eA study group

Coherent VM production

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אוניברסיטת בן-גוריון בנגב
جامعة بن غوريون في النقب
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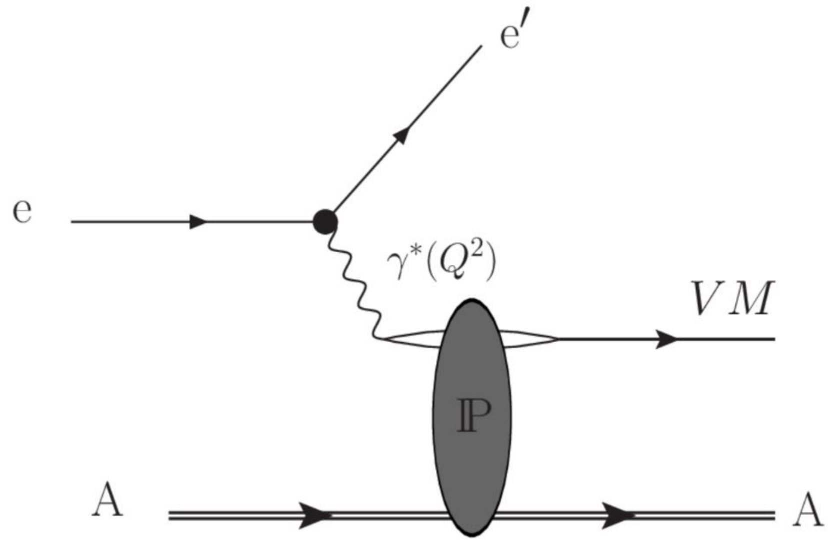
KU

Introduction

Goals

- Probing the low-X structure of the nucleus
- Probing spatial parton structure of nuclei



Methodology

- Measuring coherent vector meson (VM) production
- Differential cross-section $(d\sigma/dt)$ as a function of momentum transfer → spatial distributions of gluons

Coherent and incoherent production

Event Kinematics

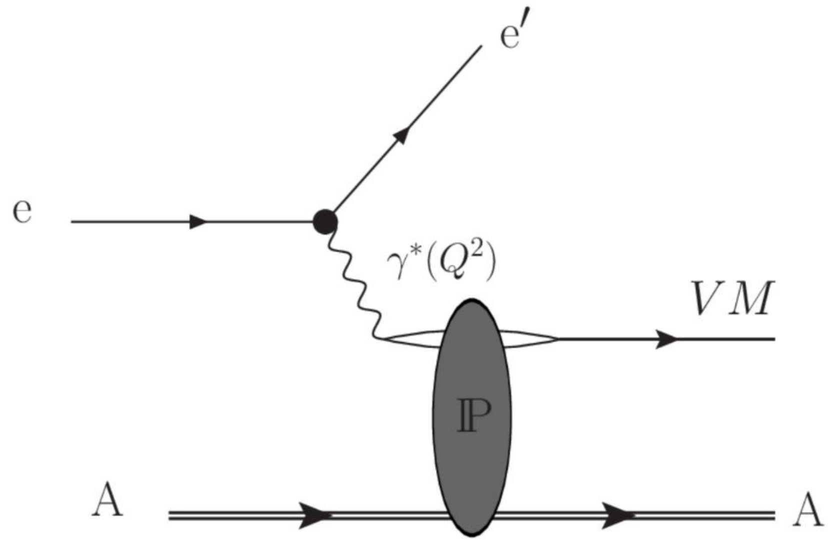
Reconstruction of parameters of interest:

e – incoming electron (**determined by beam parameters**)

e' – outgoing electron (**measured**)

VM – vector meson (**measured**)

- Energy scale $Q2$ =−(e – e').$M2$()
- Momentum transfer –t =(VM −(e−e')).M2()
- Meson transverse momentum VM_PT=$VM.Pt$()



Coherent and incoherent production

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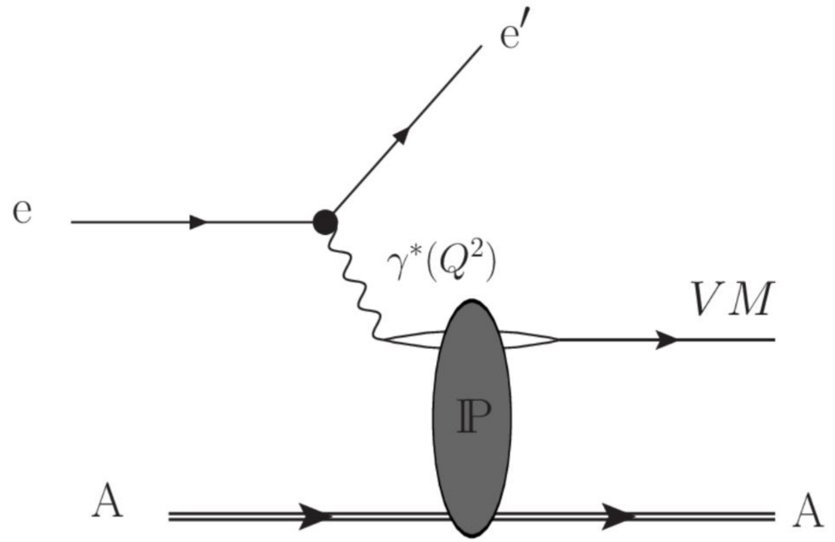
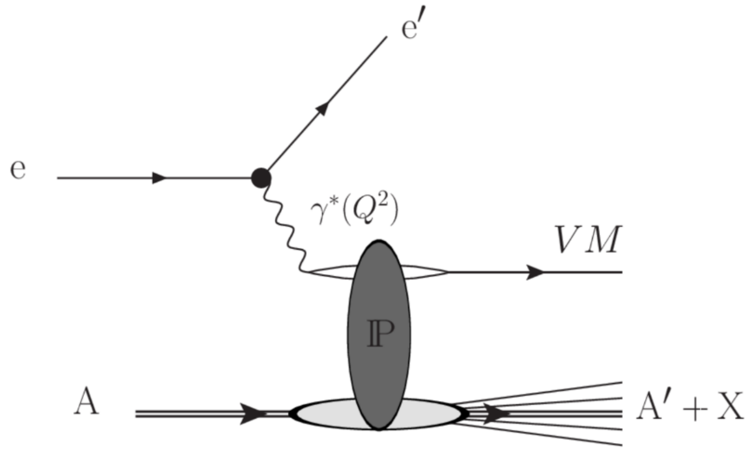
The main background is e + A → e' + A' + VM + X, with A≠A'





Coherent and incoherent production

Signal simulation

- Simulation with eStarlight[1]: ***e + A →VM + e' + A'***
- Options (consider only one):

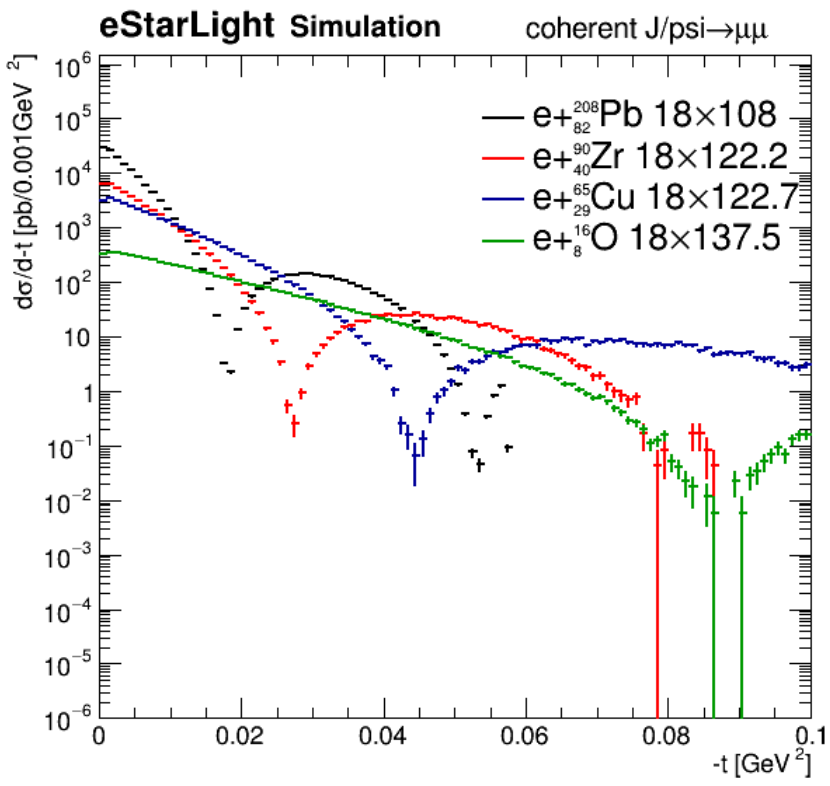
  Ions ^{16}O, ^{63}Cu, ^{90}Zr and ^{208}Pb

  Vector mesons: rho, omega, J/ψ, Phi, Upsilon

  Beam energy: 18x275 (~18x108 for ePb), 5x41
- Consider two Q2 regions:

Process	Cross section (different Q2)	
	-4 < log(Q2) < 0	0 < log(Q2) < 2
J/ψ→ee	66.119 nb	4.826 nb
J/ψ→μμ	66.087 nb	4.946 nb

[1] https://github.com/eic/estarlight



<u>Execution time</u>:

Standard (#23): 150 s/Event

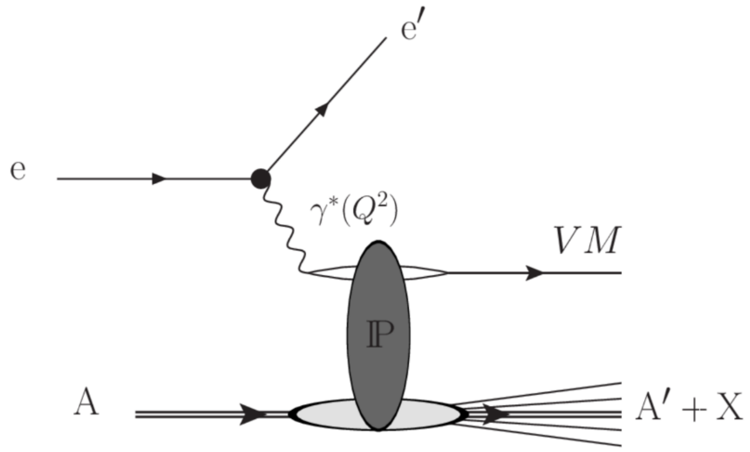
No-Ions: 1.5 s/Event

Ions+Vacuum 0.8 s/Event

Propagation through air in z>40m

Background simulation

BeAGLE V1.03.02 (https://eic.github.io/software/beagle.html)




```
PROJPAR                                   ELECTRON
TARPAR     208.0    82.0
TAUFOR      10.0    25.0    1.0
FERMI        2       0.62    1      0
*
*           yMin    yMax   Q2Min   Q2Max   theta_Min theta_Max
L-TAG       0.01    0.95    1.0    100.0     0.0     6.29
*
* model selection (0=all, 1=rho,2=omega,3=phi,4=J/psi)
PYVECTORS     4
USERSET      15      9.0
MODEL                                     PYTHIA
* if PYTHIA model specify pythia input cards
PY-INPUT                                  S3VJL003
```

Execution time:

Standard: 210 s/Event

Vacuum: 70 s/Event

Using t-Filter for t<0.07

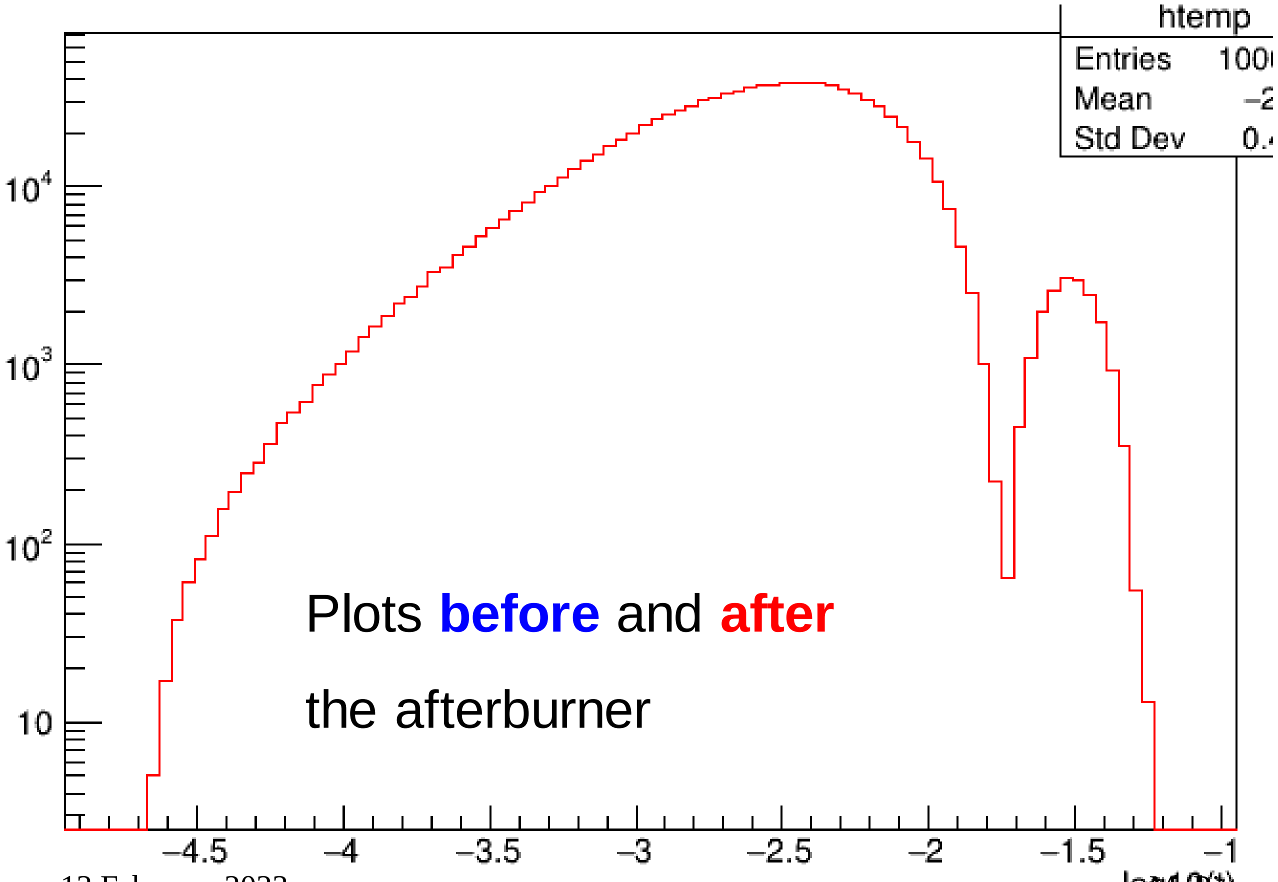
Filter efficiency ε~40%

Simulate two samples: $-4 < \log(Q^2) < 0$ **and** $0 < log(Q^2) < 2$

Coherent and incoherent production

Afterburner configuration

Using eic-shell and abconv –p 2 (https://github.com/eic/afterburner)



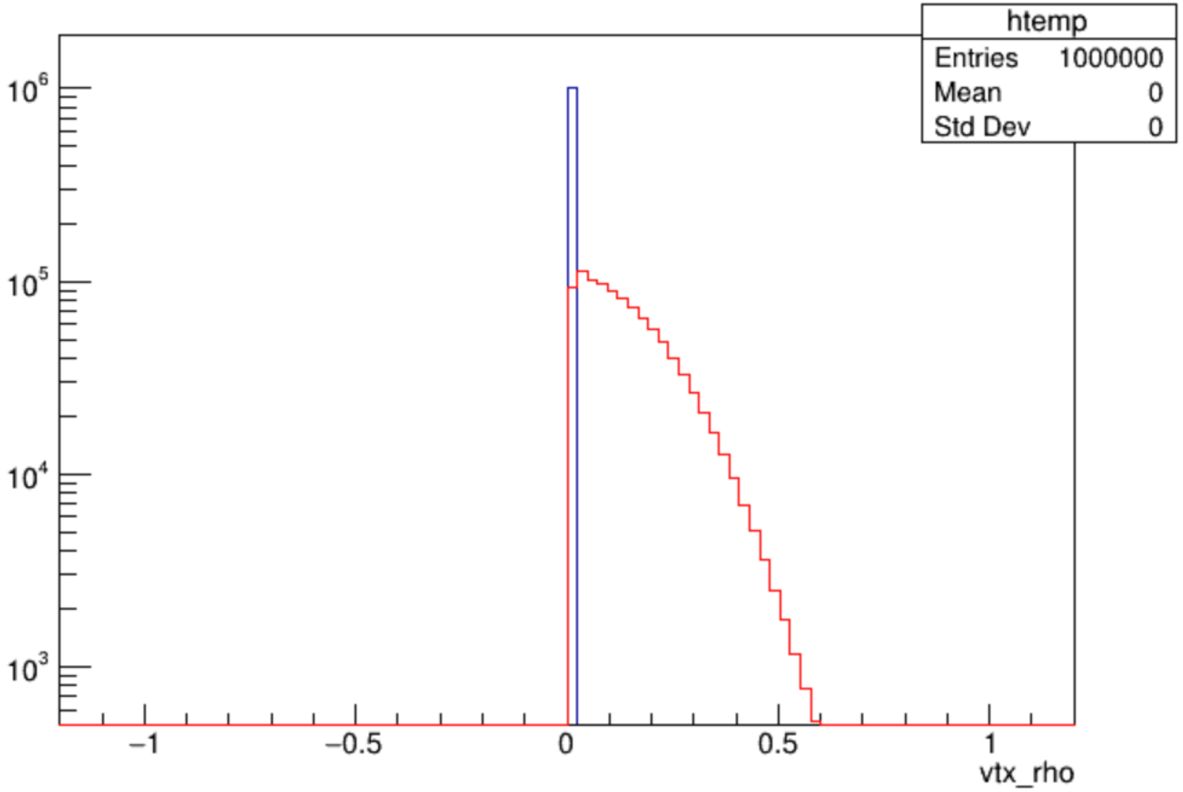
Plots **before** and **after** the afterburner

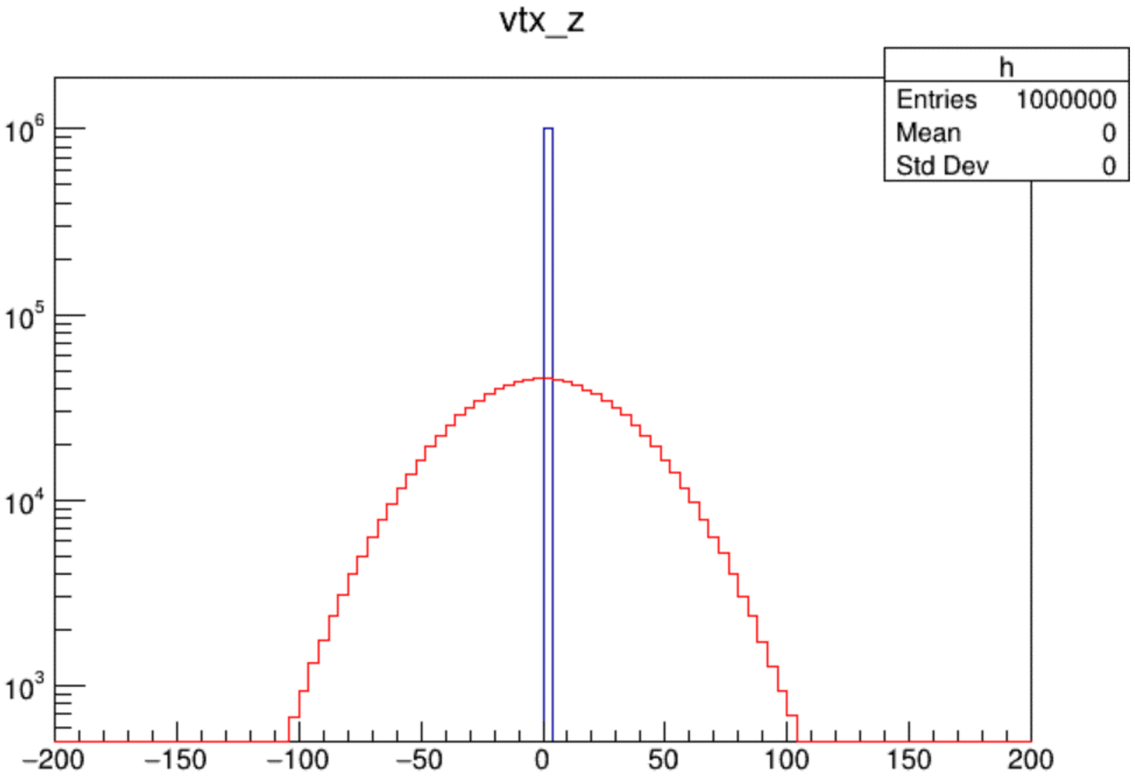
A ab_afterburner_is_used 1
A ab_crossing_angle 0.025
A ab_hadron_beta_crab_hor 500000
A ab_hadron_beta_star_hor 910
A ab_hadron_beta_star_ver 40
A ab_hadron_divergence_hor 0.000218
A ab_hadron_divergence_ver 0.000379
A ab_hadron_rms_bunch_length 70
A ab_hadron_rms_emittance_hor 4.32e-05
A ab_hadron_rms_emittance_ver 5.8e-06
A ab_lepton_beta_crab_hor 150000
A ab_lepton_beta_star_hor 1960
A ab_lepton_beta_star_ver 410
A ab_lepton_divergence_hor 0.000101
A ab_lepton_divergence_ver 3.7e-05
A ab_lepton_rms_bunch_length 9
A ab_lepton_rms_emittance_hor 2e-05
A ab_lepton_rms_emittance_ver 6e-07
A ab_use_beam_bunch_sim 1

Afterburner configuration

Compare vtx distribution stored in hepmc files used in the simulation **before** and **after** the afterburner

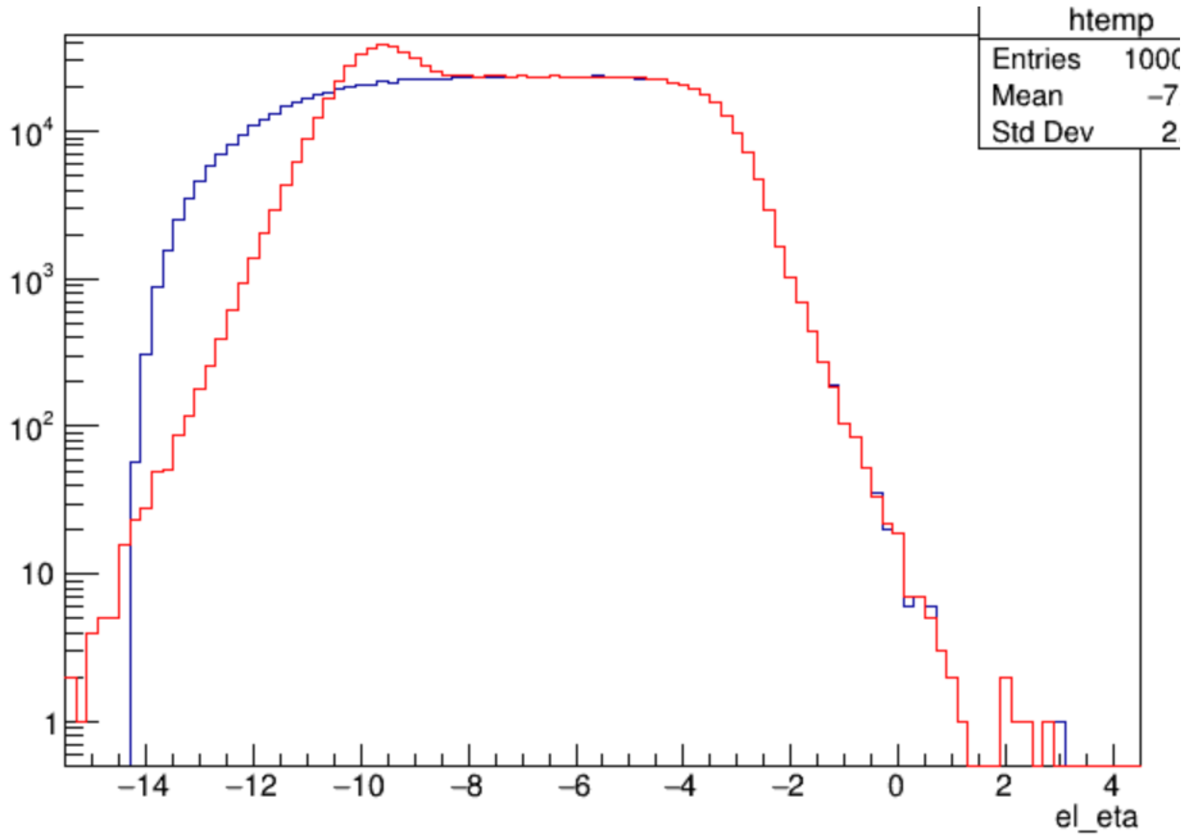
Vertex coordinates (x,y,z,t?) obtained from "E" line in the hepmc files (in mm)

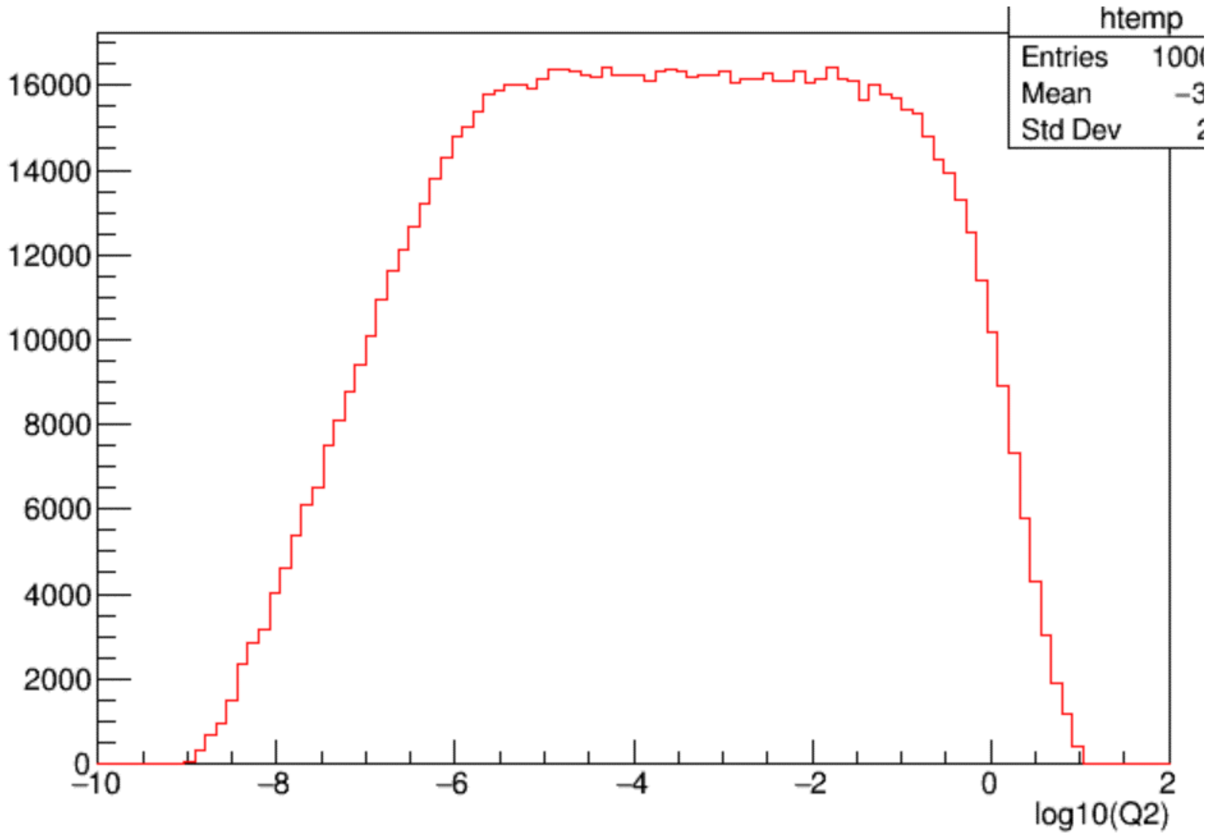




Afterburner configuration

Compare outgoing electron distribution **before** and **after** the afterburner

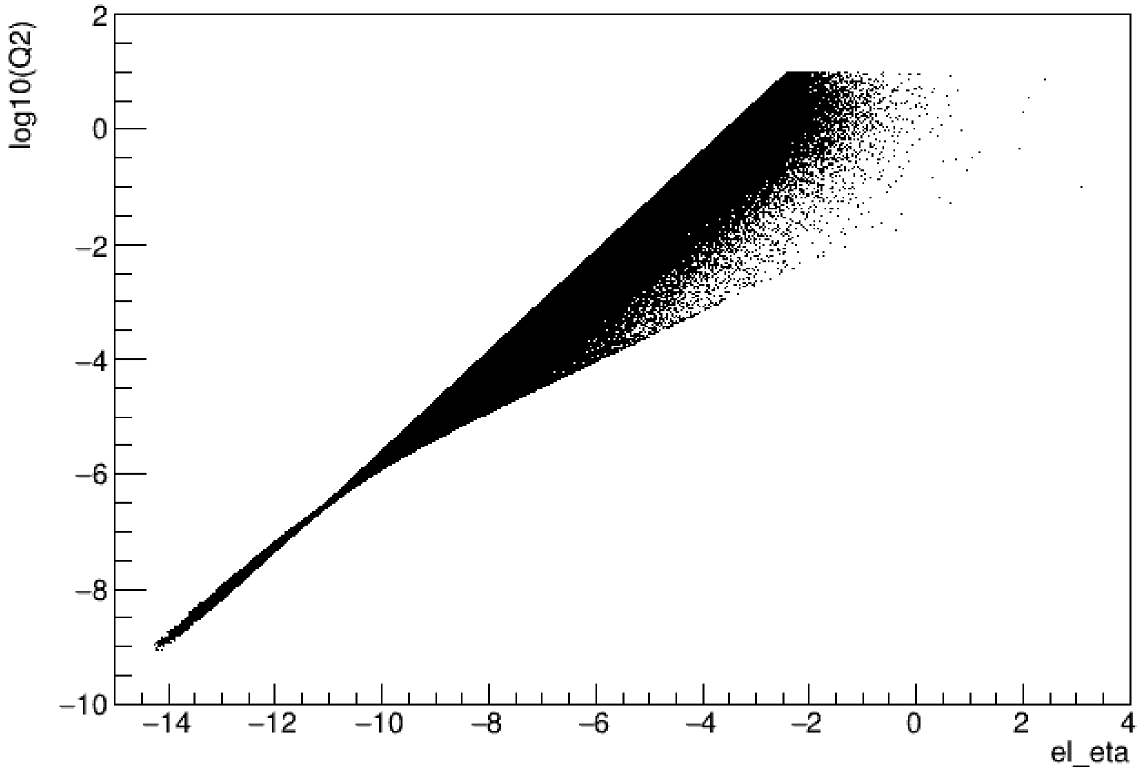


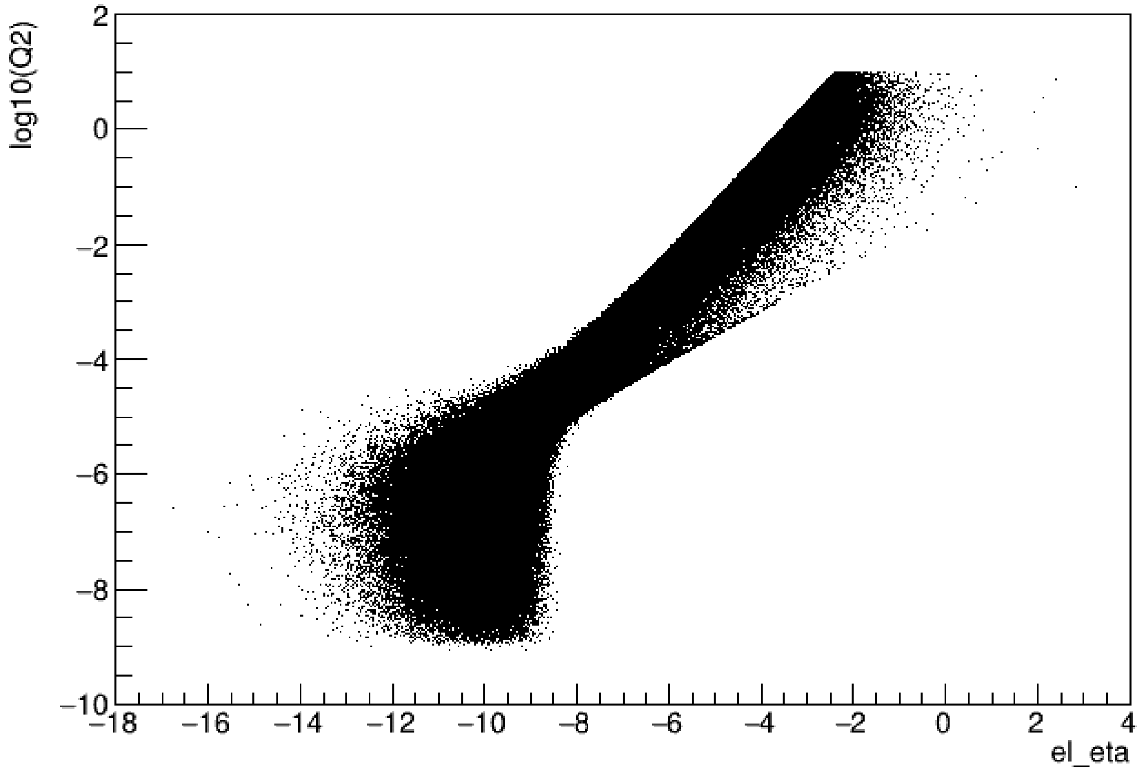


Afterburner configuration

Compare outgoing electron distribution before (left) and after (right) the afterburner

Correlation with Q2 are lost for low log(Q2) values (Q2 > 10^{-4})

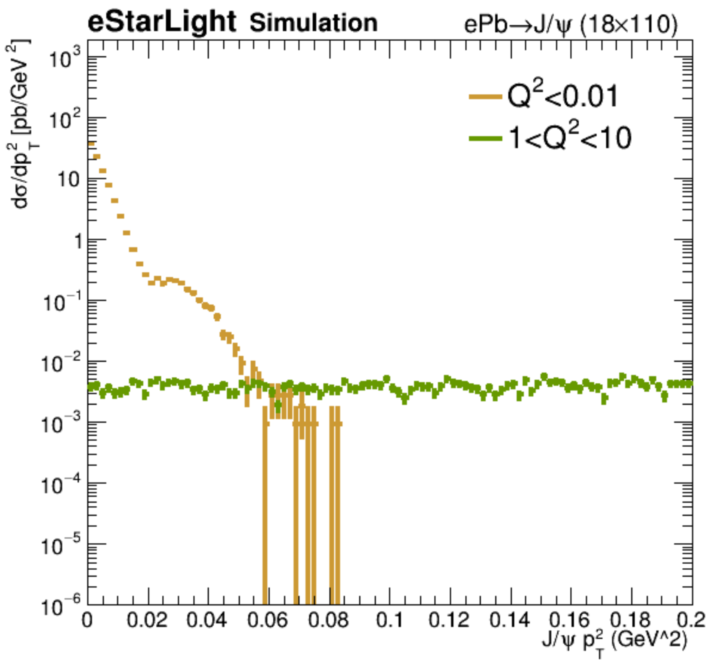


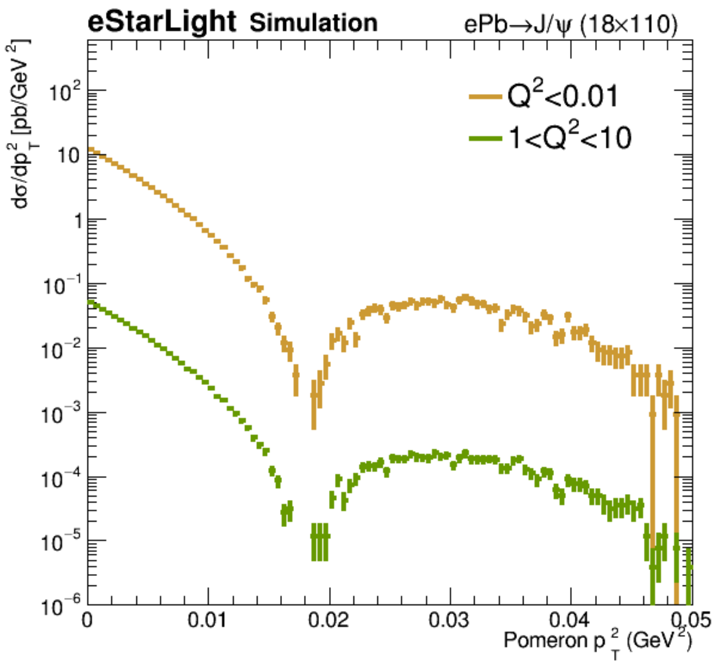


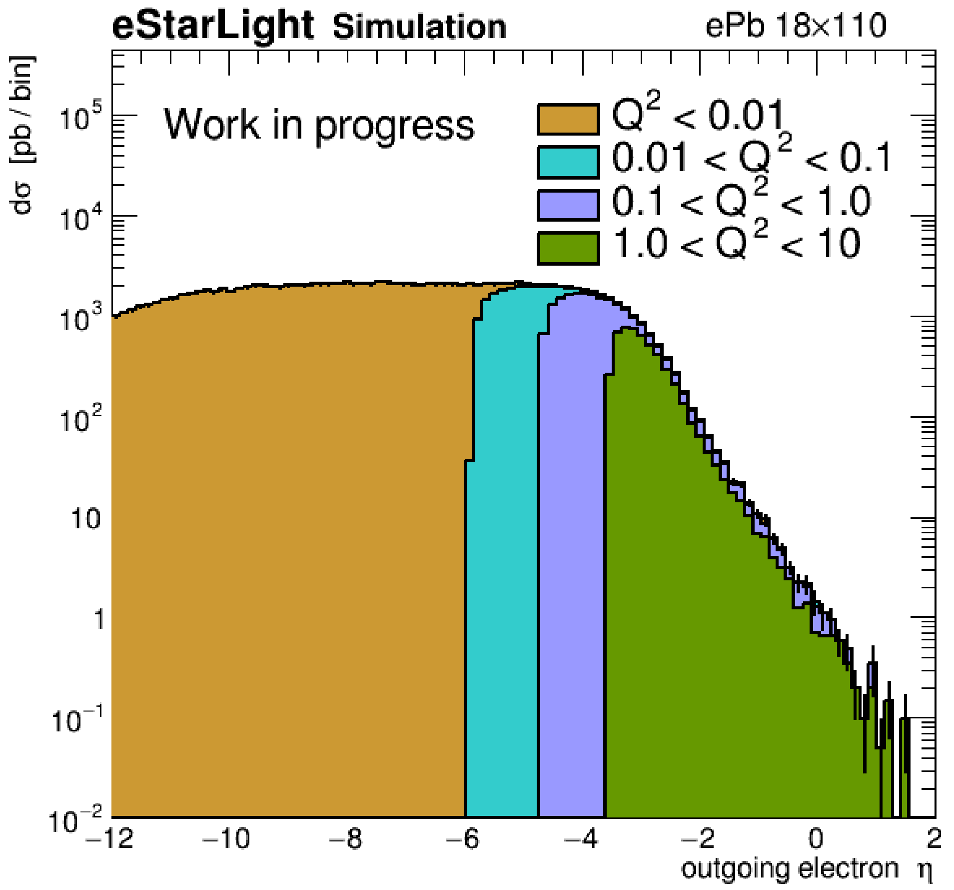
Momentum transfer and Q2

Q2 dependence

- Q^2 is correlated with outgoing electron rapidity.
- Only for low Q, VM pT is correlated with the *t*
- Can we measure backward electron to reach a low Q?







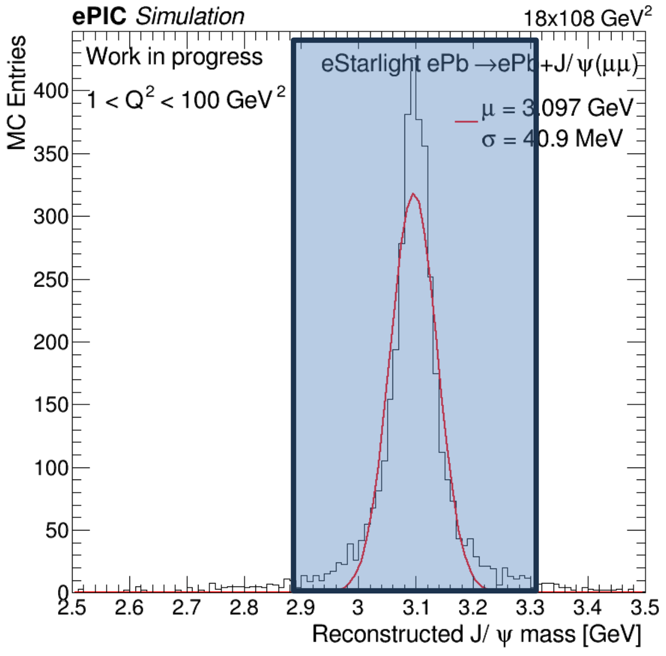
Analysis

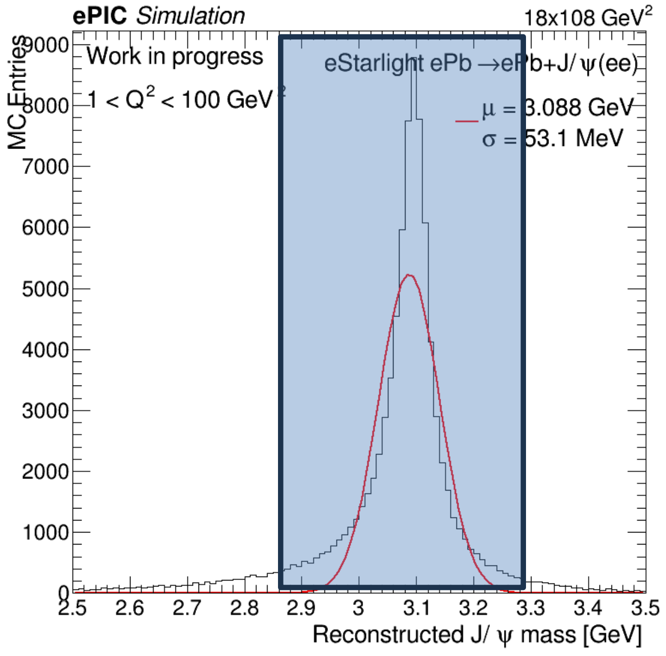
Event Selection

- 3 track events (with 2 tracks in |η|<4)
- VM mass window of 0.4 GeV
- Veto activity in forward region (reco/hits):

B0 tracks, B0 clusters, OMD tracks, RP tracks,

Ecal and Hcal ZDC Clusters





Signal efficiency for different Q^2 regions:

	electrons		Muons	
Cut	1 GeV <Q < 10 GeV	0.01 GeV <Q < 1 GeV	1 GeV <Q < 10 GeV	0.01 GeV <Q < 1 GeV
3 tracks	0.975394	0.366818	0.9755	0.371375
VM mass cut	0.858704	0.100727	0.9235	0.107313
Veto FFD	0.858693	0.100727	0.9235	0.107313

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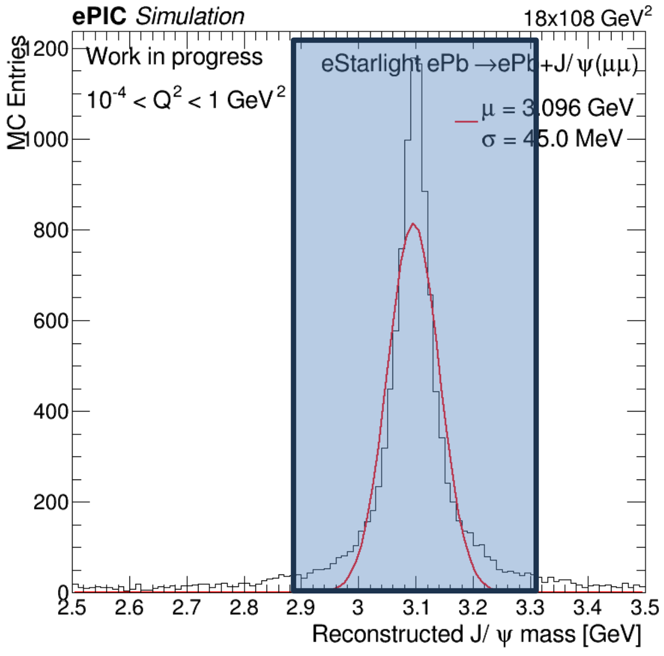

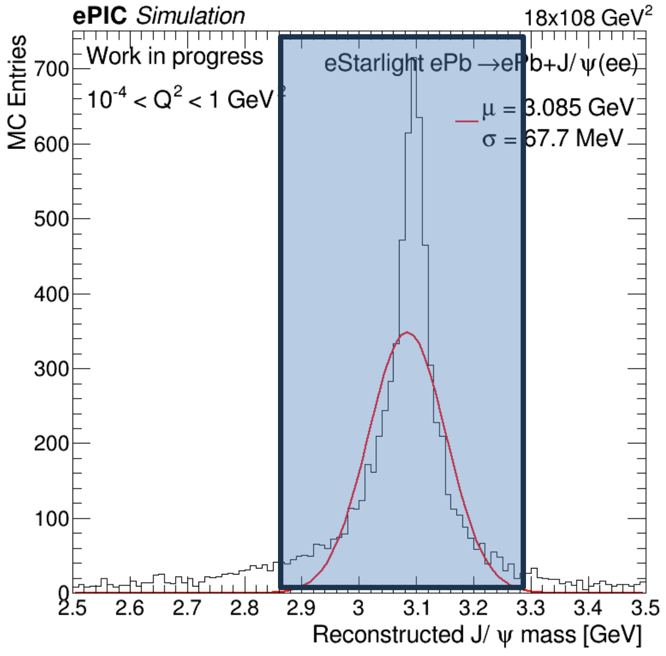

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Analysis

Event categorization

- Depends on the electron reconstructed eta
  - Central detector: 4.9 nb x 0.9 ~ 4.4 nb
  - Low-Q2 taggers: 66 nb x 0.1 ~ 6.6 nb

Event Kinematics

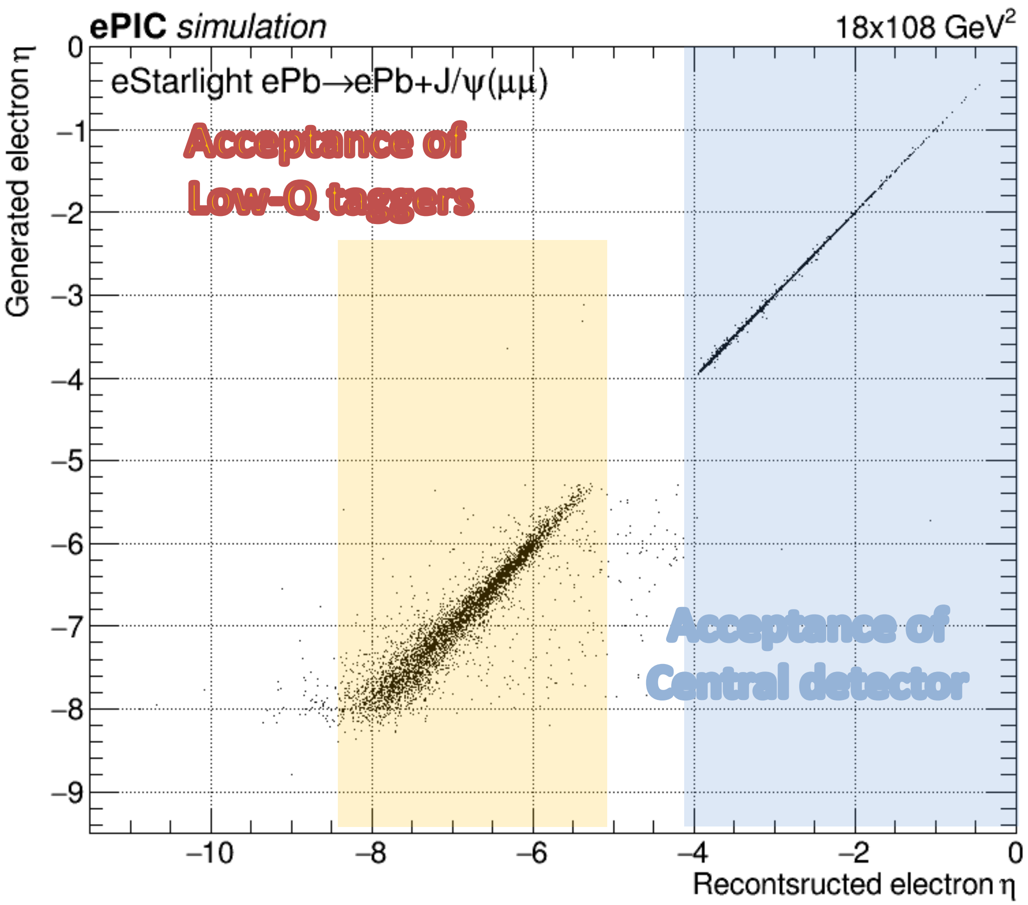
Reconstruction of parameters of interest:

e – incoming electron (**fixed**)

e’ – outgoing electron (**measured**)

VM – vector meson (**measured**)

- Momentum transfer –t =(VM −(e−e')).M2()



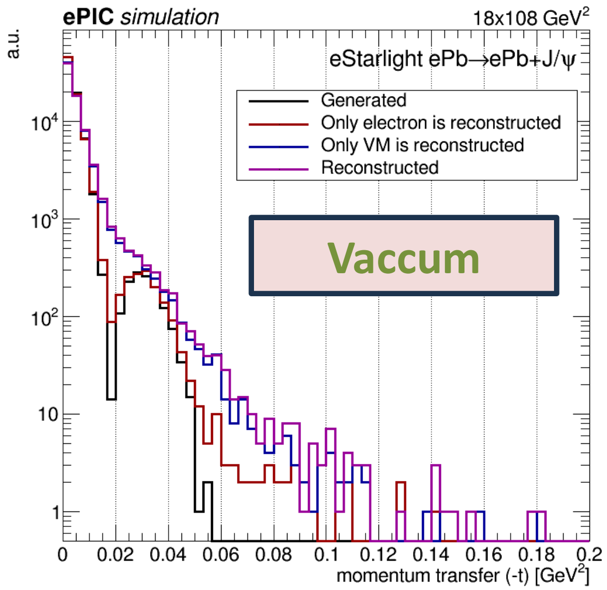
Adding low-Q2 category double statistics

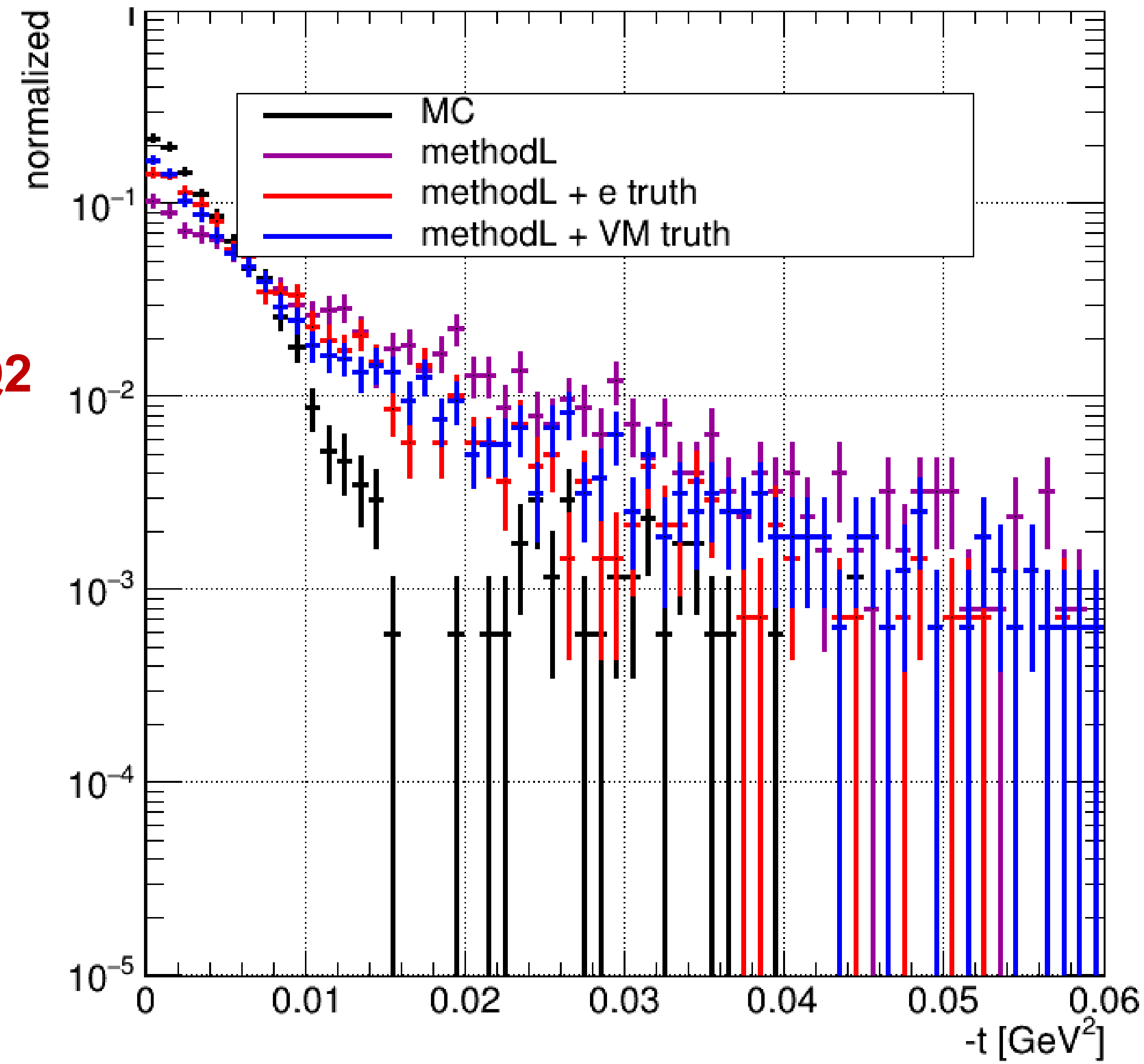
t reconstruction

- Using MethodL (with Pb mass constrain link):
  - **Better modeling of the t variable**

Compare to results with "vaccum" at very low Q2

  - Reconstruction is much worser

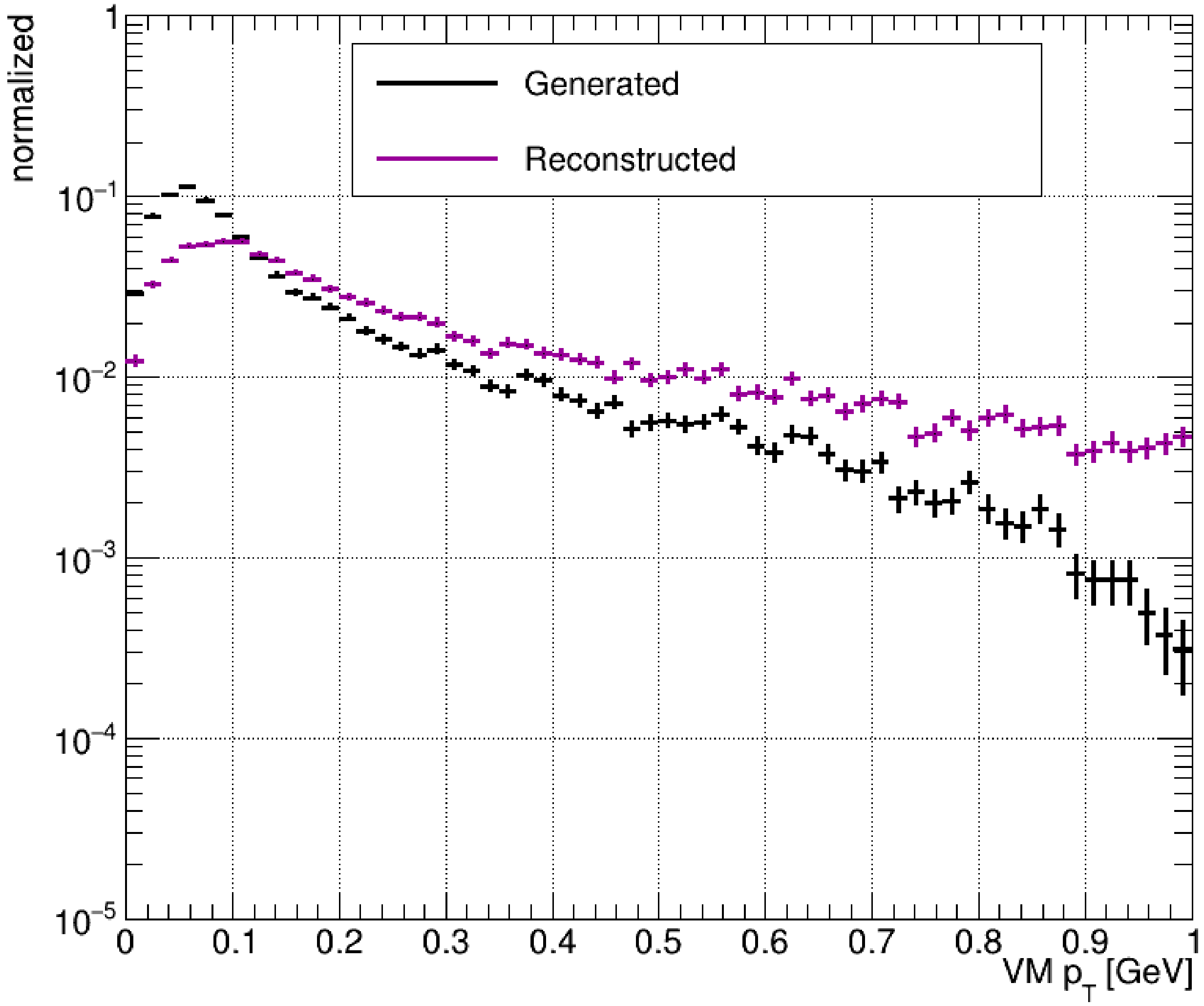




Analysis

VM PT reconstruction

- At very low Q, t can be approximated as VM PT, but not for Q>0.01
  - ➢ **The dip is not seen at the generated level**
  - Only very low Q2 category can be used



Summary and discussion

Summary

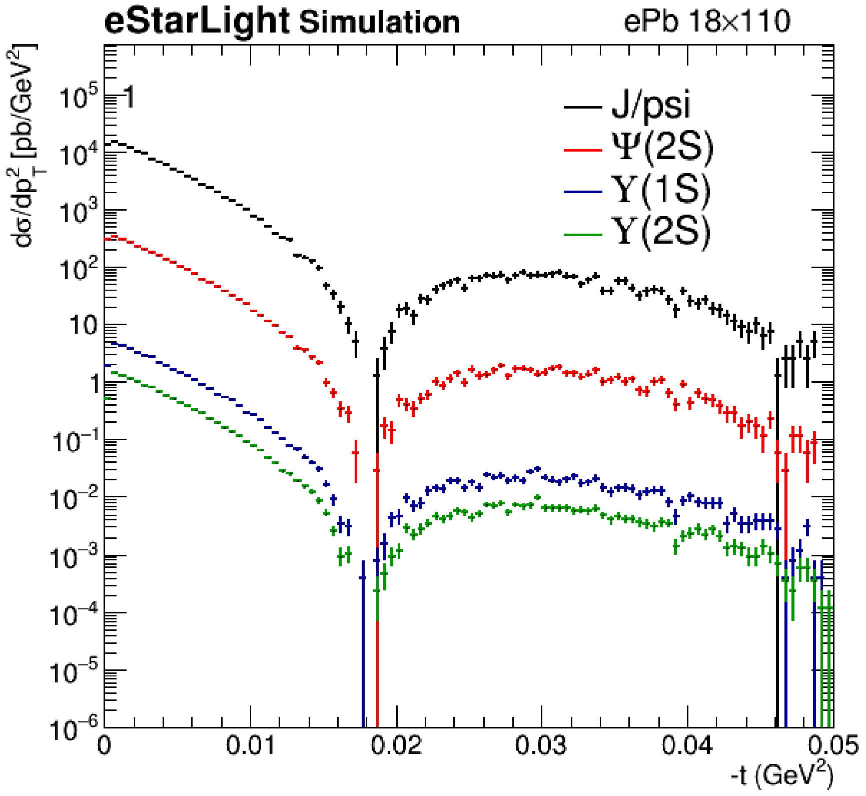
- Simulation:
  - Signal: Ions removed (air at Z>40)
  - Background: Processed in vacuum (otherwise take too long)
  - Condor jobs take forever
- t-reconstruction for the signal gets much worse with world="Air" – need to improve particle resolution
  - Unfolding?
  - e/mu energy corrections?

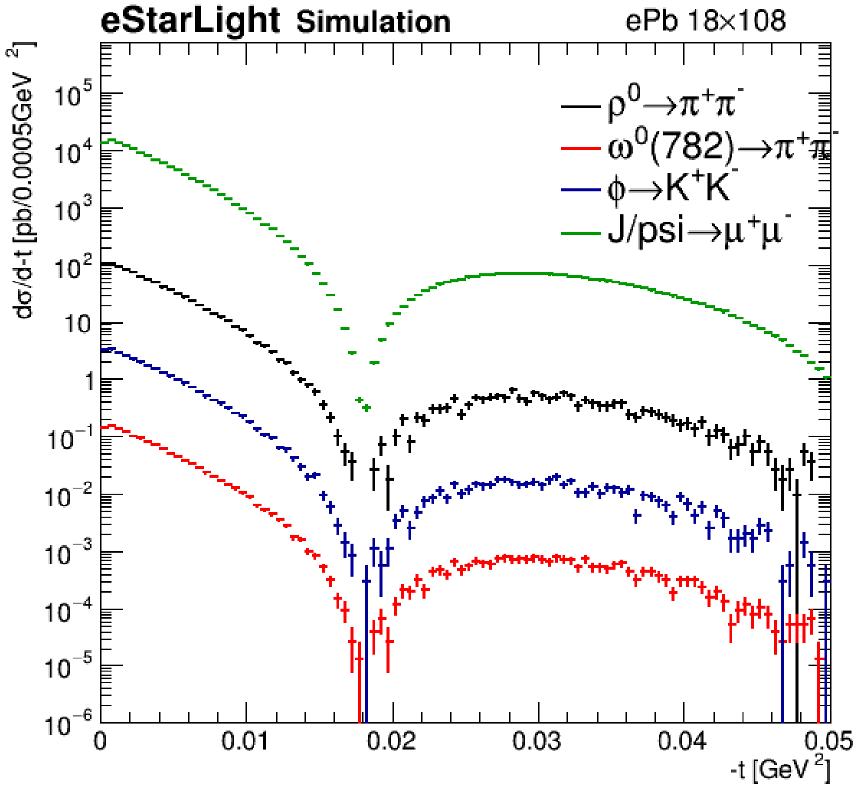
Backup

Cross-sections

Different mesons

- All vector meson production processes show the same t spectra, J/psi has the highest cross-section.

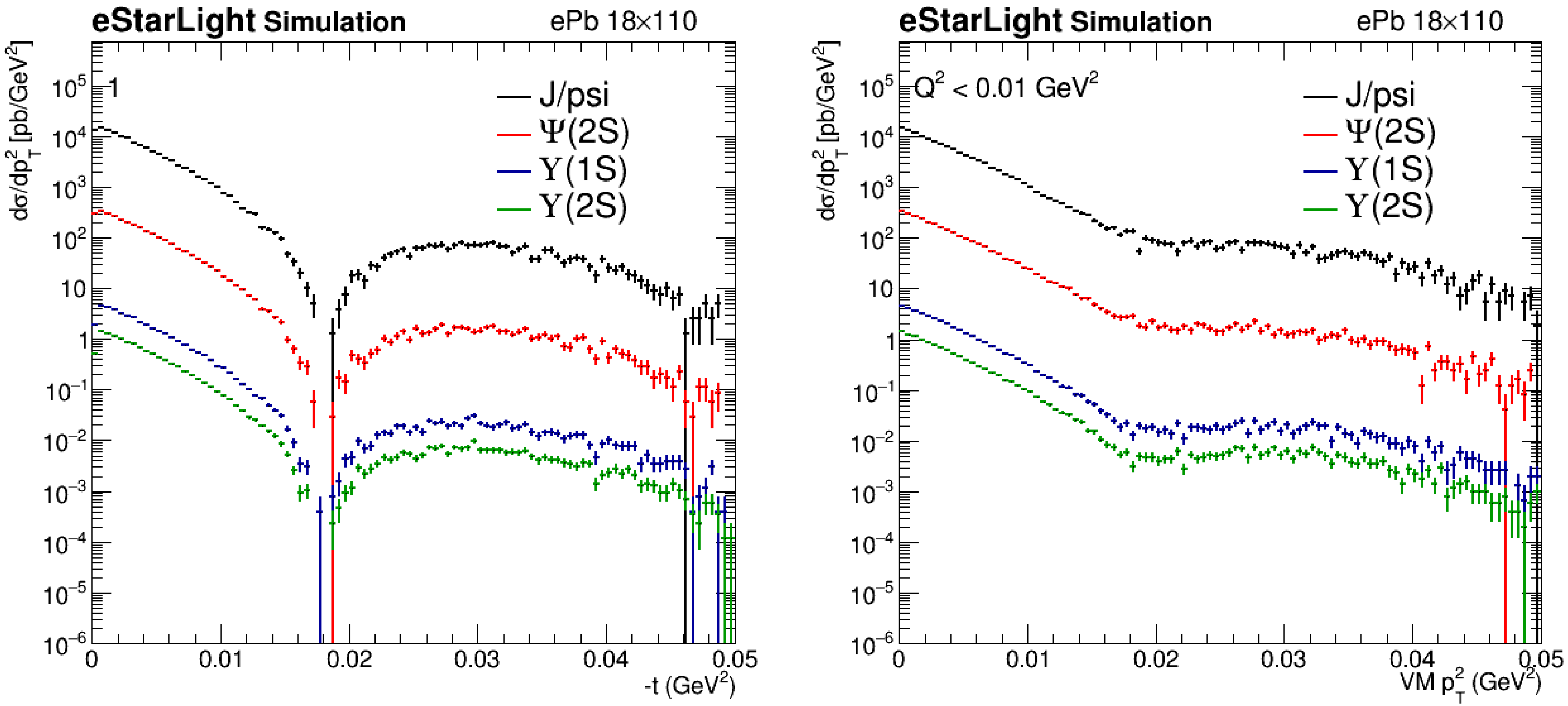




Decay	BR
$\rho^0 \rightarrow \pi^+\pi^-$	99.9%
$\omega^0 \rightarrow \pi^+\pi^-$	1.53%
$\phi \rightarrow K^+K^-$	50%
$J/\psi \rightarrow \mu^+\mu^-$	6%

Different mesons at low Q2

- Similar spectra for different VM



Analysis

Event categorization

- Depends on the electron reconstructed eta
  - Central detector: ~10% of all $Q^2<10$ GeV
  - Low-Q2 taggers: ~40% of all $Q^2<10$ GeV

Event Kinematics

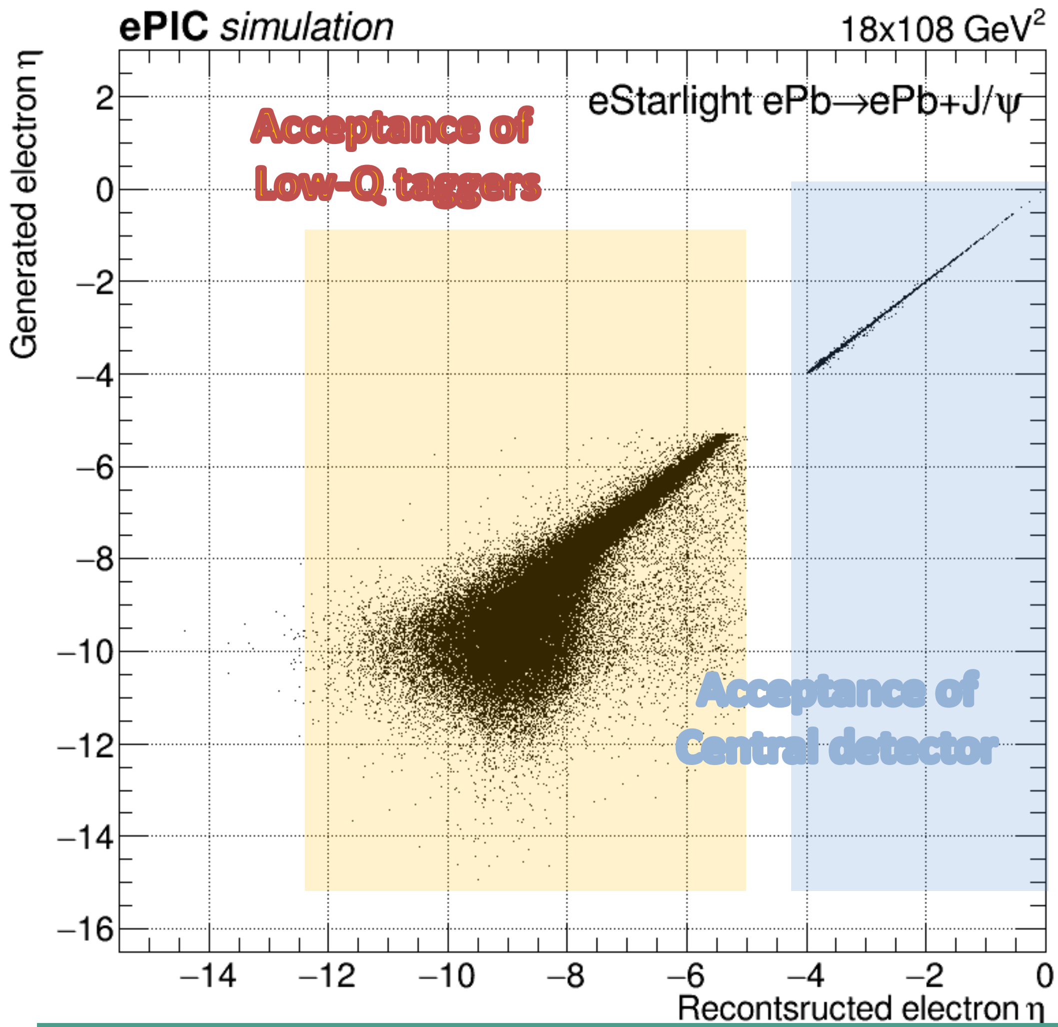
Reconstruction of parameters of interest:

e – incoming electron (**fixed**)

e' – outgoing electron (**measured**)

VM – vector meson (**measured**)

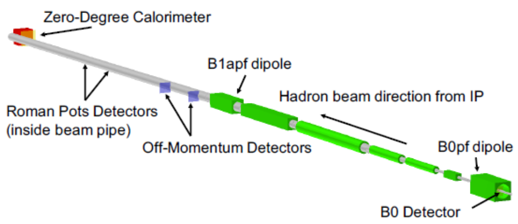
- Momentum transfer $-t = (VM - (e - e')).M2()$

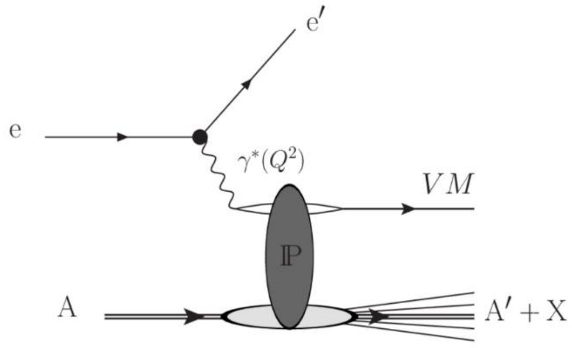


Adding low-Q2 category increases signal acceptance by x5

Backgrounds

- The main background is incoherent VM production
- Modify the strategy (from object rejection to signal rejection)
- Work by Eden Mautner (in progress)





- Veto.1: no activity other than e^- and J/ψ in the main detector ($|\eta| < 4.0$ and $p_T > 100$ MeV/c) ;
- Veto.2: Veto.1 and no neutron in ZDC;
- Veto.3: Veto.2 and no proton in RP;
- Veto.4: Veto.3 and no proton in OMDs;
- Veto.5: Veto.4 and no proton in B0;
- Veto.6: Veto.5 and no photon in B0;
- Veto.7: Veto.6 and no photon with $E > 50$ MeV in ZDC.

Background efficiency based on ePIC FFD simulation

Cut	1GeV<Q^2<10 GeV	10^{-4} <Q^2 <100 GeV
3 tracks	0.876579	
VM mass cut	0.843891	
Veto B0	0.488994	
Veto RP/OMD	0.0953154	
Veto ZDC	0.0255769	

Analysis

t reconstruction

- Using MethodL (with Pb mass constrain link):
  - **Better modeling of the t variable**

  Larger effect from VM reconstruction

  - At low Q electron do not have impact