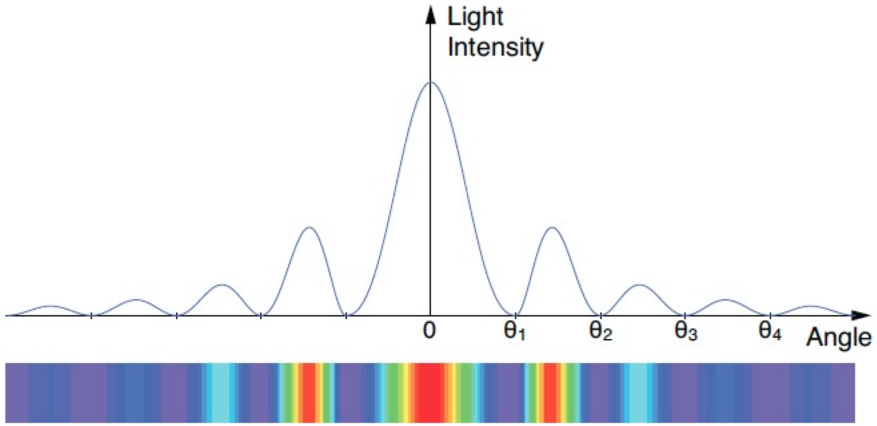
The *Beginning*, the *End*, and the *End of the Beginning*



Kong Tu and Thomas Ullrich

BNL

04.15.2022

Diffractive Vector Meson production at the EIC

This talk will be the basis for the DIS talk on Diffractive VM in ATHENA [#260]

The *Beginning*

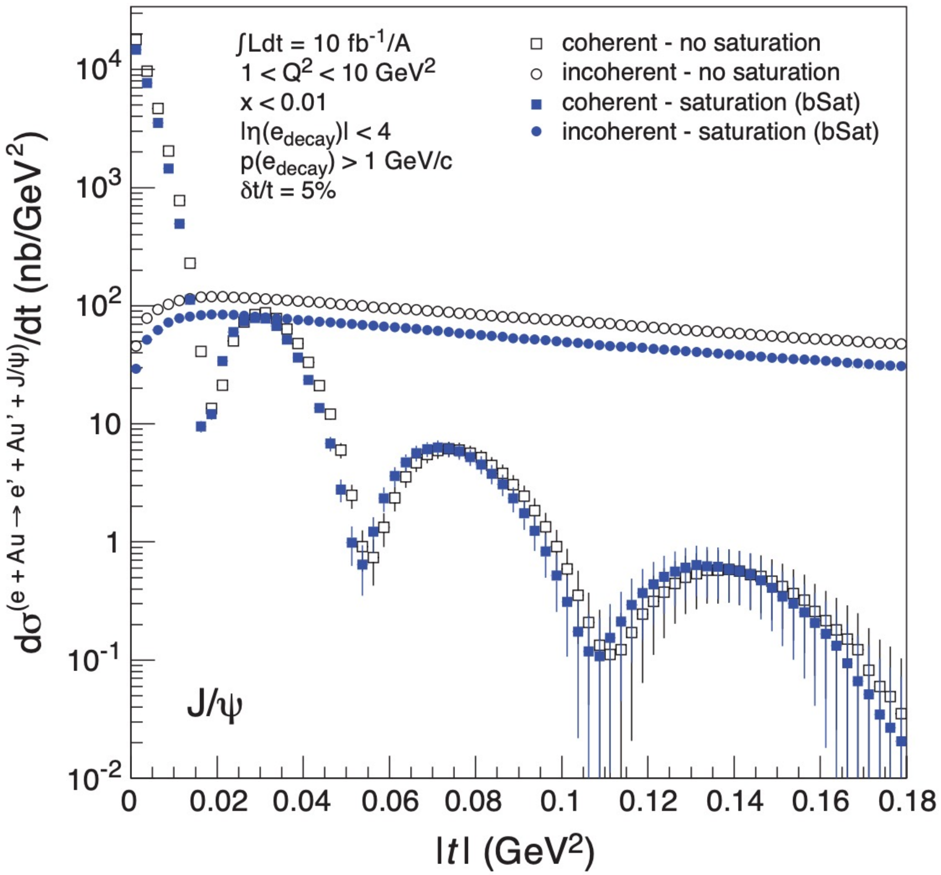
- EIC detector proposal – a reference detector that can study/deliver the physics from the EIC White Paper and the NAS report.

- One of the most difficult measurements, if not the most, is the <u>diffractive VM |*t*| distributions</u>.

- The experimental question to be addressed by THIS proposal is simple:

  Given the proposed detector, how well can one measure the diffractive |t| distribution?

(EIC White Paper)



Two major experimental challenges

- The magnitude of the momentum transfer (|t|) off a heavy nucleus is very small (~0.01-0.1 GeV^2)

➢ ***requires* excellent detector resolutions.**

- Physics background from Incoherent VM productions, where the heavy nucleus breaks up.

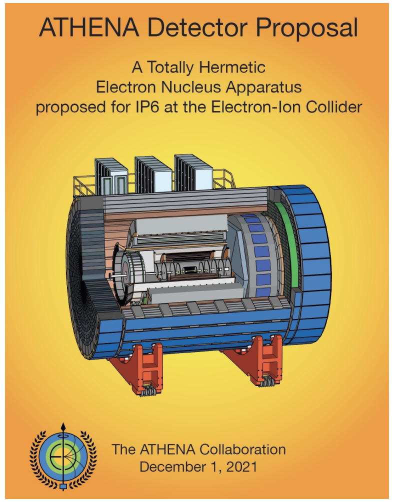
➢ ***requires* excellent far-forward detector acceptance to veto.**

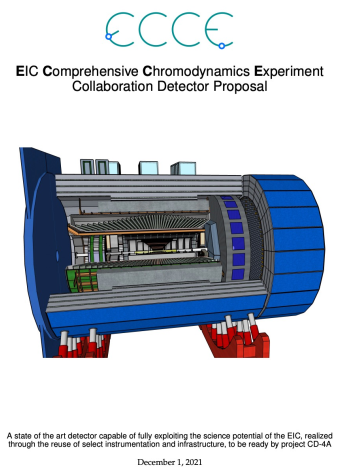
Proposal short summary

What matters to this measurement: ATHENA VS ECCE

	SAME	DIFFERENCE
Magnetic field (Tracking resolution)	X	3.0T ATHENA vs 1.4T ECCE (better tracking res vs low p_T accept.)
Calorimetry (e' reco.)	✓X	*Note: ATHENA did NOT use ECal in the proposal (not enough time for FullSIM)*
Far-forward detector (vetoing capability)	✓	
-t reconstruction algorithm	X	Method. L ATHENA vs Method. P_T ECCE
Beam effects: XA, *p* spread, angular div.	✓	

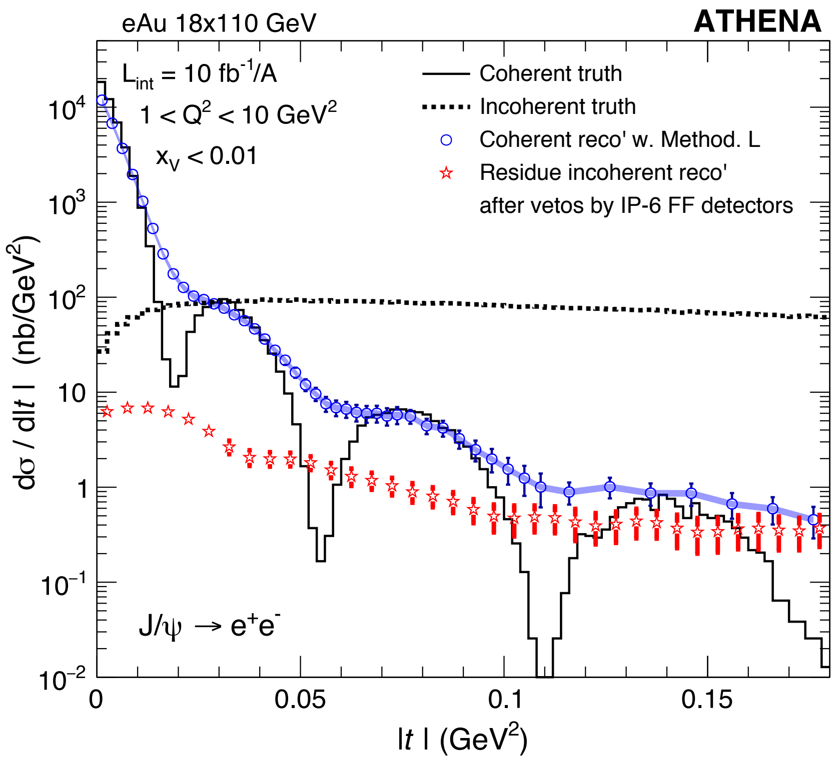
*CORE proposal did not explicitly present this measurement



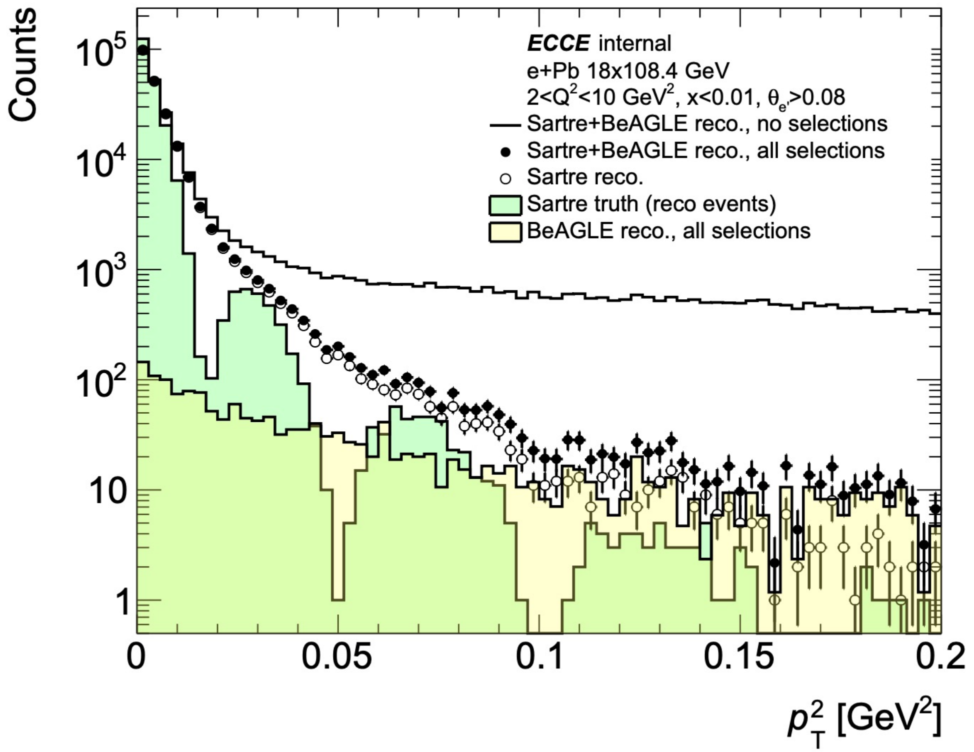


The *End*

(ATHENA DPAP Report)



(ECCE proposal Fig. 3.11)



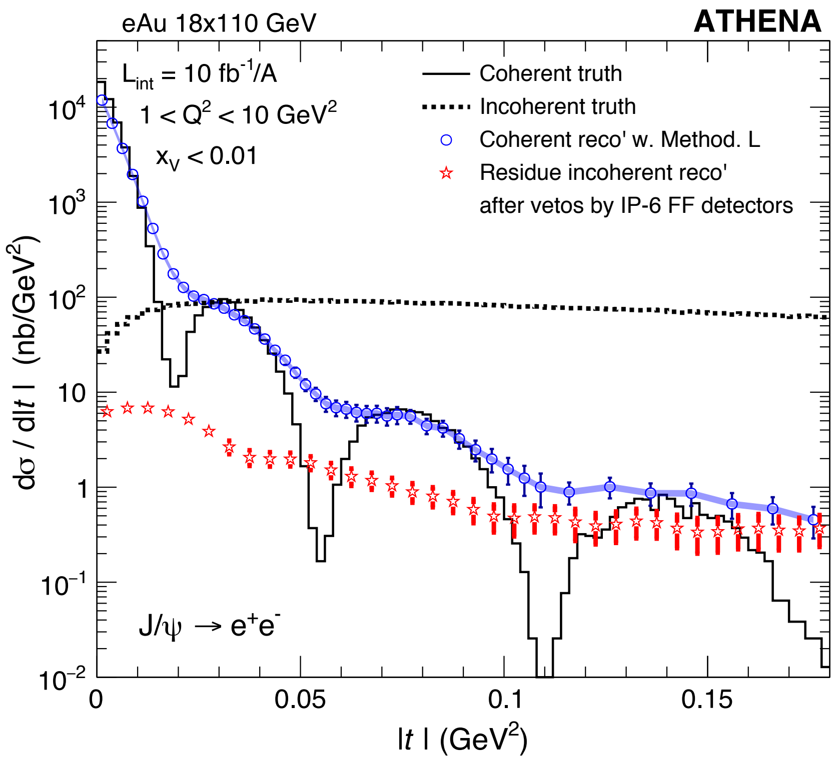
Challenge #2: Incoherent backgrounds are under control for both proposals.

ATHENA reco. Performance is found to be slightly better, although it doesn't matter! BUT WAIT!

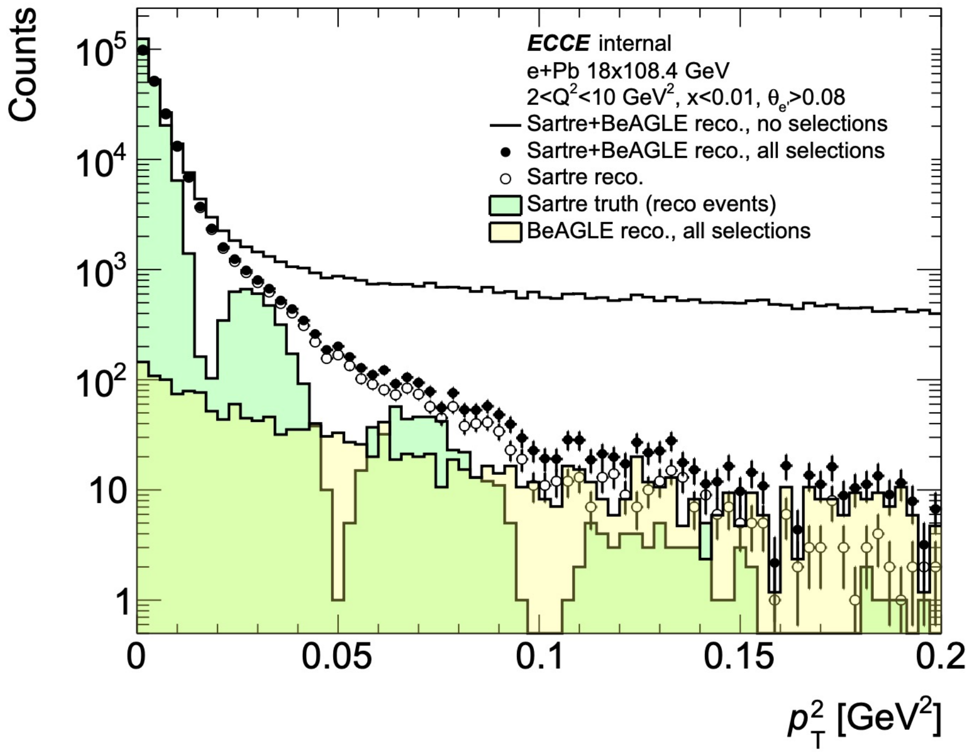
The *End*

3 differences:
1. Tracker (1.4T vs 3T)
2. Tracker vs Tracker+Ecal
3. -t reco. algorithm

(ATHENA DPAP Report)



(ECCE proposal Fig. 3.11)



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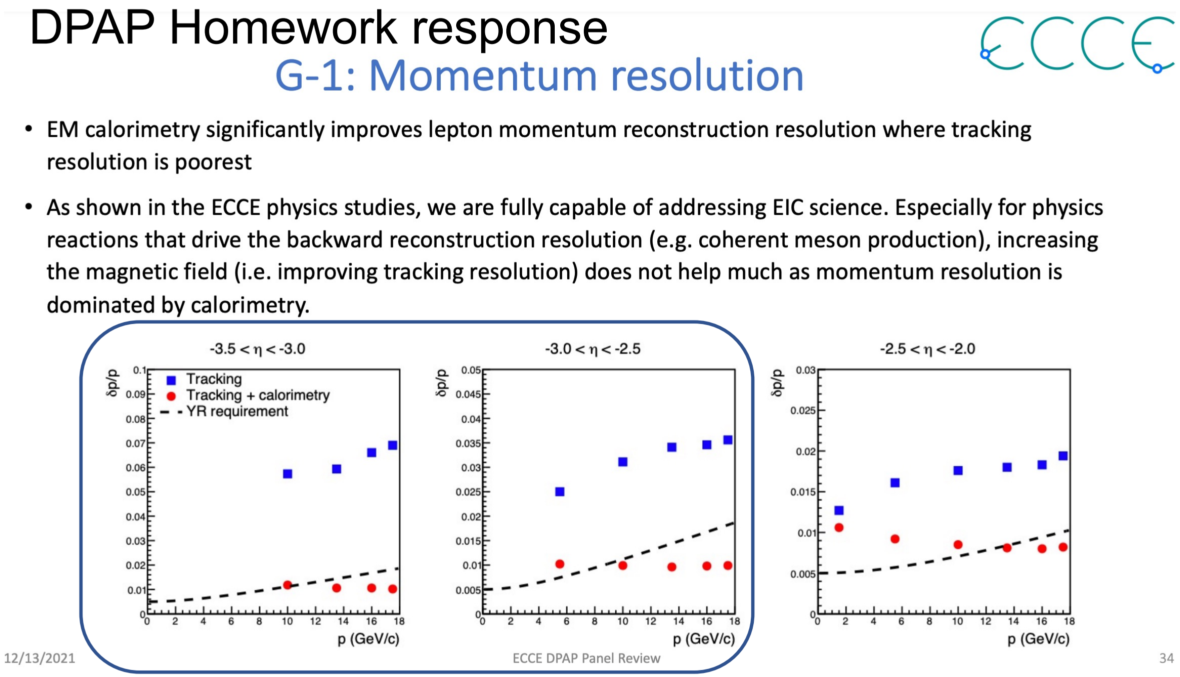
Difference #1

Difference #2

Tracker (1.4T vs 3T) vs Tracker+ECal



Great study done by ECCE

Difference #1

Difference #2

Tracker (1.4T vs 3T) vs Tracker+ECal

ATHENA Proposal Fig 2.4

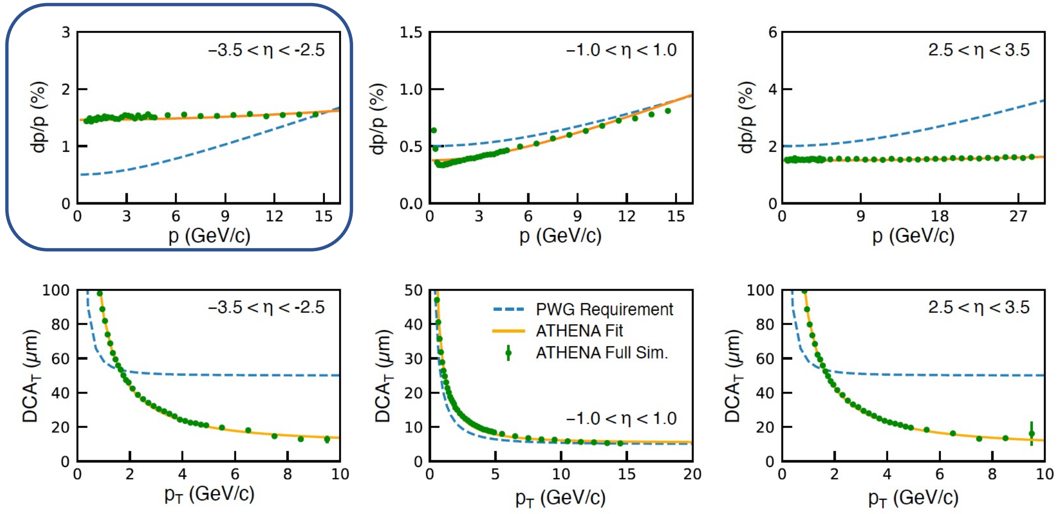
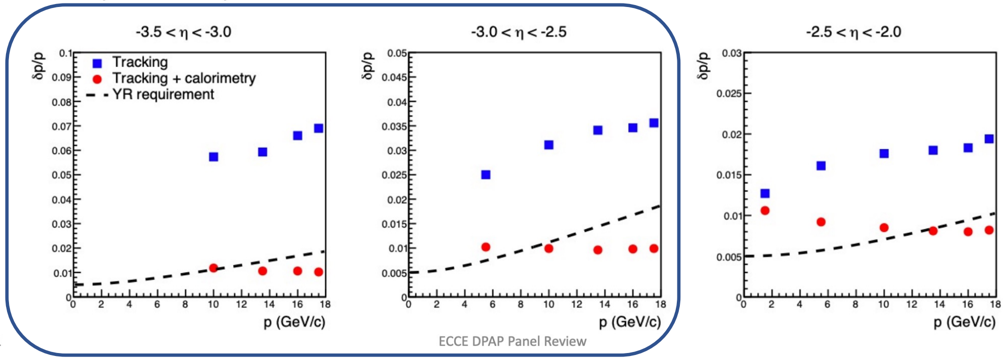


Figure 2.4: ATHENA tracking performance of generated pions compared to the Yellow Report requirements (dashed lines) for selected η bins. Top row: momentum resolutions versus momentum. Bottom row: Transverse DCA performance versus momentum (FullSim).

DPAP Homework response

G-1: Momentum resolution

- EM calorimetry significantly improves lepton momentum reconstruction resolution where tracking resolution is poorest
- As shown in the ECCE physics studies, we are fully capable of addressing EIC science. Especially for physics reactions that drive the backward reconstruction resolution (e.g. coherent meson production), increasing the magnetic field (i.e. improving tracking resolution) does not help much as momentum resolution is dominated by calorimetry.



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Qualitatively, these comparisons make sense!
→ 1.4T Tracker only < 3.0T Tracker Only < ECal + Any tracker
[“<“ means worse performance]

Great study done by ECCE

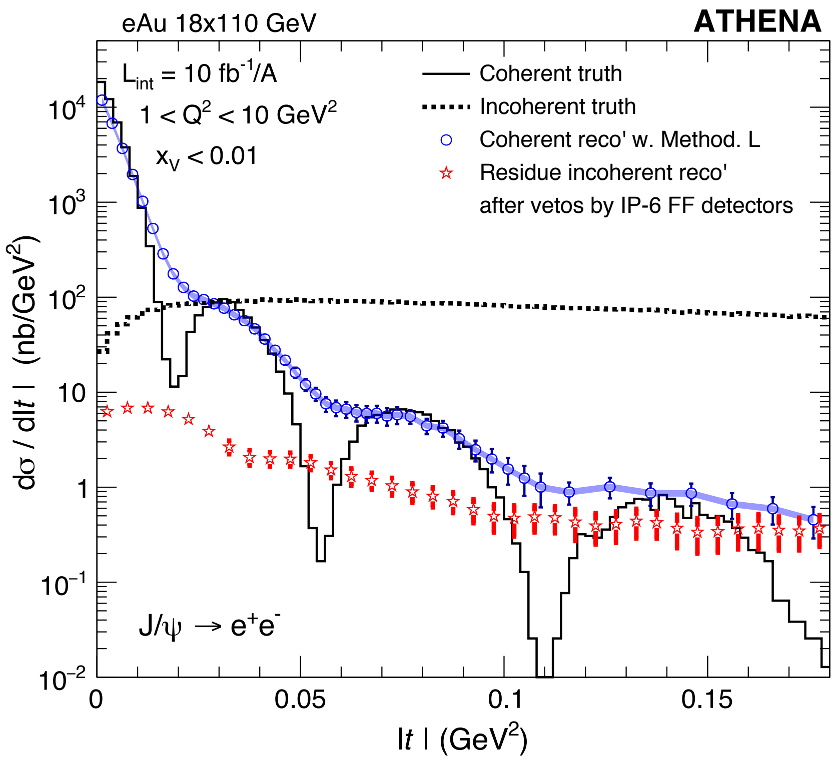
(Quantitative level: ATHENA number quotes the Gaus width without including the non-Gaussian tail)

The *End*

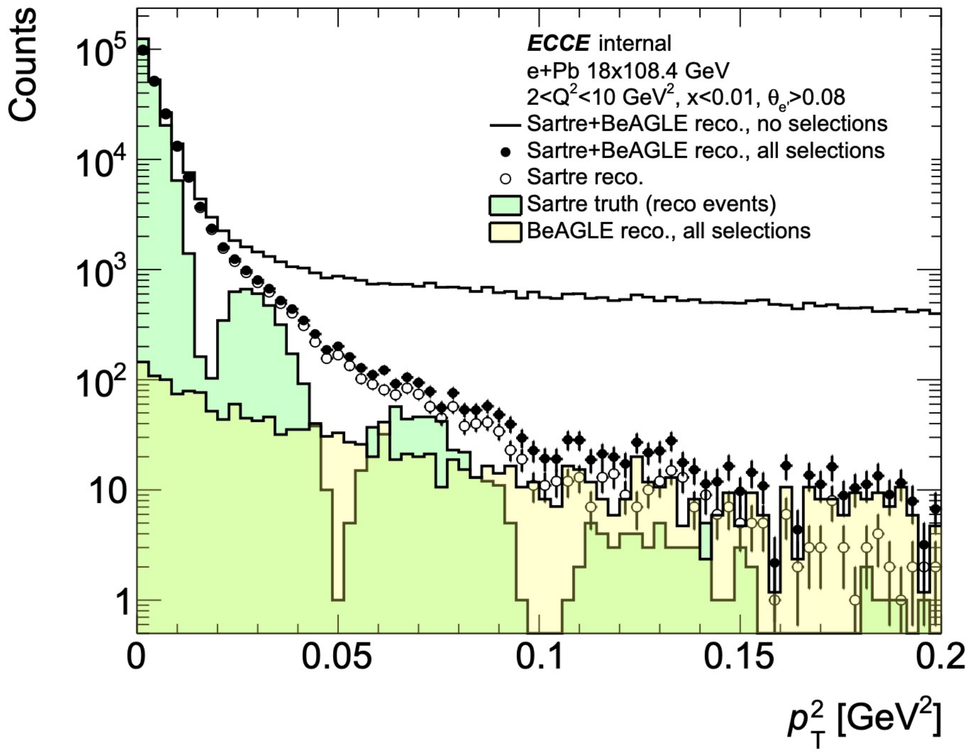
Only difference remained:

1. Tracker (1.4T vs 3T)
2. Tracker vs Tracker+Ecal
3. -t reco. algorithm

(ATHENA DPAP Report)



(ECCE proposal Fig. 3.11)



Puzzle – ECCE should have better |t| resolution with Ecal included, but looked worse?

Beam effects and Method. L

- Lessons learned from the Yellow Report, starting Page 346, the conclusion is, Method. L is robust against Beam effects.

- Method. A and E are NOT!

Method L

- Calculate the outgoing nucleus momenta from the measured final state particles and the nominal hadron beam kinematics, p_A as

$$p_{A'} = p_A - (p_V + p_{e'} - p_e), \tag{5}$$

where the r.h. bracket term essentially represents method E. Note that $|p_{A'}|^2 \neq M_A^2$ in the presence of smearing effects, with M_A being the true nuclear mass.

- Next we express the outgoing nucleus in light cone variables

$$p_{A'}^{+} = E_{A'} + p_{z,A'} \tag{6}$$
$$p_{T,A'}^{2} = p_{x,A'}^{2} + p_{y,A'}^{2} \tag{7}$$
$$p_{A'}^{-} = (M_A^2 + p_{T,A'}^2)/p_{A'}^{+}, \tag{8}$$

where $p_{A'}^{-}$ is now modified by using the true mass M_A. The corrected outgoing momentum of the nuclei is now:

$$p_{A'}^{\text{corr}} = \begin{bmatrix} p_{x,A'} \\ p_{y,A'} \\ (p_{A'}^{+} - p_{A'}^{-})/2 \\ (p_{A'}^{+} + p_{A'}^{-})/2 \end{bmatrix} \tag{9}$$

- We thus obtain the corrected t as

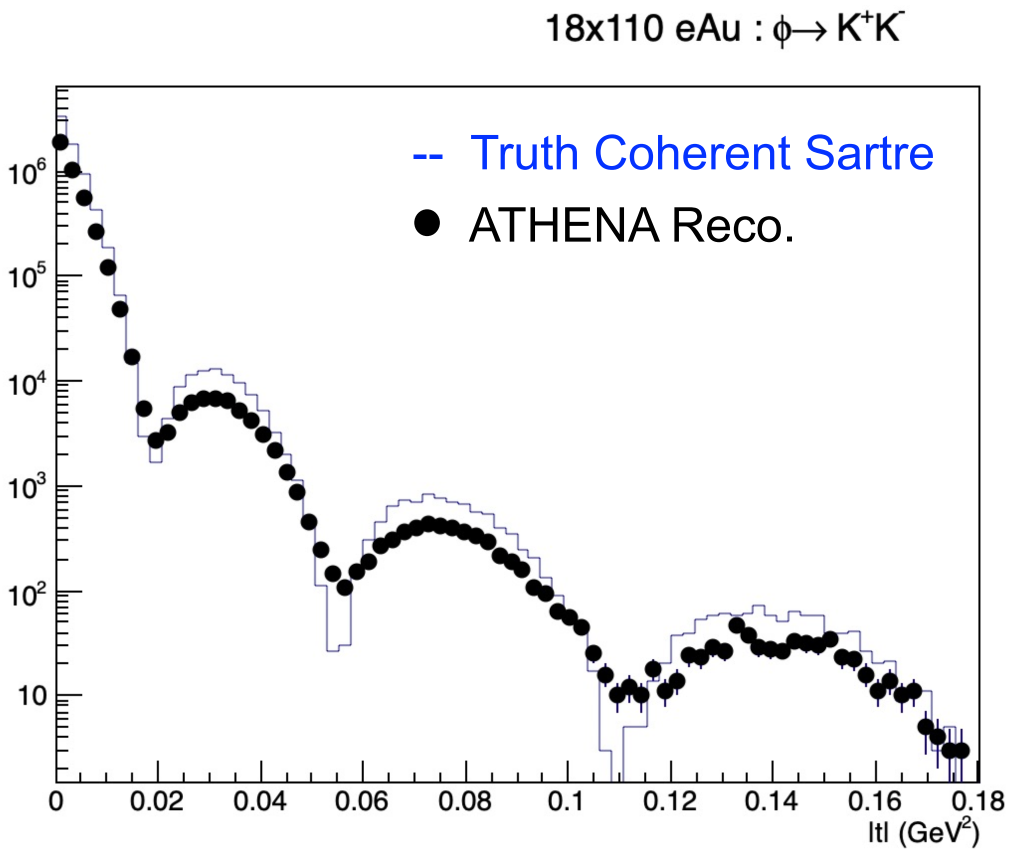
$$t_{\text{corr}} = |p_A - p_{A'}^{\text{corr}}|^2 . \tag{10}$$

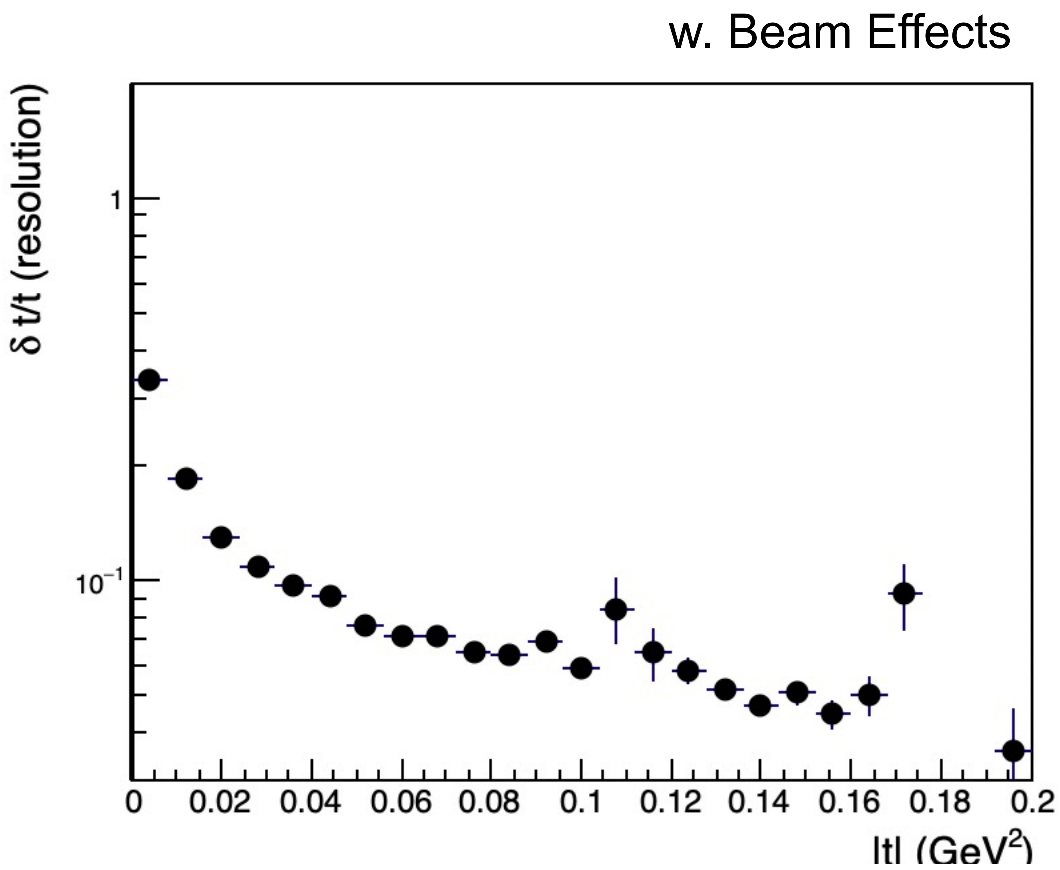
In short, you are using the true invariant mass of the nucleus to compensate the smearing in the larger component of the electron 4-momentum by modifying $E_{A'}$ and $p_{z,A'}$ simultaneously. As we will discuss later, this method is considerable more robust as method E in coherent events.

(Method by Thomas Lappi, shown by Thomas Ullrich in one of the YR meetings)

3.0T

ATHENA w. ECAL+Tracker w. Method L

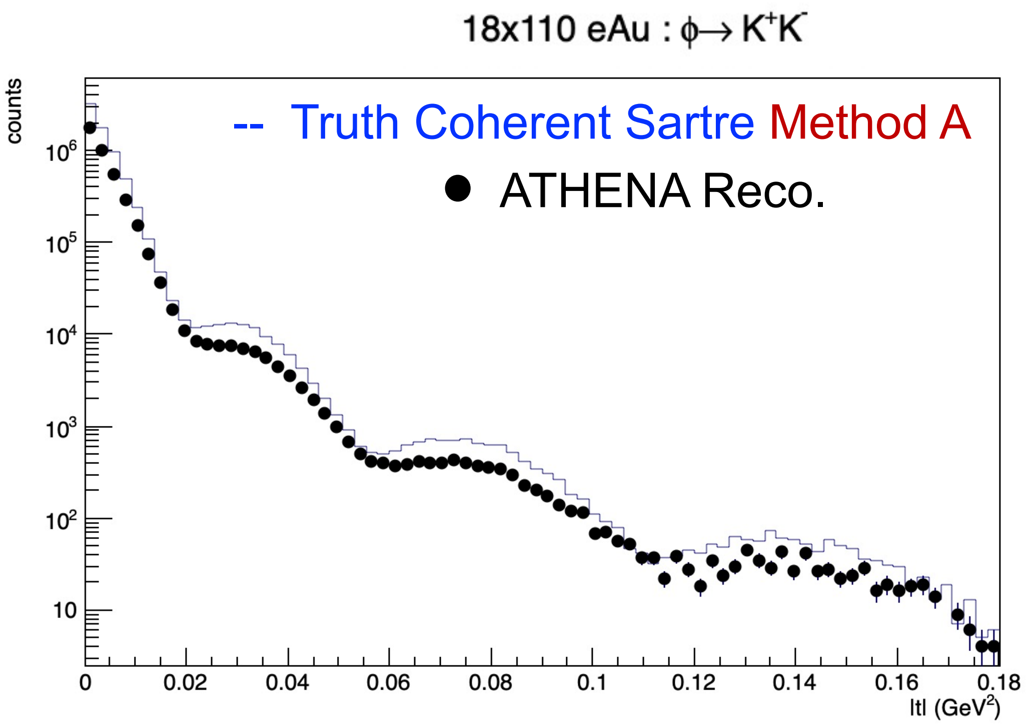




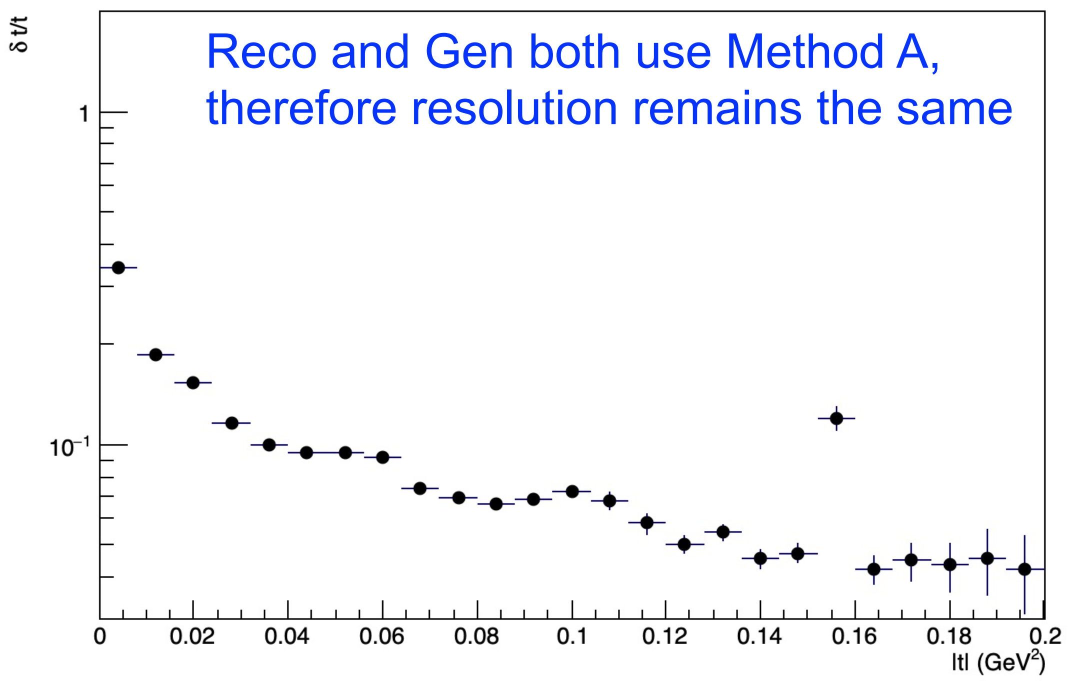
Delphes Fast Simulation with Backward ECAL -3.5< eta < -3: $\frac{2\%}{\sqrt{E}} \oplus 1\%$

3.0T

ATHENA w. ECAL+Tracker w. Method A



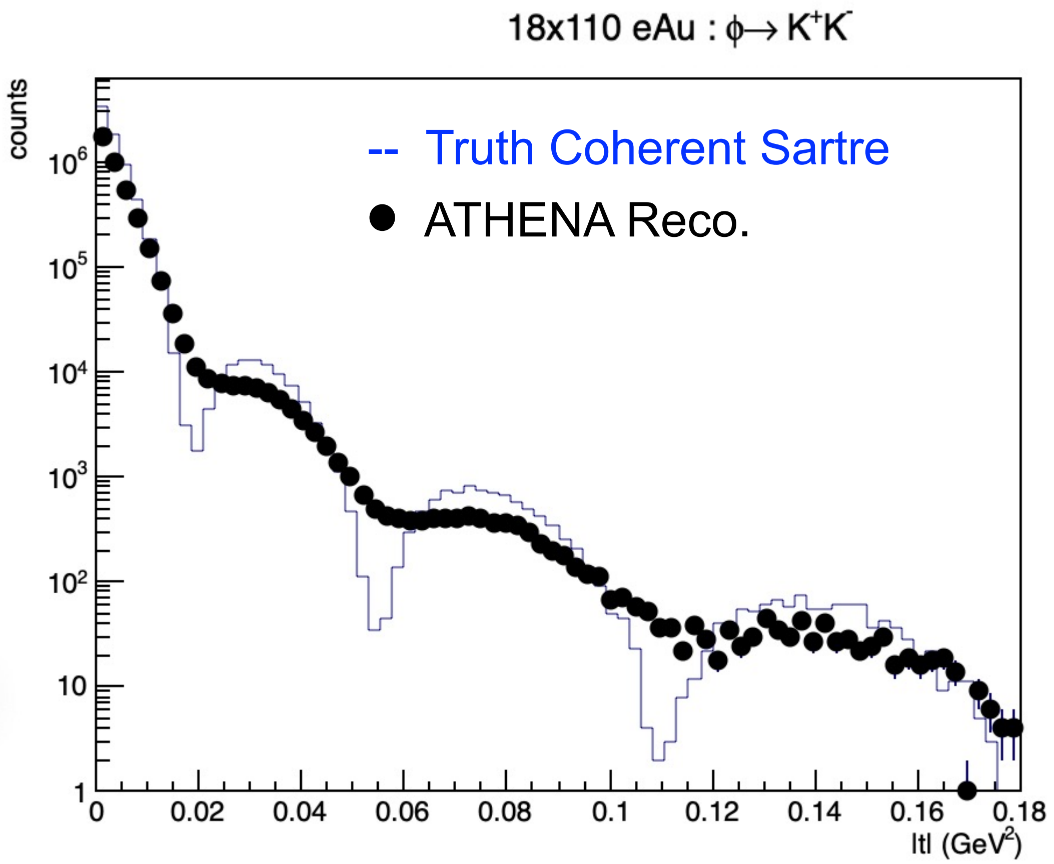
w. Beam Effects



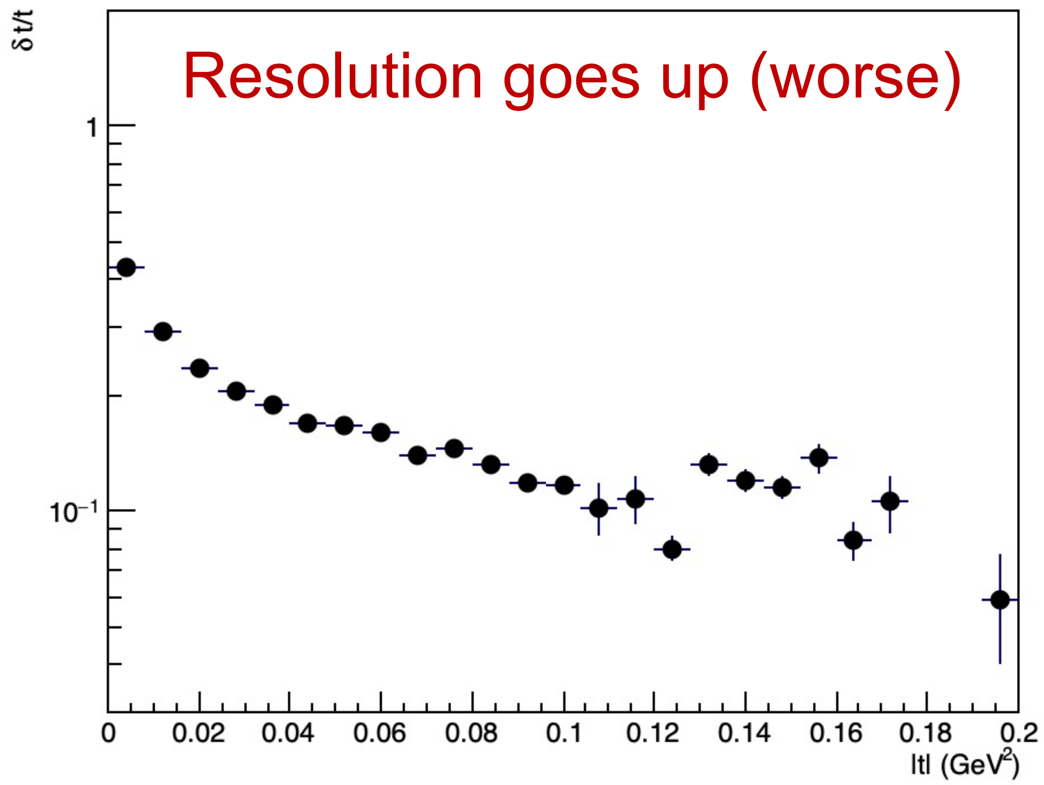
Even for the truth, without any detector effect, Method A cannot recover the |t| distribution due to beam effects

3.0T

ATHENA w. ECAL+Tracker w. Method A



w. Beam Effects



Now the truth uses the real generator truth ~ Method L

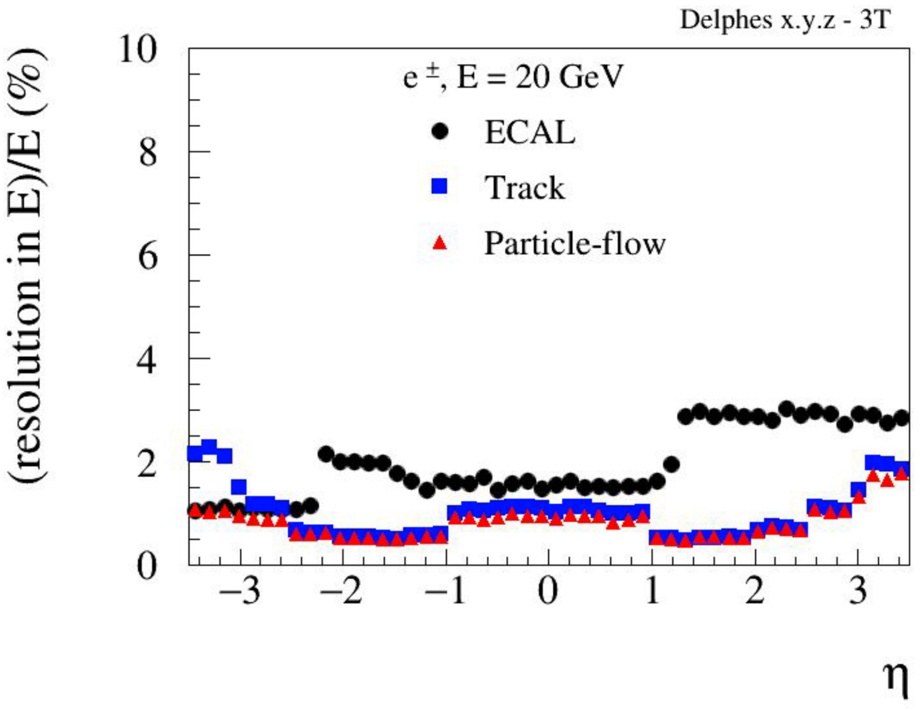
The *End of the Beginning*

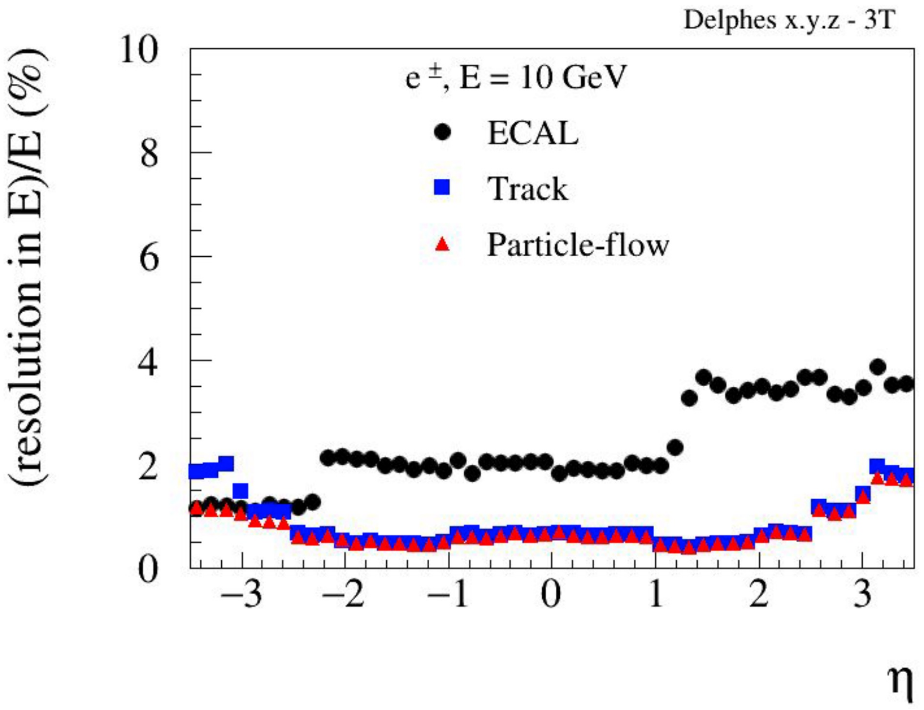
- The reality is better than what both proposals had shown!
- What happened:
  - ATHENA did not manage to include ECAL in the |t| reconstruction in the proposal; however, this was done by ECCE. For this measurement, magnetic field strength does not matter!
  - ECCE did not manage to get Beam Effects under control with Method A (p_T); For this measurement, the |t| reco method does matter!
- What happens next (I propose):
  - ECCE should confirm what ATHENA find, like what ATHENA showed in this talk.
  - Baseline settlement → New era begins → New baseline with new full simulations with reference detector of ECCE.

This measurement of diffractive VM is possible with a high resolution backward ECAL and wide acceptance FF detectors.

Backup

Energy resolution by Miguel Arratia





The improvement is at very backward eta<-3, and larger improvement for higher energy

What ATHENA had in the DPAP report