity as a function of included noise

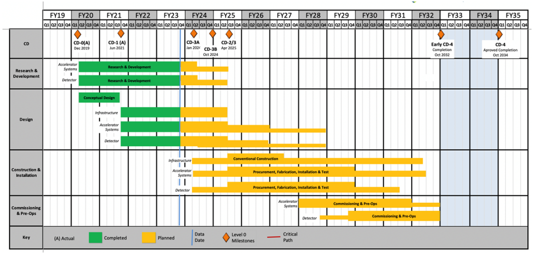
STATUS AND PLANS

Tracker

Date	
Jan 2024	2 x SPIDR4 kits in Glasgow
Summer 2024	Tests in Glasgow
December 2024	Tests in Mainz
Summer 2025	Engineering + DAQ tests in JLab
Autumn 2025	Final Design complete
Oct 2026	Start of construction
Oct 2030	Ready for installation

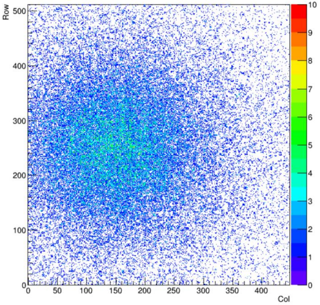
Calorimeter

Date	
May 2025	Final design complete, review, start of construction
Oct 2030	Ready for installation

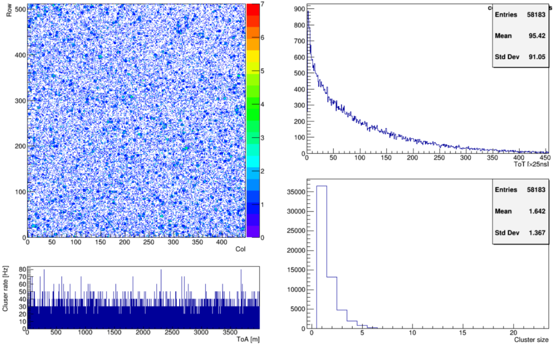


Hardware and Tests

- Glasgow Tests:
  - Tests by summer student over the Summer.
  - Single chip, ironing out technical issues and readout code.
  - Slight damage to equipment has stunted progress.



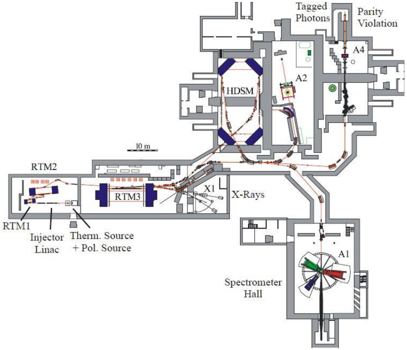
^{90}Sr acquisition for 30 seconds



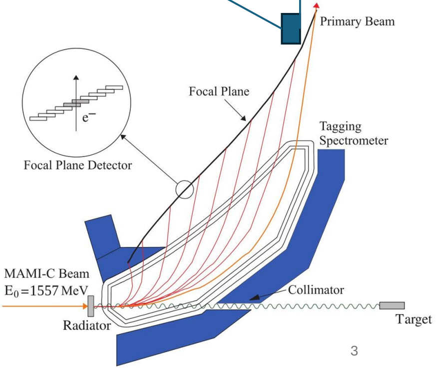
Cosmic data for a weekend

Hardware and Tests

- Beamtest:
  - Mainz 3-6th December
  - High(ish) rate 1.5 GeV electrons
  - Measure tracks from two layers



2xTimepix4, detector telescope



Conclusions

- Tests underway with Timepix4 assemblies and readout.
- Simulation, analysis and benchmarks included in ePIC software framework.
- GNN approaches for track identification and reconstruction on FPGA.
- Fast Simulation of detector effects and digitization.
- Progress on beamline and synchrotron studies, need many more iterations to optimize outcome.
- Questions?