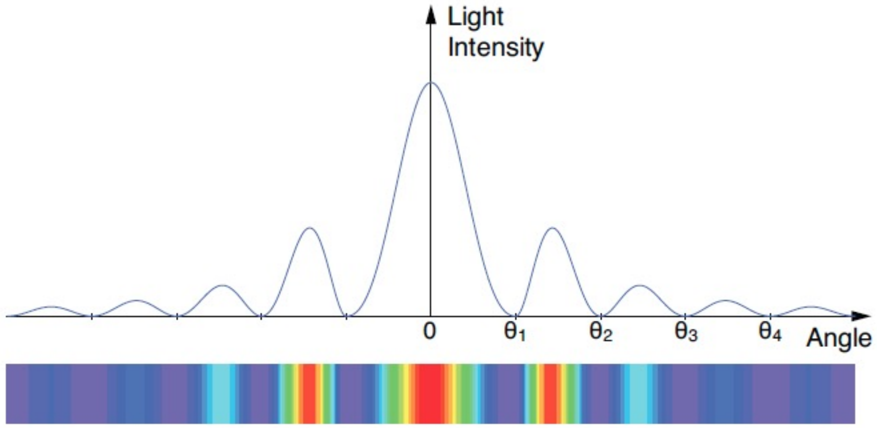
VM program in *eA* at the EIC – ~~EIC@IP6~~, ~~ATHENA~~, ~~Detector-1~~, **EPIC**



Keywords in this talk:

I. Coherent ϕ with ρ^0 bkg
II. Barrel PID impacts
III. TOF and hpDIRC
IV. …

Kong Tu, Thomas Ullrich, and Zhangbu Xu

BNL

08.22.2022

Physics-driven questions for detectors

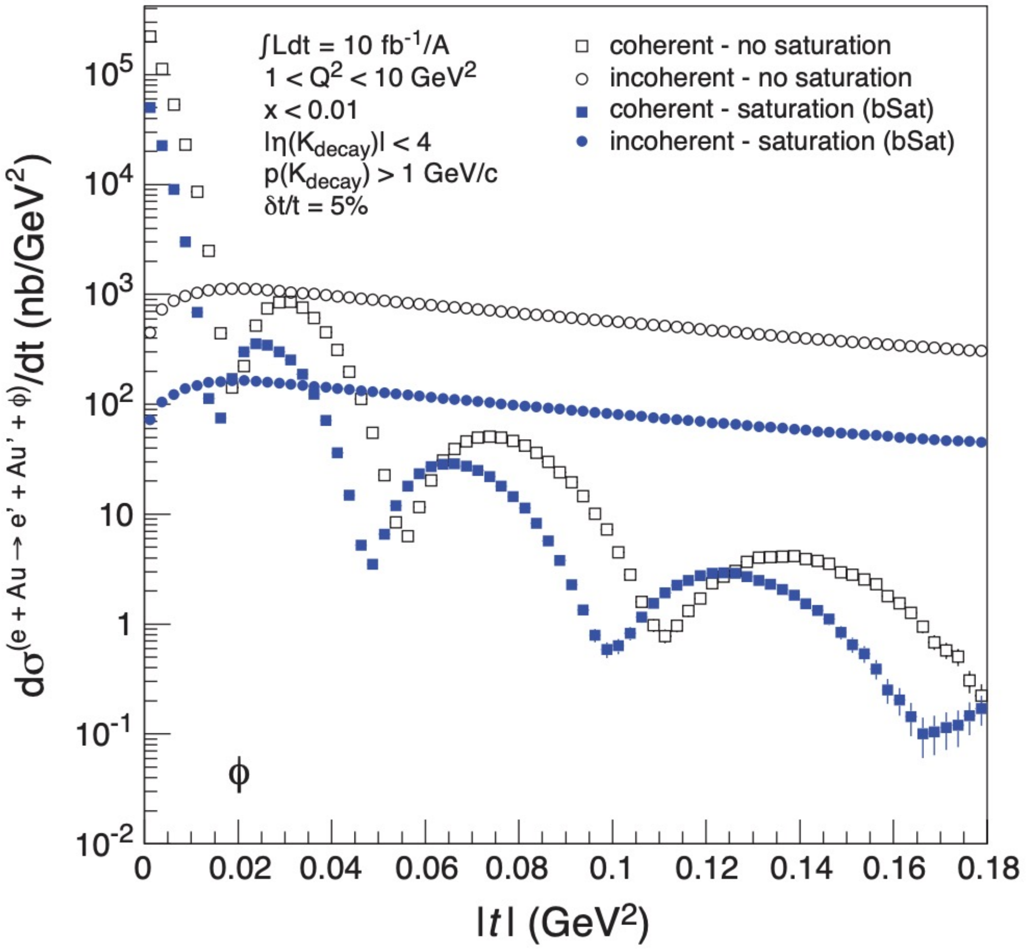
- Diffractive ϕ meson at the EIC has been considered one of the most important and challenging channels:

  a) Outstanding resolution of tracking and nECAL for coherent ***-t .***

  b) Excellent far-forward detector acceptance for incoherent background

  c) Physics background from mis-identification of final-states

(EIC White Paper)



Physics-driven questions for detectors

- Diffractive ϕ meson at the EIC has been considered one of the most important and challenging channels:

Common to all VMs

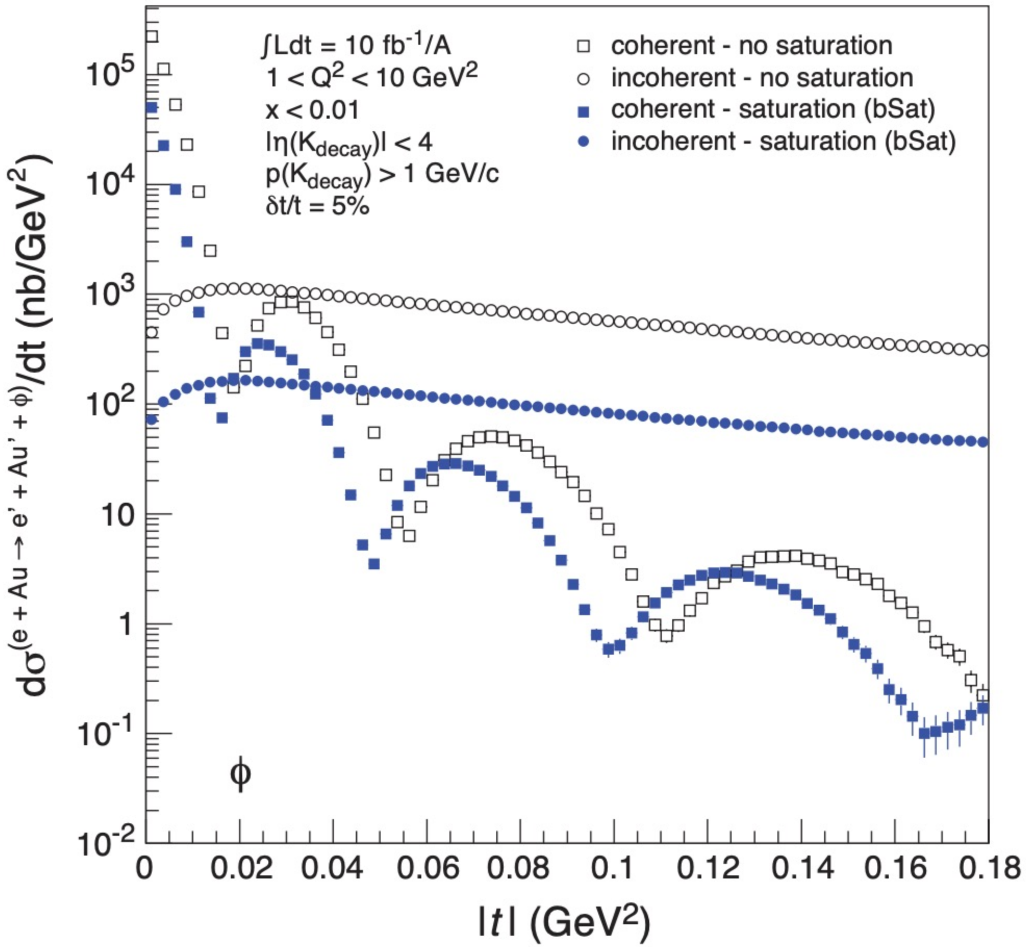
a) Outstanding resolution of tracking and nECAL for coherent ***-t .***

b) Excellent far-forward detectors acceptance for incoherent backgrounds;

c) Physics background from mis-identification of final-states.

Unique to ϕ meson

(EIC White Paper)



Sample, phase space, and magnet

- **Samples**

Sartre generator eAu 18x110 GeV of ρ^0, ϕ, and J/Ψ with **NO** saturation.
(/gpfs02/eic/DATA/sartre/data/bnonsat/sartre_bnonsat_Au_*_.root)

- **Phase space**

$1<Q^2<10$ GeV^2, $x < 0.01$, $|y_{VM}| < 4.0$

- **Magnet**

1.7T (relevant for TOF only in my study later)
All studies are generator level without detector simulations

Mis-identification of final-states w/o PID

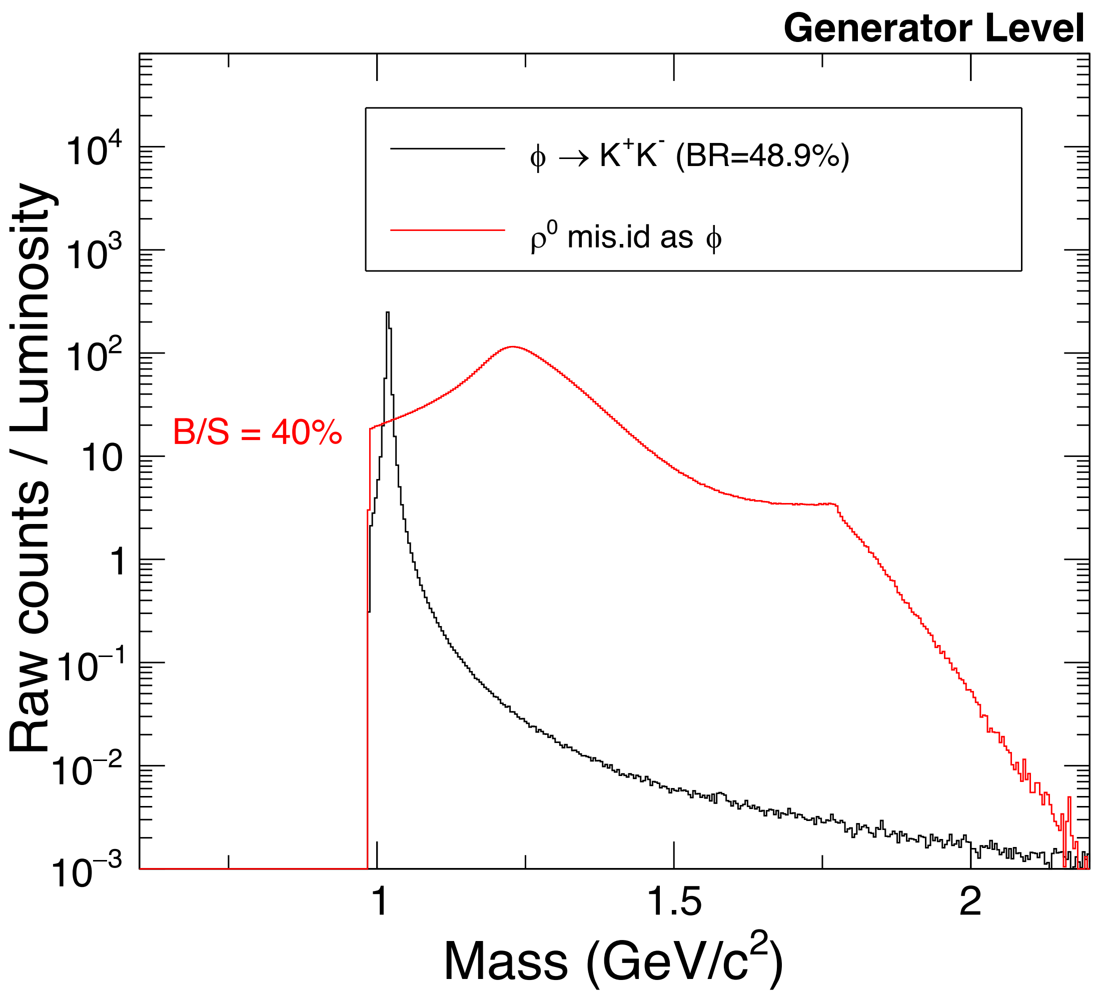
Signal:

e + Au → e' + Au' + (ϕ→ K^+K^-)

Dominant background:

e + Au → e' + Au' + (ρ^0 →$\pi^+\pi^-$)

Background/Signal (B/S) ~ 40%!

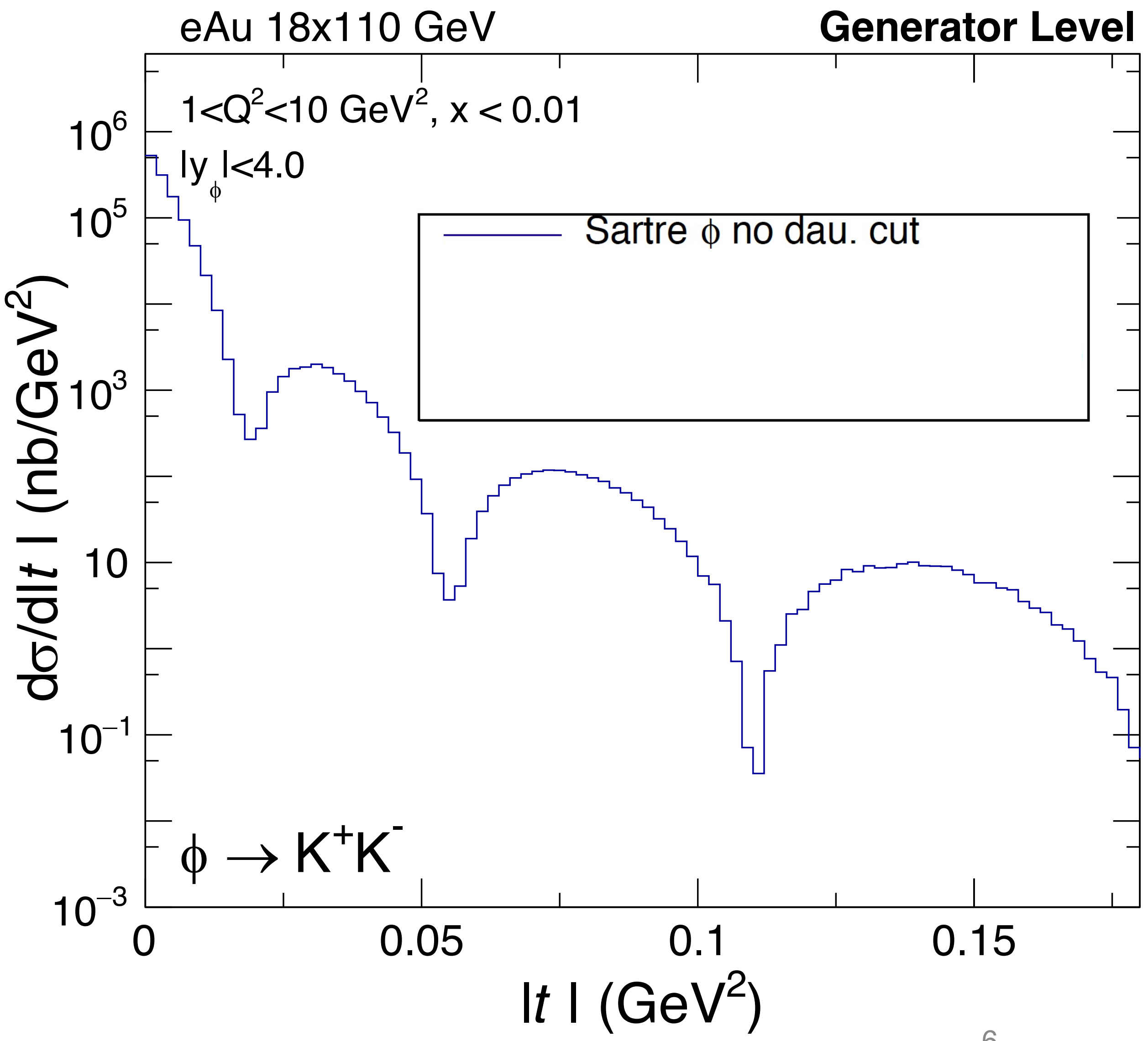


How come?

- Cross section of ρ^0 is ~ 10 times higher than ϕ;
- BR is only 48.9% for ϕ→ K^+K^- but ~ 100% for ρ^0 →$\pi^+\pi^-$
- Tail contribution under the ϕ mass peak (1.019 +/- 0.02 GeV)

What's the impact on -*t*

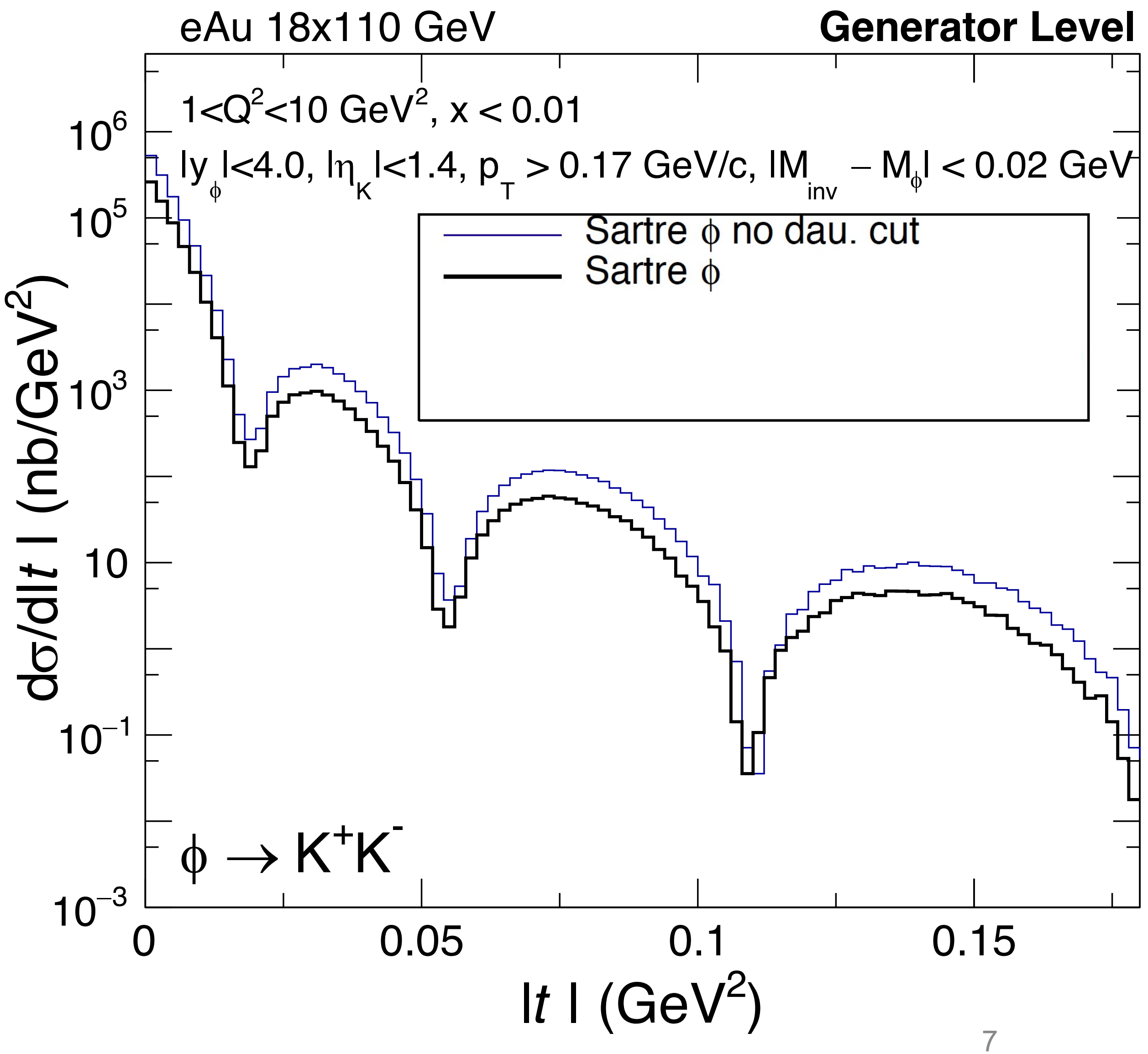
1) This is the truth distribution, given what the phase space is (the final measurement level);



What's the impact on -*t*

1) This is the truth distribution, given what the phase space is (the final measurement level);

2) Phase space selected on the daughters in the barrel region, with minimum p_T , pseudorapidity, and their invariant mass;



What's the impact on -*t*

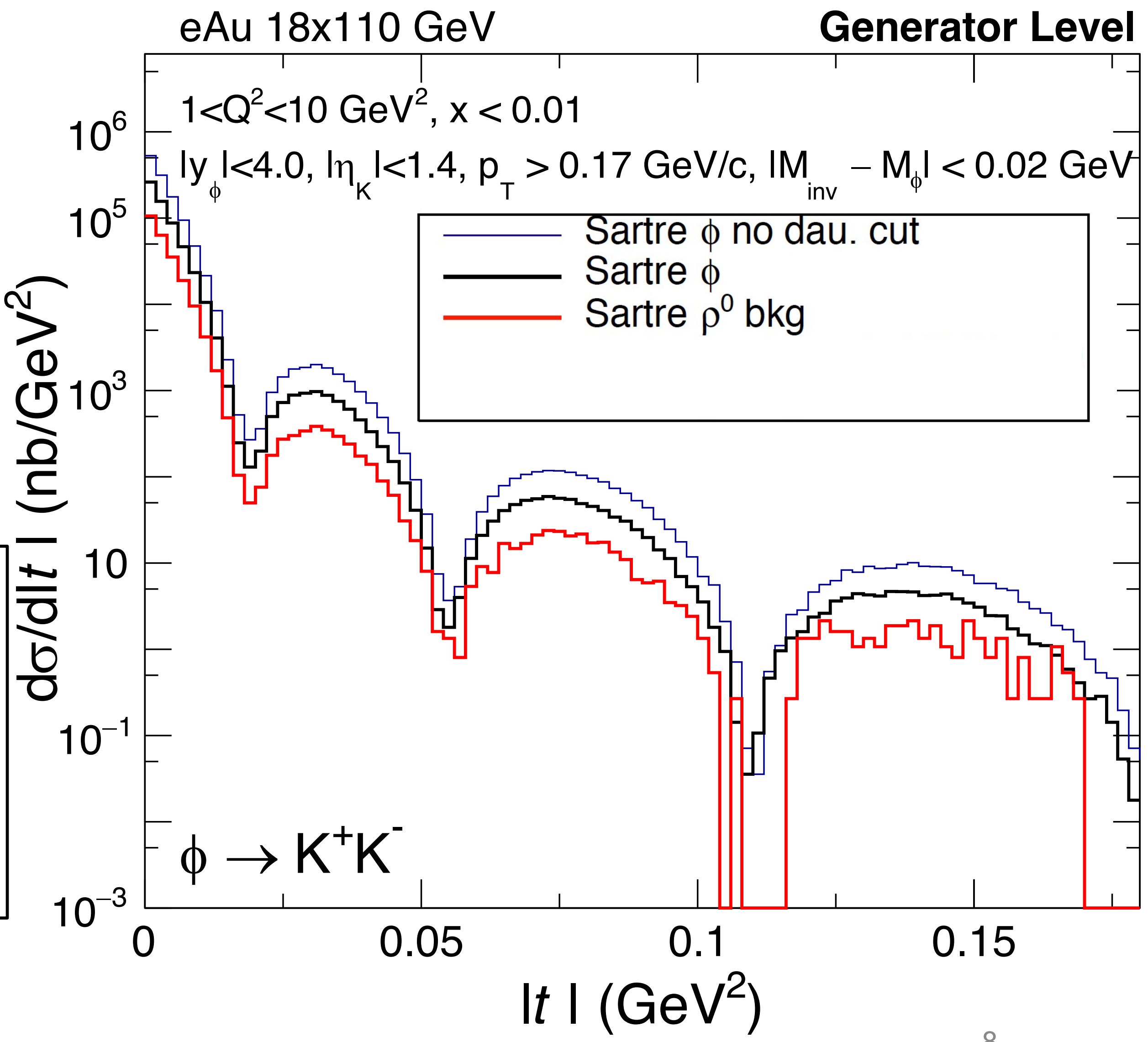
1) This is the truth distribution, given what the phase space is (the final measurement level);

2) Phase space selected on the daughters in the barrel region, with minimum p_T , pseudorapidity, and their invariant mass;

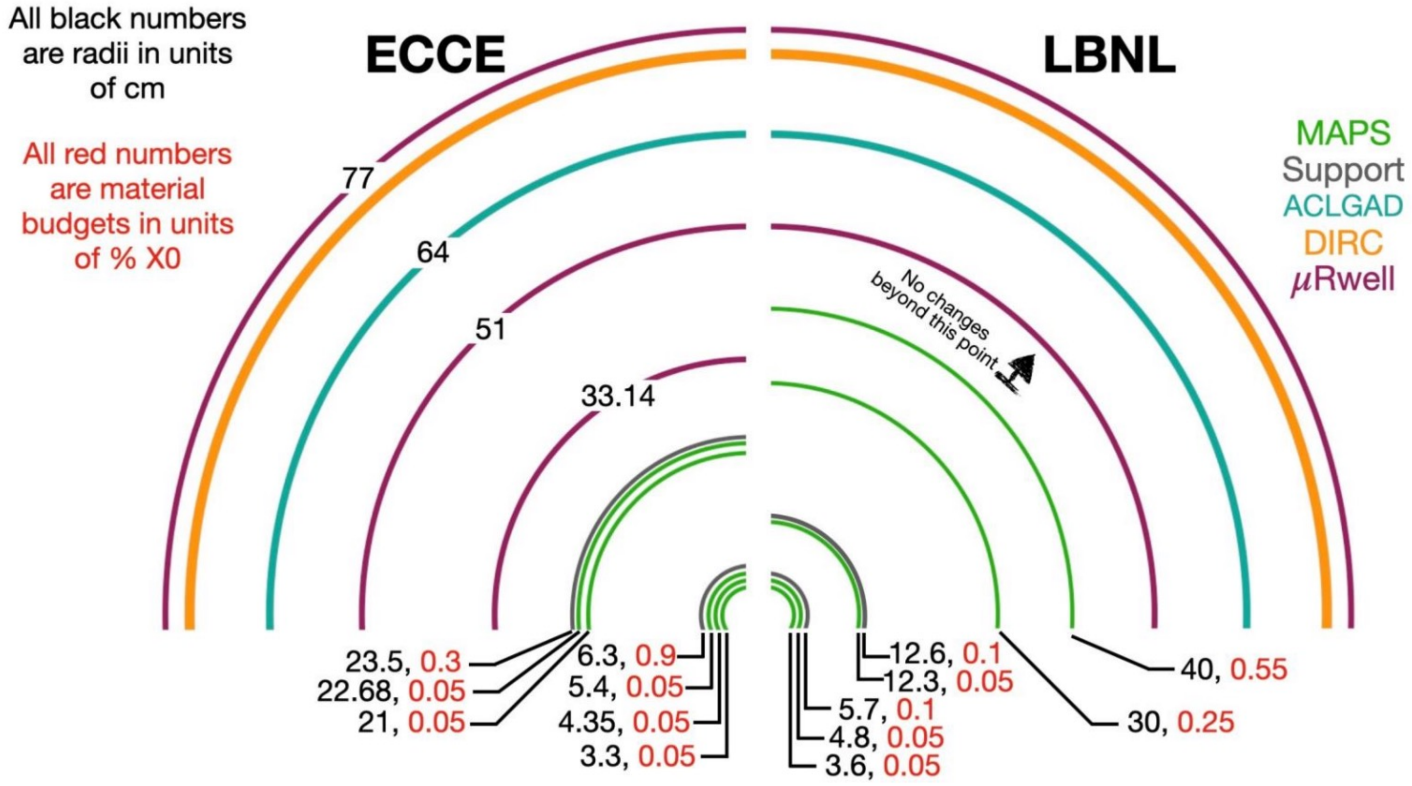
3) Background from ρ^0 within ϕ mass window

The problem therefore is:

If the ρ^0 distribution shifts left or right (Saturation, etc), the signal will be largely smeared, e.g., the dip position



Barrel PID detectors at low momentum



- hpDIRC can separate pi vs nonpi above 0.25 GeV/c in barrel except a gap +/- 0.15. (See s10 in Joe Schwiening's talk)
- ACLGAD (TOF) can go down to lower tracking limit p_T ~ 0.17 GeV/c (and assume 25ps resolution)

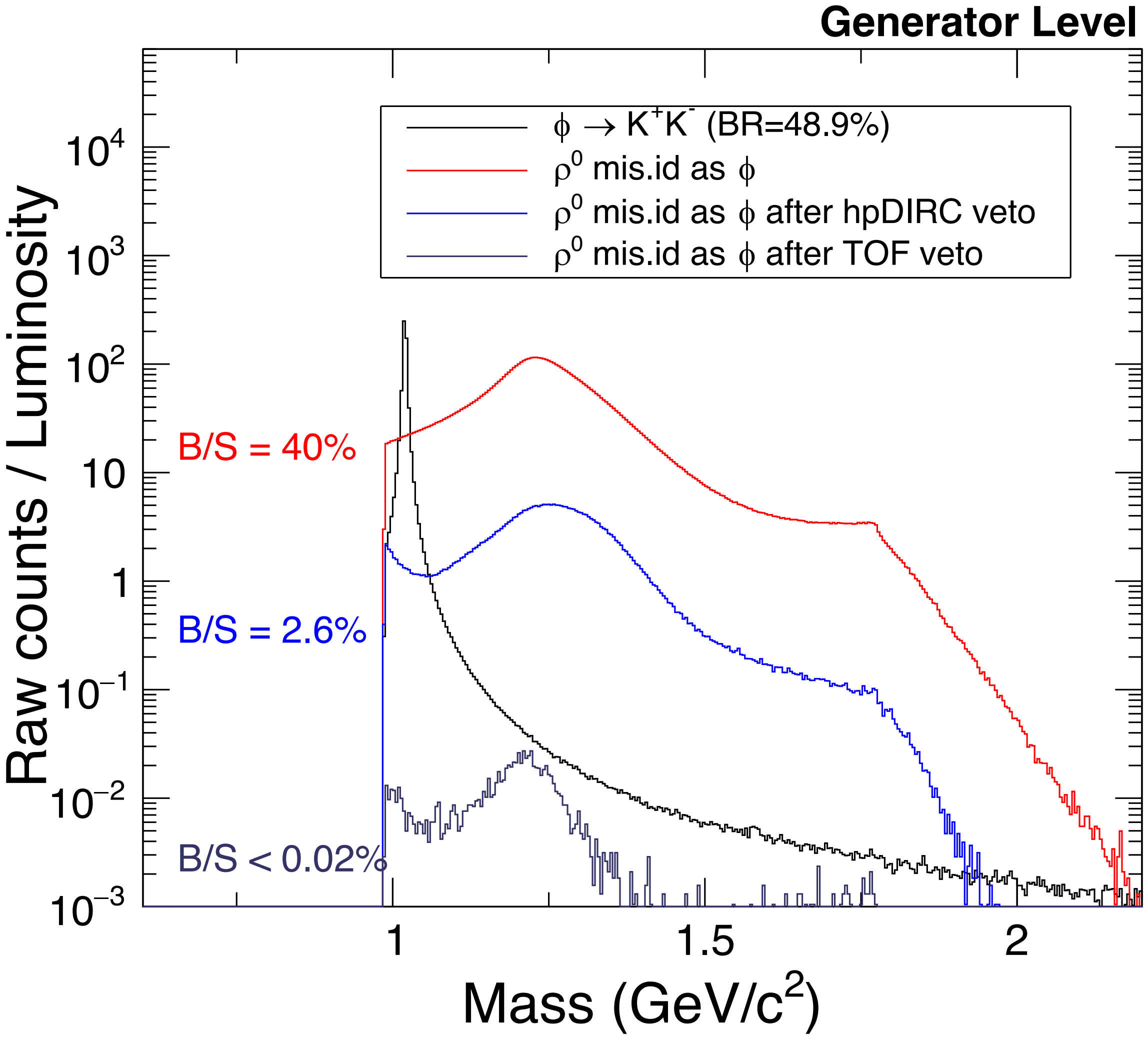
- hpDIRC: we assume 3σ separation between pi and nonpi, given the above phase space;
- TOF: @64cm, 1.7T field, 25ps resolution, and 30ps start time resolution. (Toy study done by Zhangbu Xu)

Mis-identification of final-states w. PID

Signal:
e + Au → e' + Au' + ($\phi \rightarrow K^+K^-$)

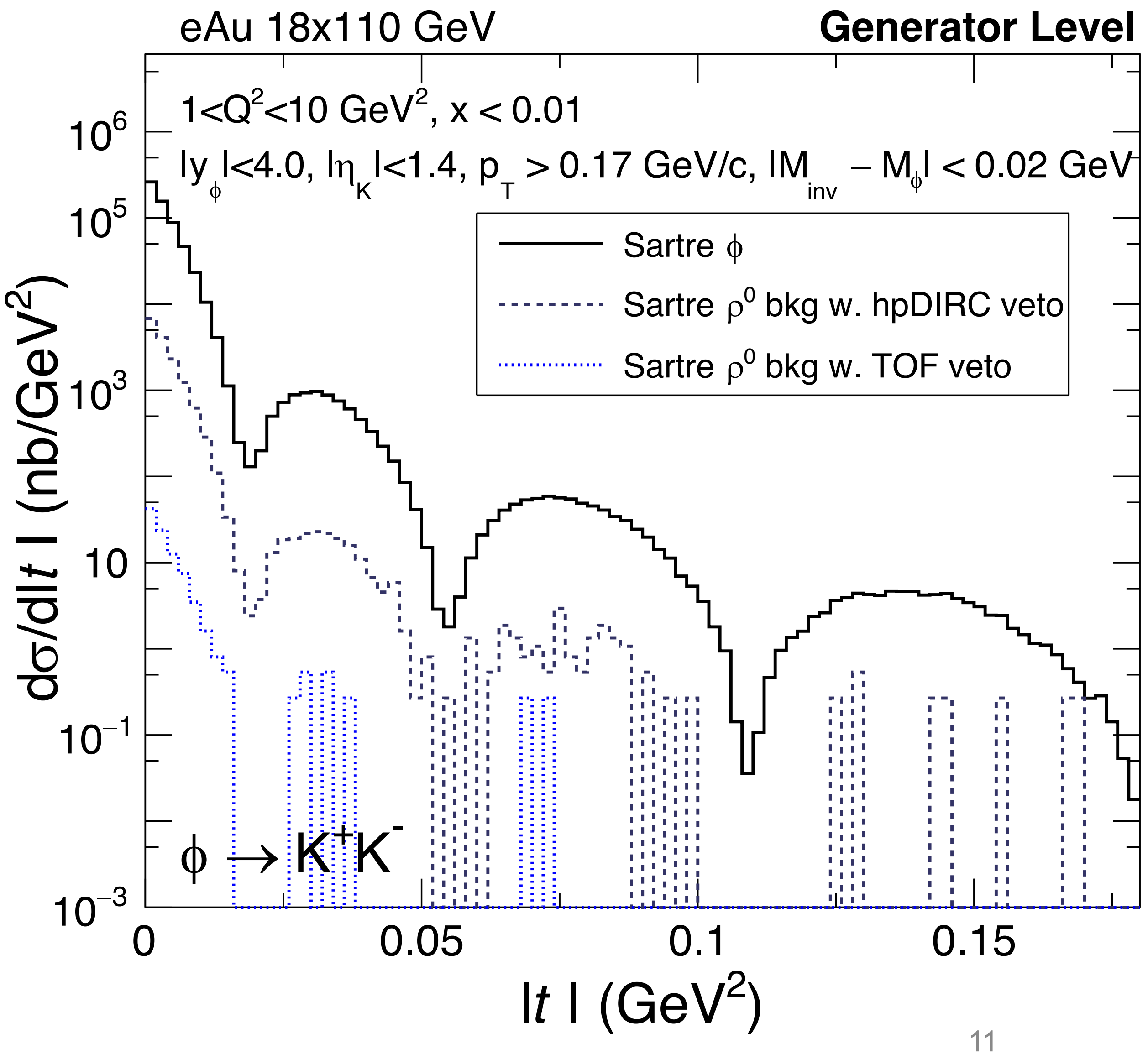
Dominant background:
e + Au → e' + Au' + ($\rho^0 \rightarrow \pi^+\pi^-$)

B/S ~ 40% → 2.6% → 0.02%



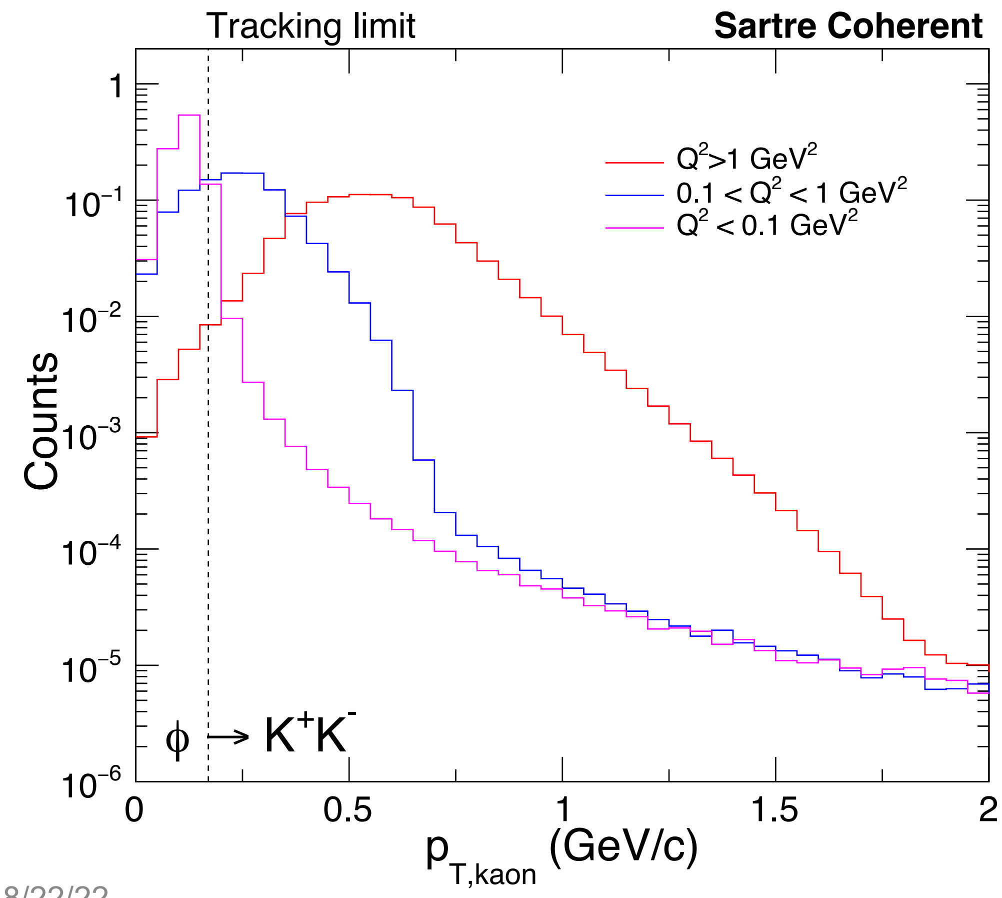
What's the impact on -*t*

- PID detectors have significant improvement on suppressing background from ρ^0
- hpDIRC seems to be sufficient, because incoherent ϕ background will dominate, except for –t < 0.02. (Go to backup to see why)
- Of course, TOF will kill this problem entirely; bottle neck then will be the first 2 challenges on page 2.



What if we go down in Q^2 ?

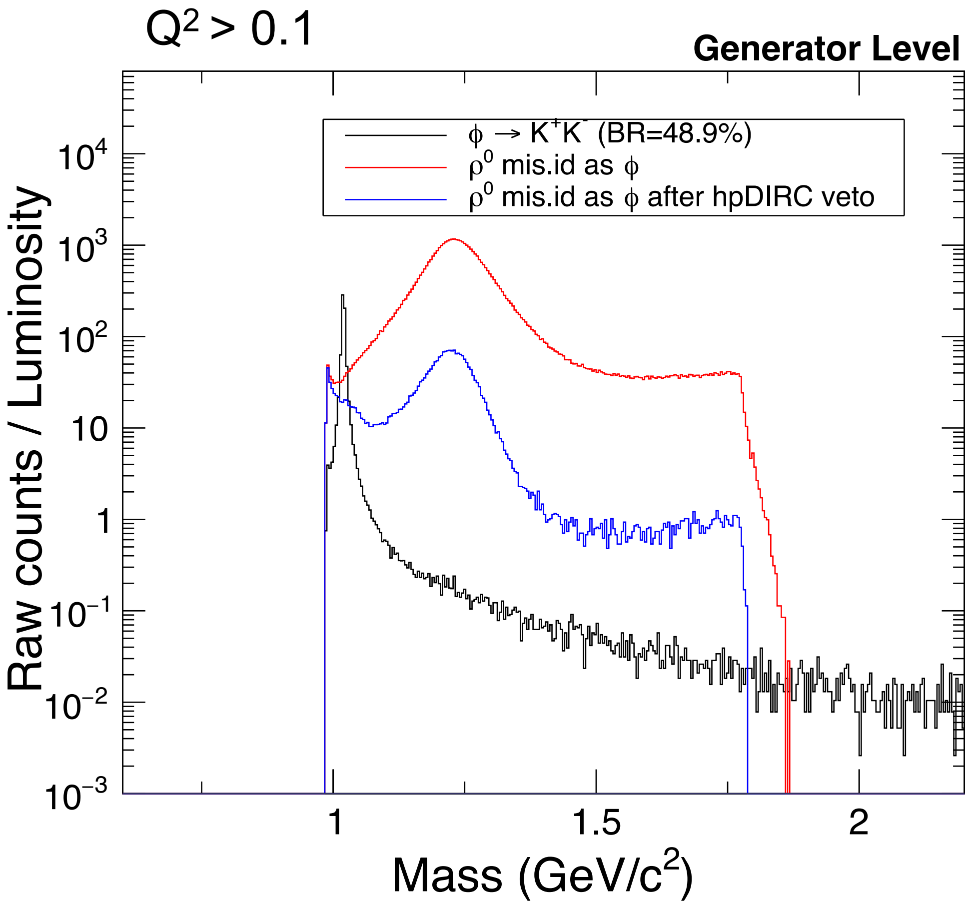
- This will get more difficult, not just background but acceptance.



- We don't need full simulation to see the issue.
- Photoproduction of ϕ of $Q^2 <$ 0.1 is extremely difficult.

What if we go down in Q^2 ?

- This will get more difficult, not just background but acceptance.



- Background to signal is > 60%.
- hpDIRC performance goes down because more pions are below 0.25 GeV threshold. B/S ~ 33%
- TOF performance goes up, almost suppressed everything.

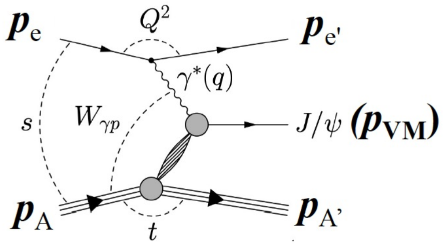
More challenges when going to small Q^2

ZT, DIS 2022

Reconstruction method of $-t$

- Method Exact (E): $-t = -(p_e - p_{e'} - p_{VM})^2 = -(p_{A'} - p_A)^2$
- Method Approximate (A) (UPCs): $-t = (\vec{p}_{T,e'} + \vec{p}_{T,VM})^2$
- Improved Method E: Method L: $-t = -(p_{A',corr} - p_A)^2$,

where $p_{A',corr}$ is constrained by exclusive reaction.



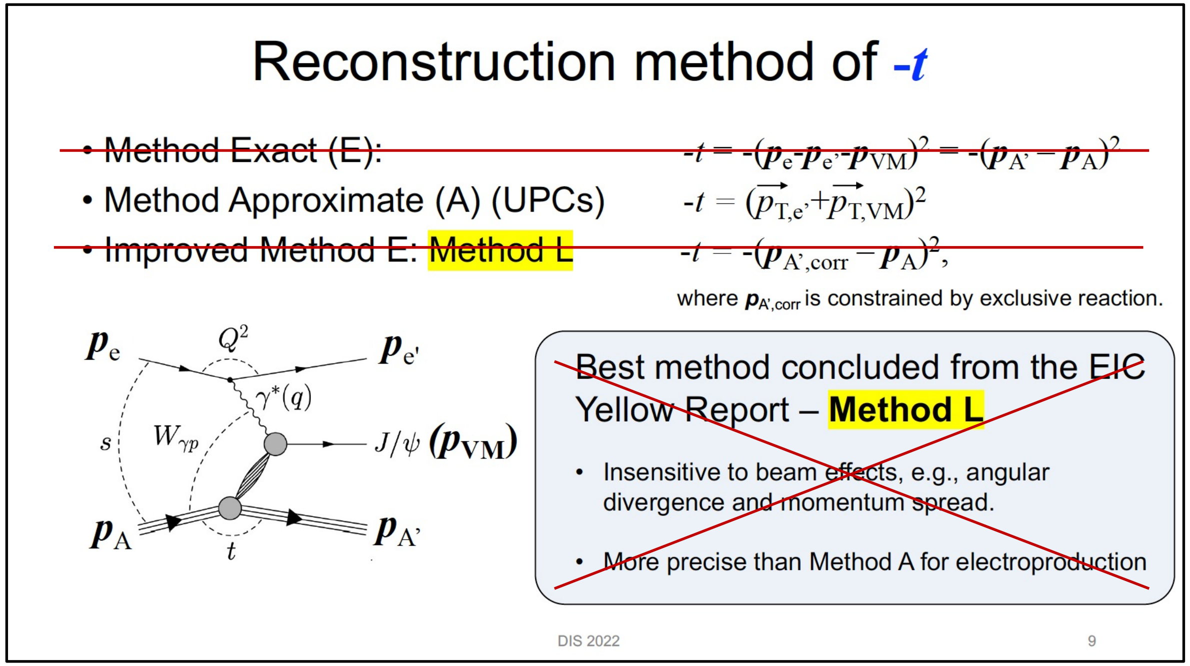
Best method concluded from the EIC Yellow Report – **Method L**

- Insensitive to beam effects, e.g., angular divergence and momentum spread.
- More precise than Method A for electroproduction

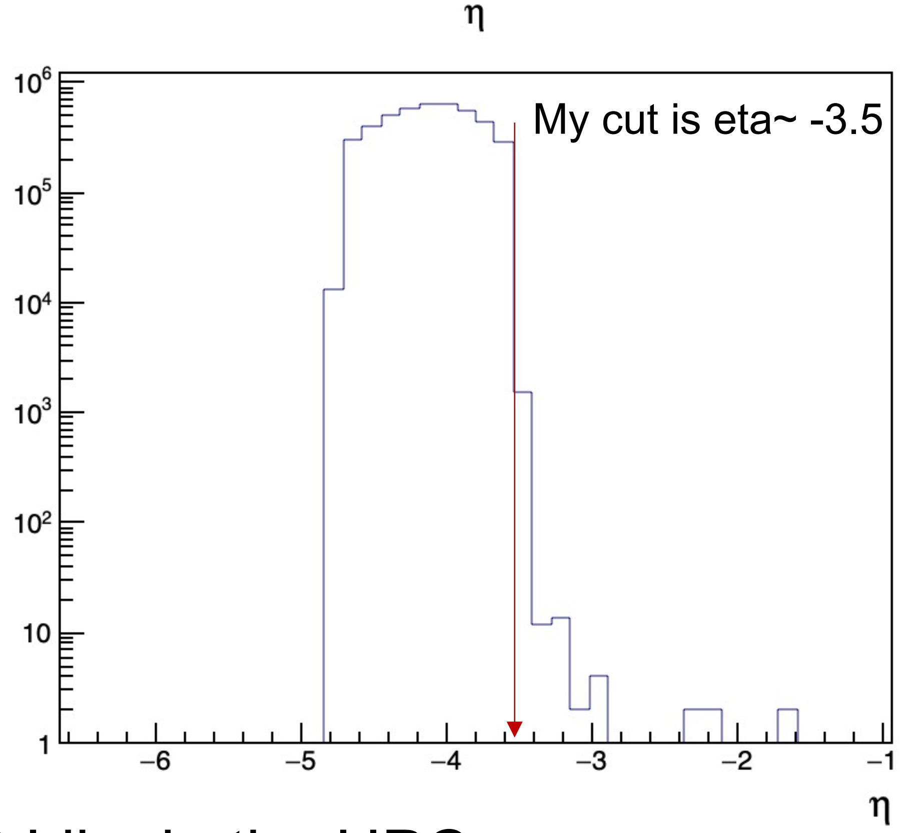
DIS 2022 9

More challenges when going to small Q^2

ZT, DIS 2022

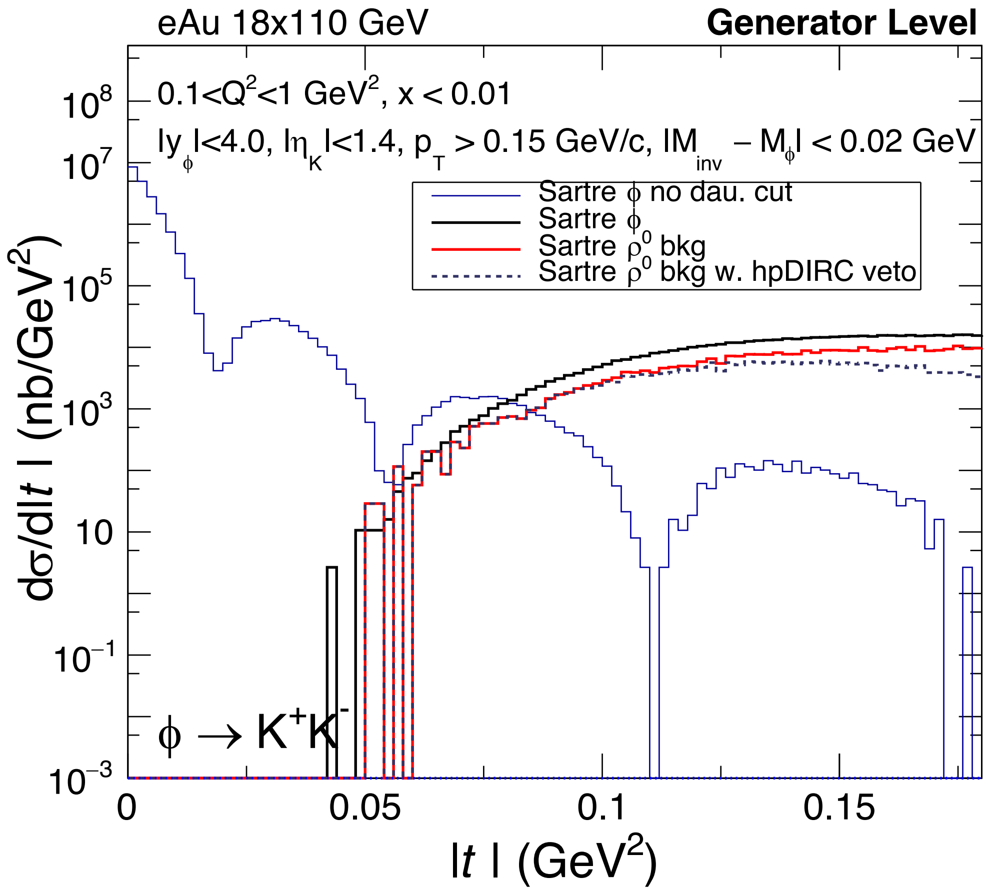


0.1 < Q^2 < 1 with 18 GeV electron,
Scattered electron is mostly not in the backward tracker.



What about Method A ? Like in the UPCs

More challenges when going to small Q^2



Maybe low Q^2 tagger can help, but then resolution might be an issue.

Method A fails terribly in this "intermediate" Q^2 range!

Summary

- Impact study on diffractive ϕ from ρ^0 background:
  - Electroproduction $Q^2 > 1$, Barrel PID is needed; threshold @ 0.25 GeV seems ok
  - What about $1 > Q^2 > 0.1$? More issues with |t| reconstruction and acceptance.
  - $Q^2 << 1$ photoproduction is extremely difficult, but if only w. inner layers of tracking? (STAR @RHIC can do this easier in UPC)

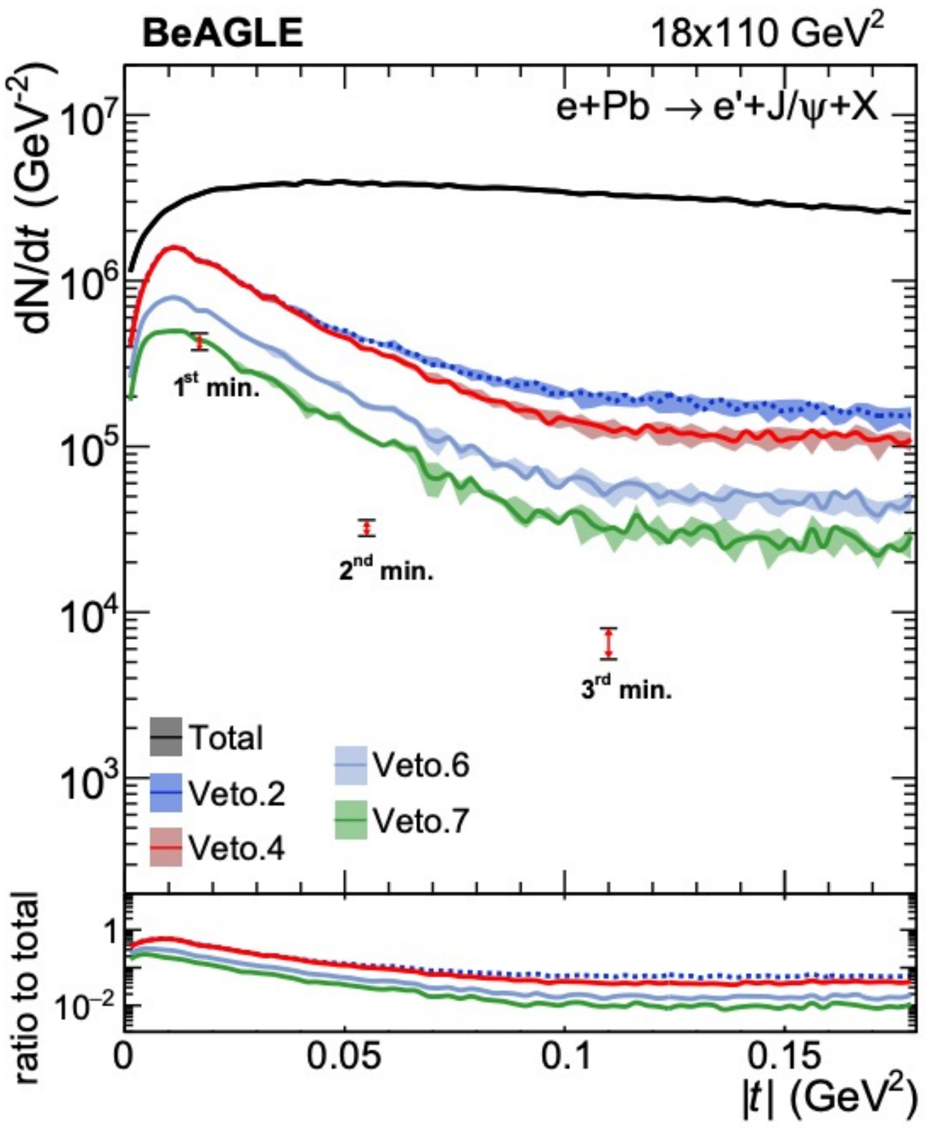
- The improvement on qualitative level can be already seen by having low momentum PID capability.
- However, this study is not intended to replace studies based on full simulations; will need to be revisited;
  - For example, hpDRIC efficiency. Important for the veto mode.

- Question: is it necessary to have PID below 0.25 GeV/c in the barrel?
- Answer: definite answer needs full sim. and more studies.

BACKUP

Incoherent veto

- 1^{ST} min. in the figure, is the first minimum position from VM's coherent distribution (when no saturation, all VMs are predicted to be the same);
- the FF detectors can veto incoherent background, best scenario indicated by the green curve
- Below the 1^{st} min., incoherent contribution is very insignificant comparing to coherent.



https://arxiv.org/pdf/2108.01694.pdf

https://indico.bnl.gov/event/16314/contributions/65336/attachments/42008/70364/20220707-hpDIRC-threshold-mode-schwiening.pdf

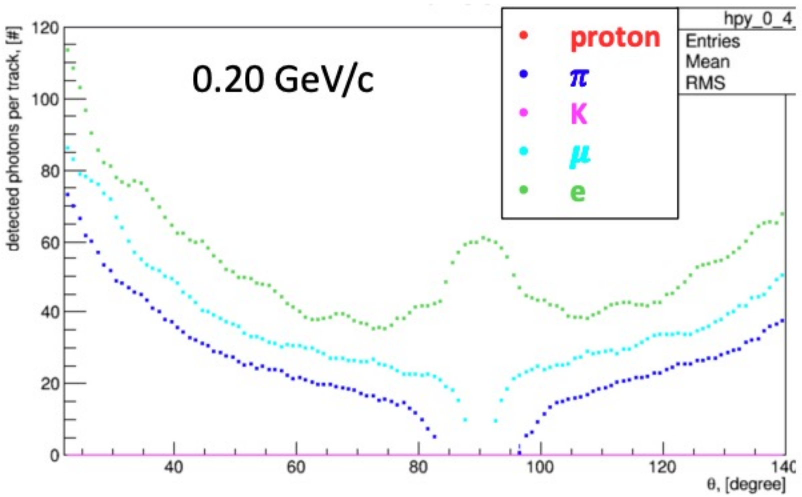
HPDIRC VETO MODE

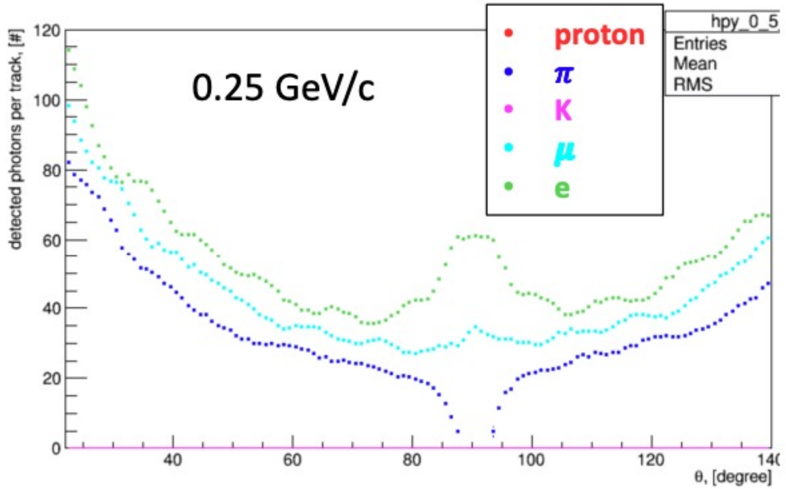
Useful π/K threshold mode contribution (with gap) possible as low as 0.2 GeV/c

pion N_{pe}>10 for polar angles <80° and >100°

π/K coverage gap at 0.25 GeV/c: pseudorapidity –0.15 … +0.15

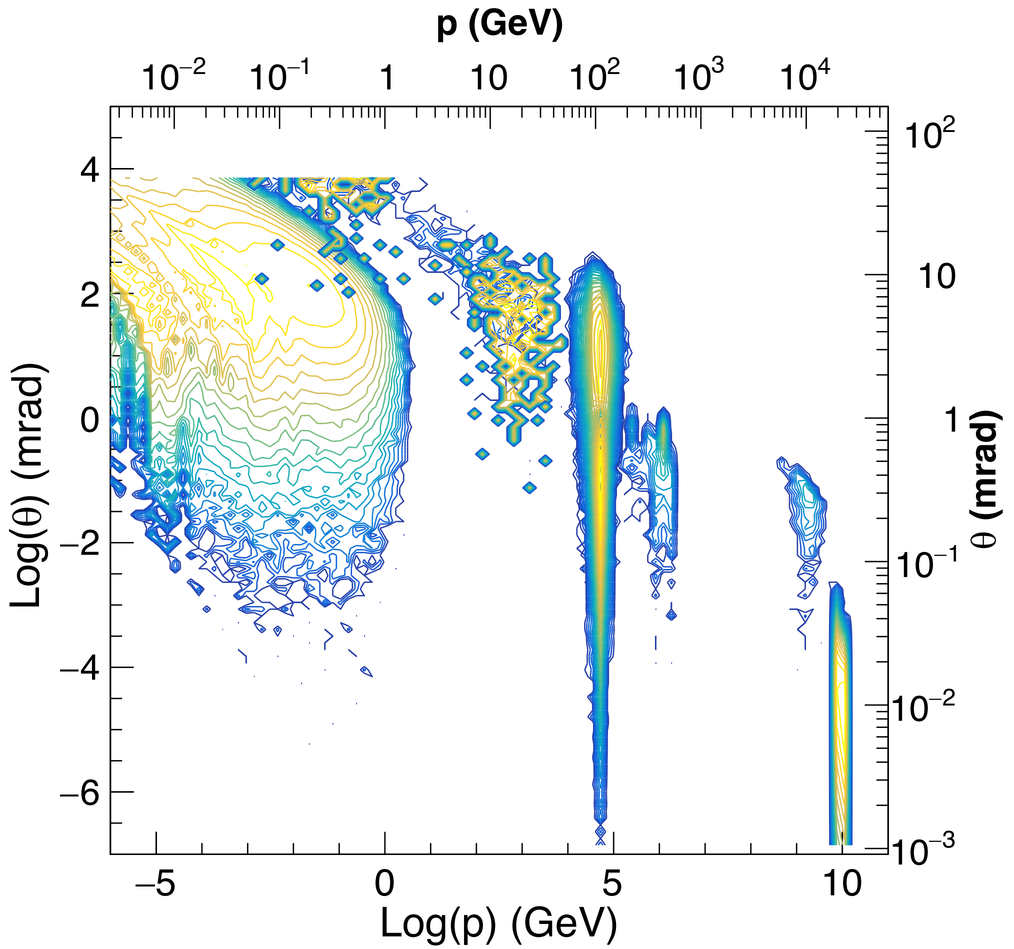
Please remember that this simulation was performed without a magnetic field, all tracks can reach the DIRC radius





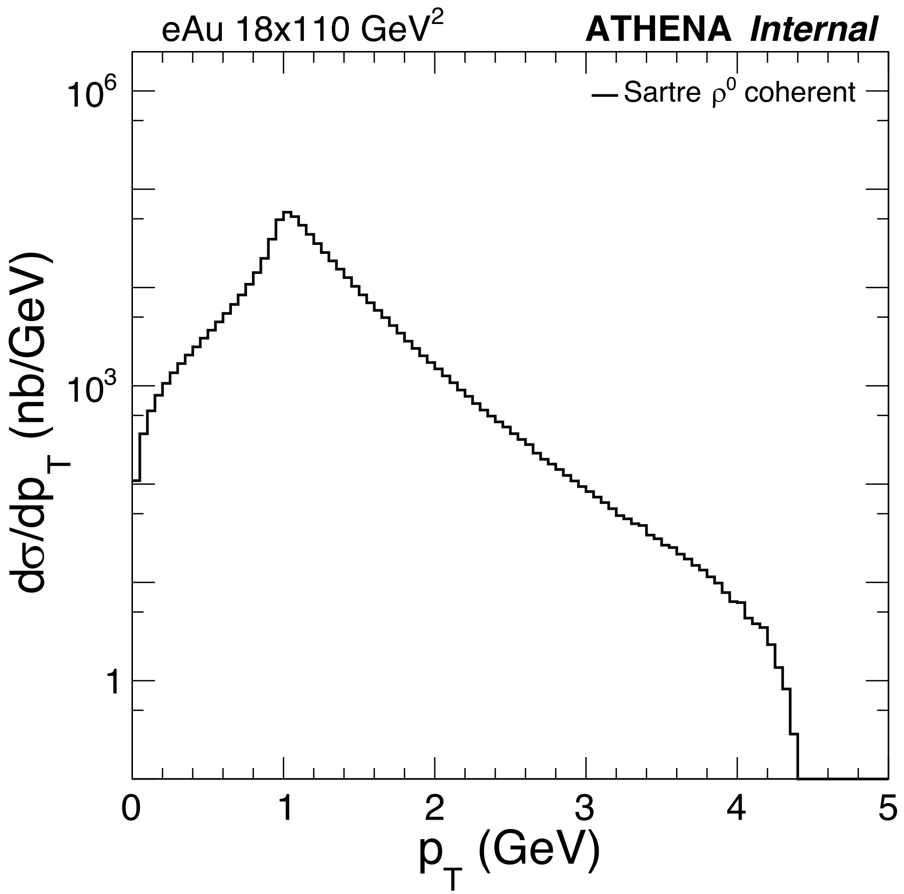
ϕ meson

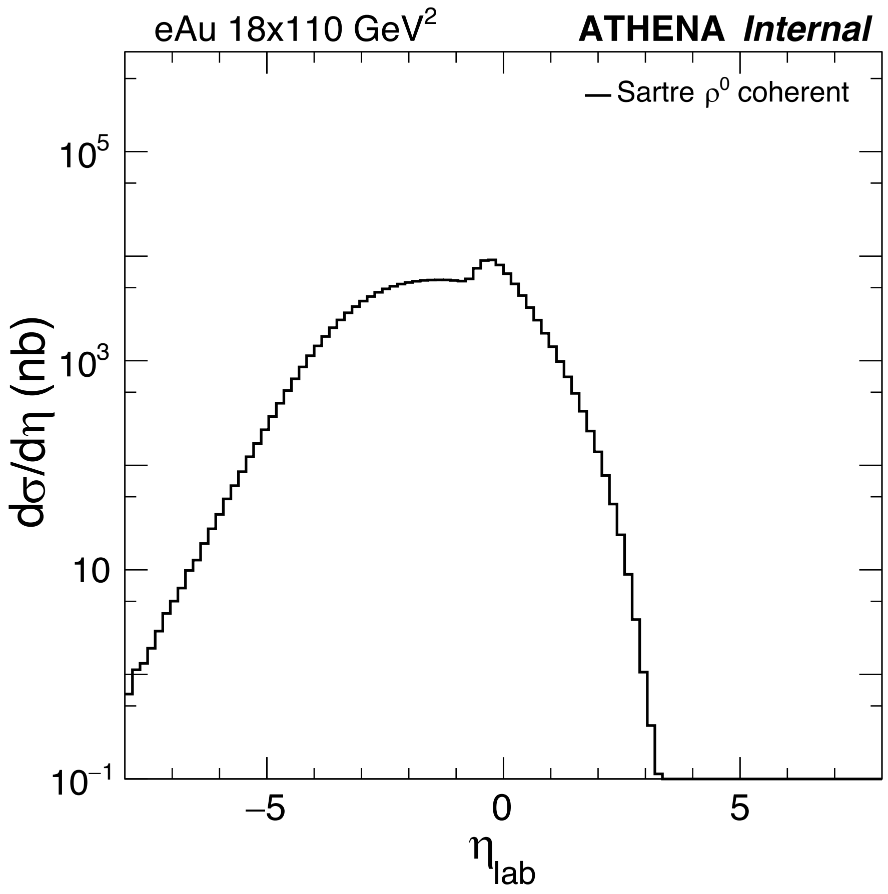
- Breakup particles BeAGLE (incoherent)
- Separate them into protons, neutrons, photons, pions, kaons, electrons, muons, nuclei.



Sartre (coherent)

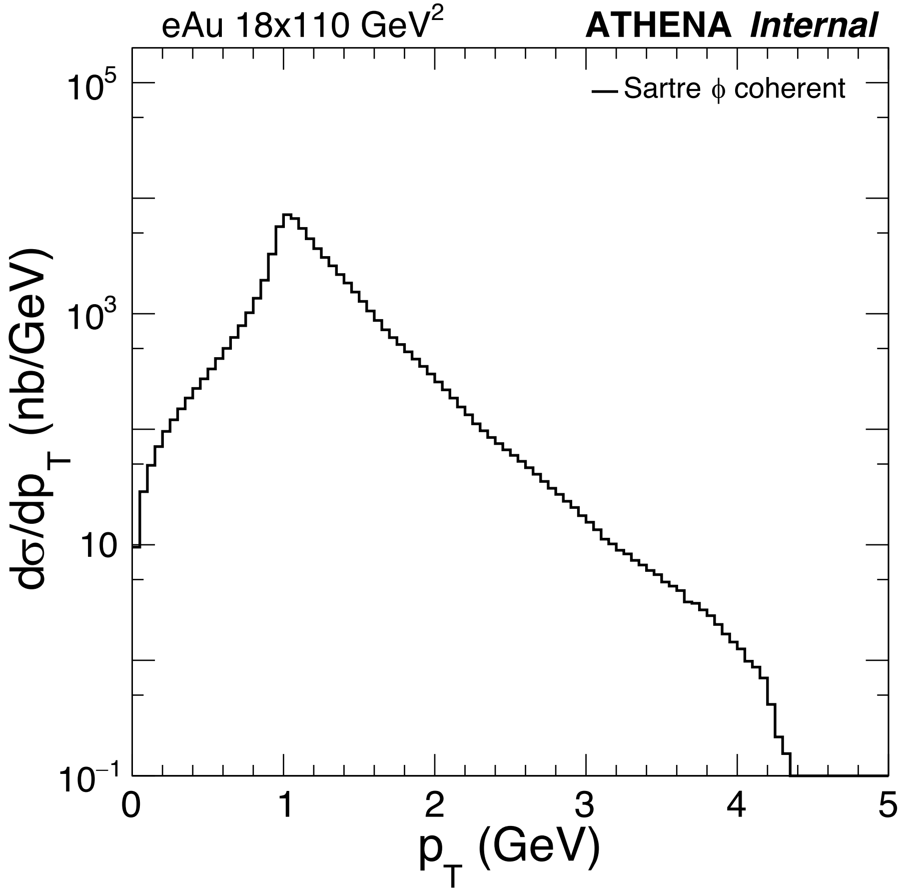
ρ^0 meson

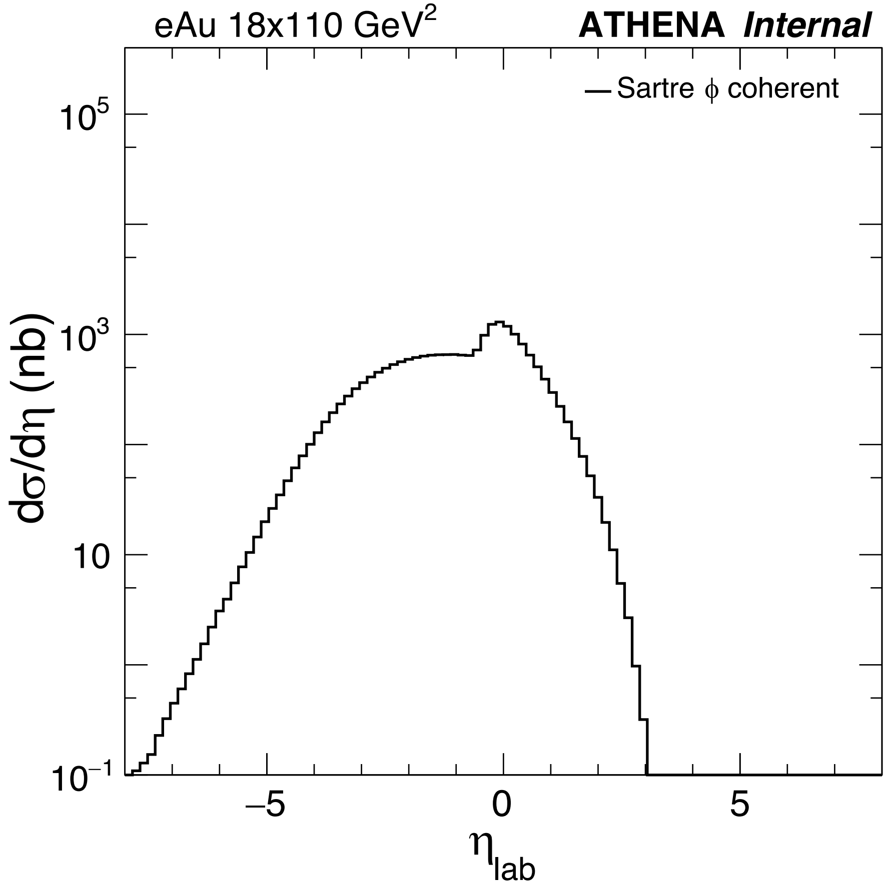




Sartre (coherent)

ϕ meson





ρ^0 meson decay to pions hitting TOF