Towards Reconstructing Dilepton Flow in Au+Au Collisions at Low Energies with HADES

RICH Time Calibration in Feb24 Data

Sukyung Kim (BUW) @ FAIRness 2024 | 2024-09-25

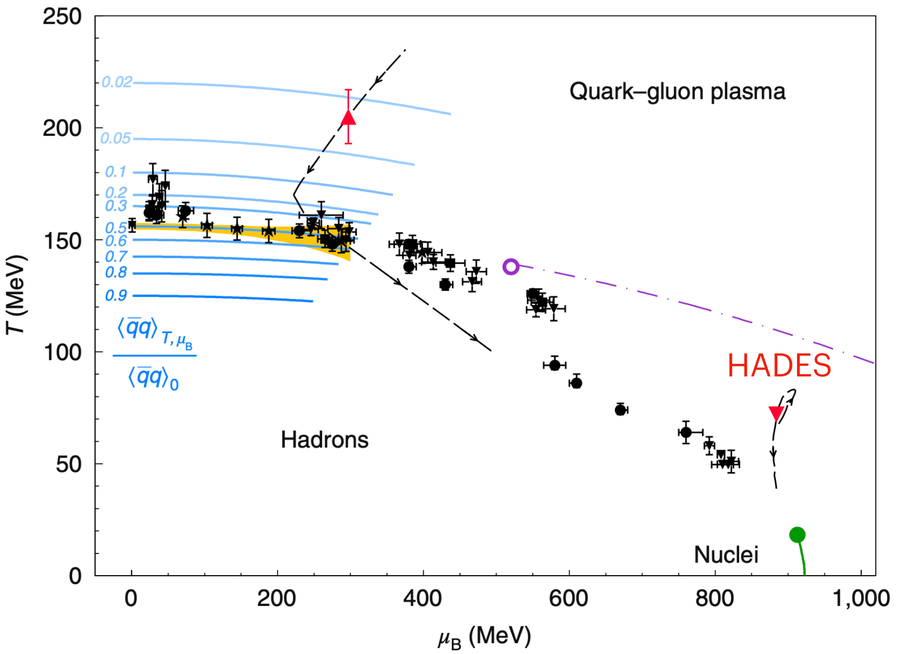
Motivation

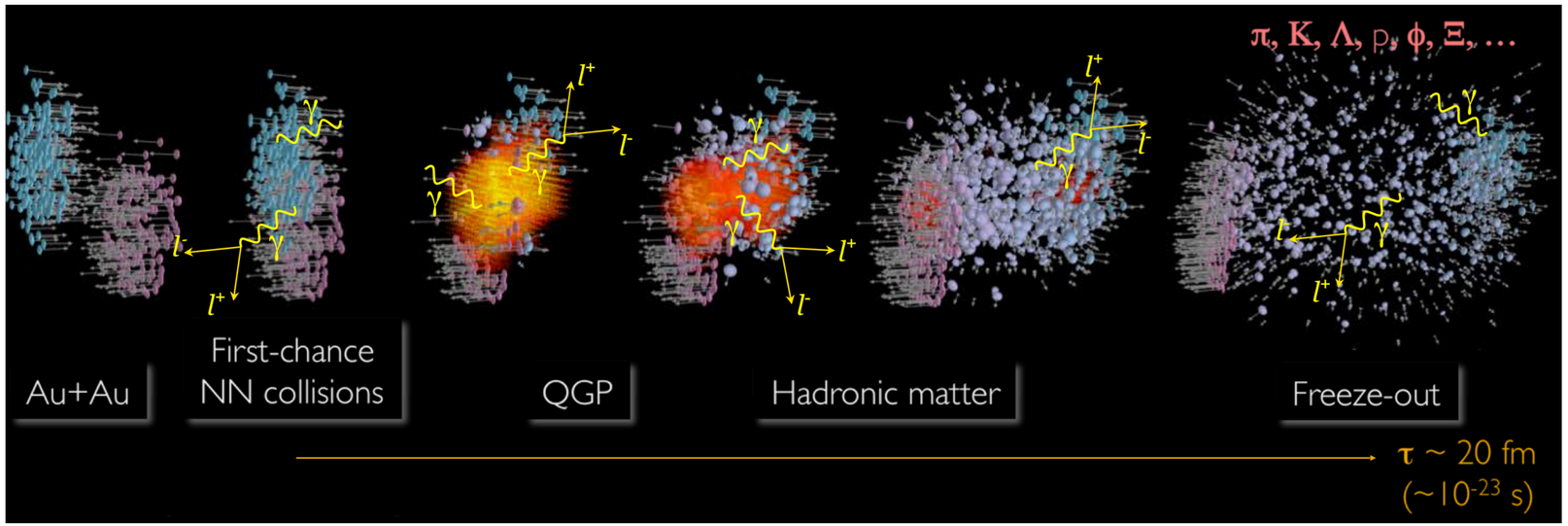
Why heavy-ion collisions at HADES energies ($\sqrt{s_{NN}} \approx 2$ GeV)?

- Binary neutron star merger resembles non-central collision of two Au nuclei in terms of densities and temperatures.

"Anisotropic flow" as a measurement of Equation-of-State ?

- Anisotropic flow is suggested to be sensitive to the earlier stages of the collision.
- Dileptons are emitted during the entire evolution of a fireball, and undisturbed by strong interaction.

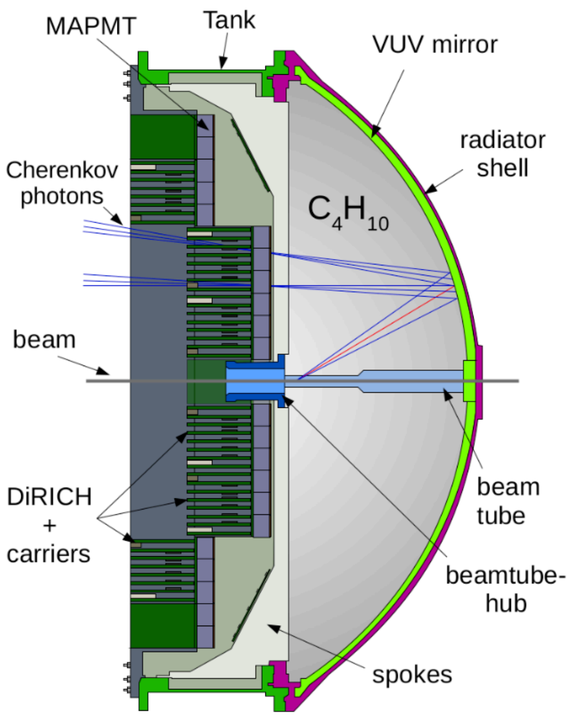


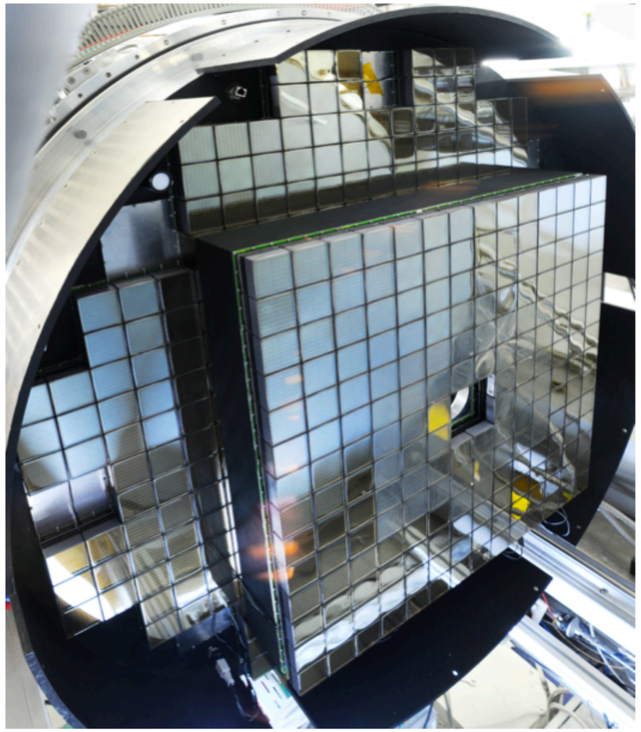


Adapted from Tetyana Galatyuk

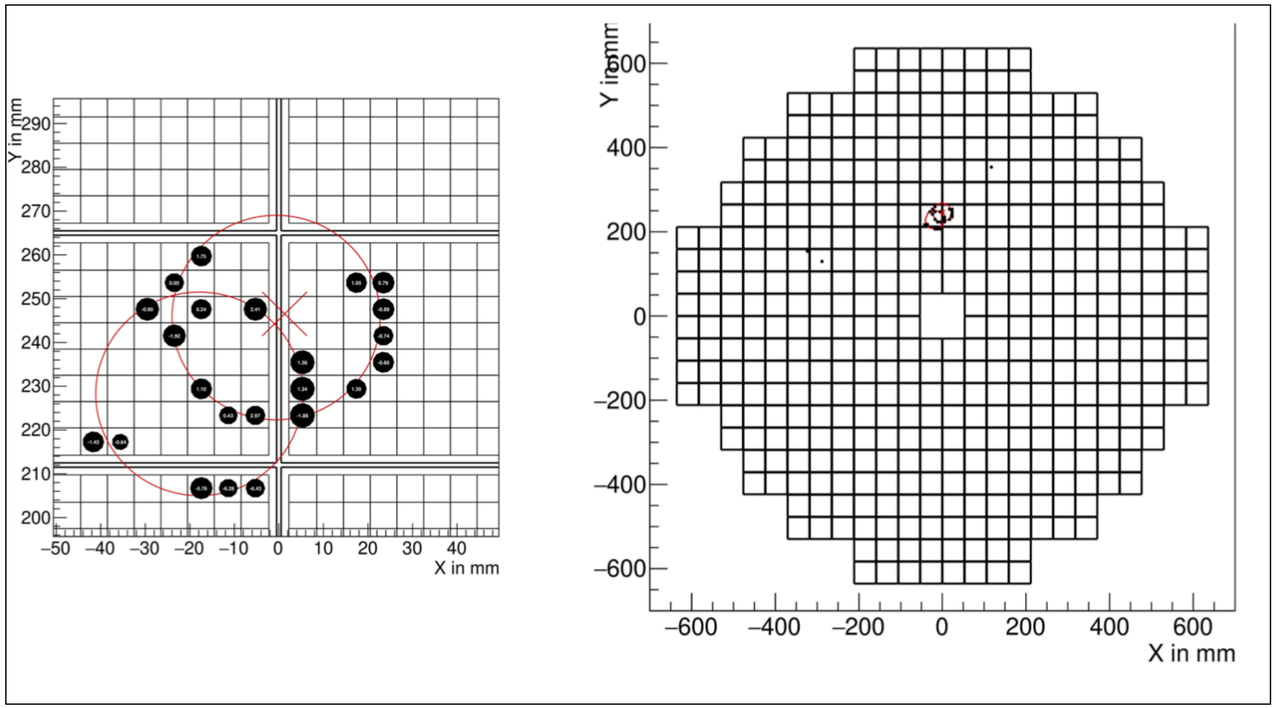
The HADES RICH detector as an electron identificator

J-H. Otto @ thesis 2022





Jörg Förtsch @ HADES CM Sep.2019



- RICH (Ring Imaging Cherenkov Detector) with 428 64-channel MAPMTs (Multi-Anode Photo Multiplier Tube)
  - Measures the electron/positron signal in a form of a ring
  - Hadron-blind up to ~ 3 GeV/c
  - Noise hits form ‘fake’ rings may be matched to any track

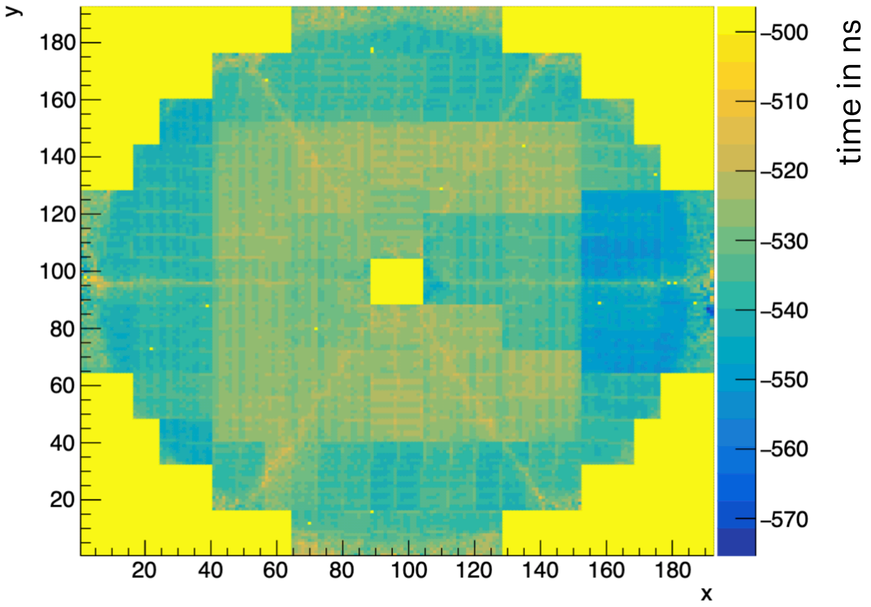
Channel dependent RICH time cut

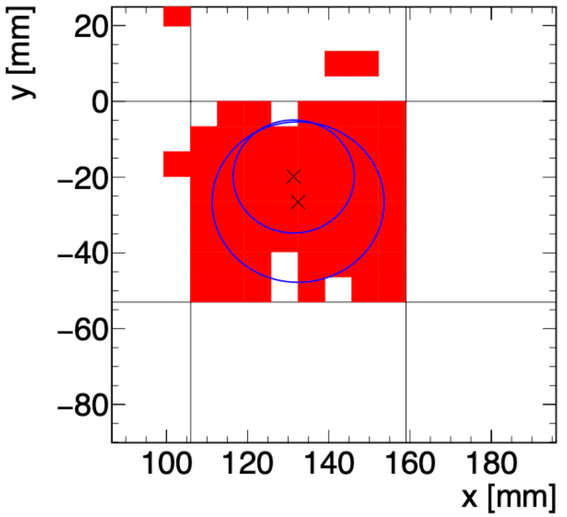
- Get rid of noise hits that contribute to “fake” rings reducing the purity
- Channel individual time cut needed

Motivation for **very narrow** time cut

- In AuAu collisions at this low energy in particular, pions with low momenta are back-scattered and hit PMTs directly, lightening up the whole PMT (blob-like structure)
  - “Fake rings” are created and matched to non-electron tracks
  - Arrive ~ 3 ns before the Cherenkov signals

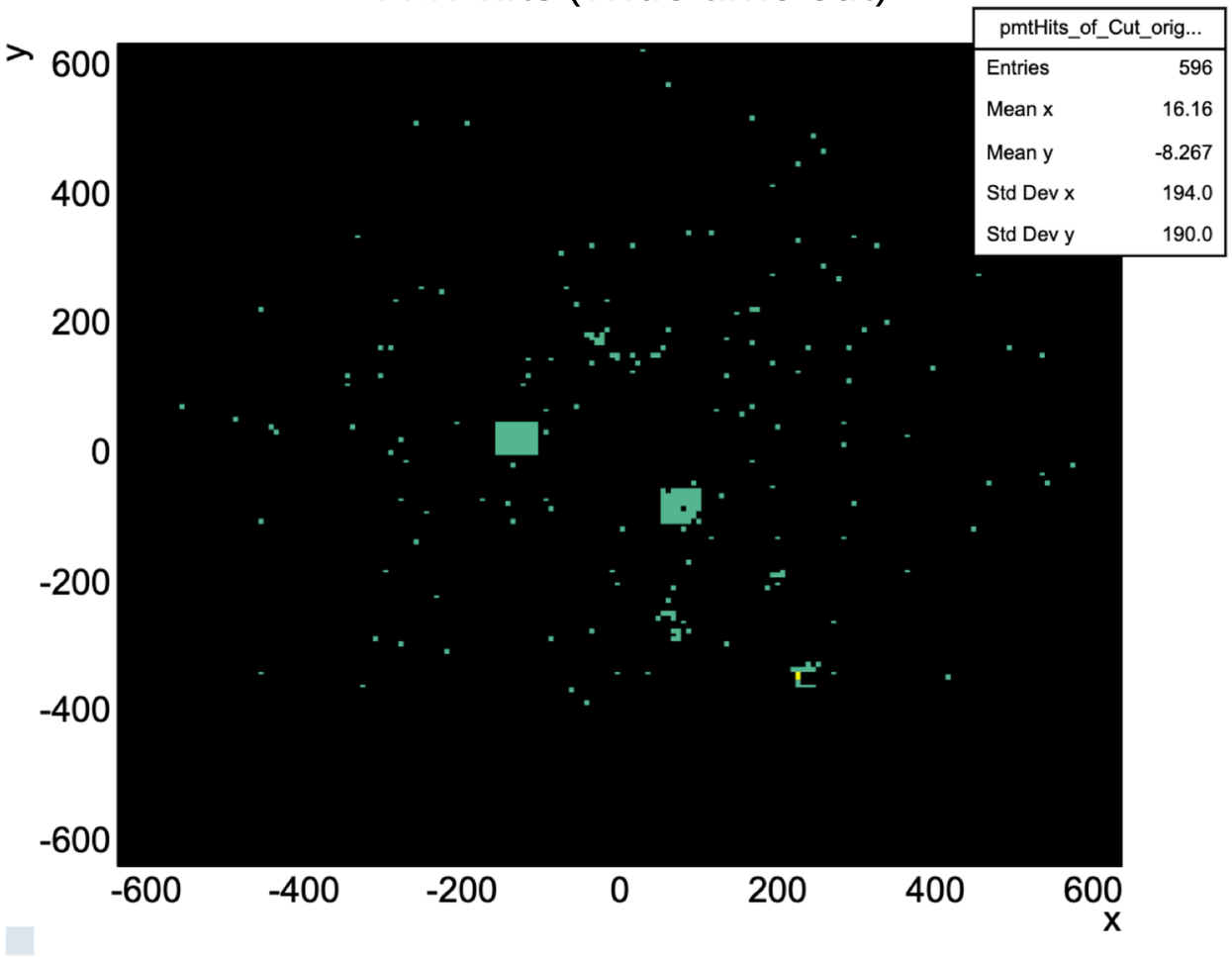
Average hit arrival time



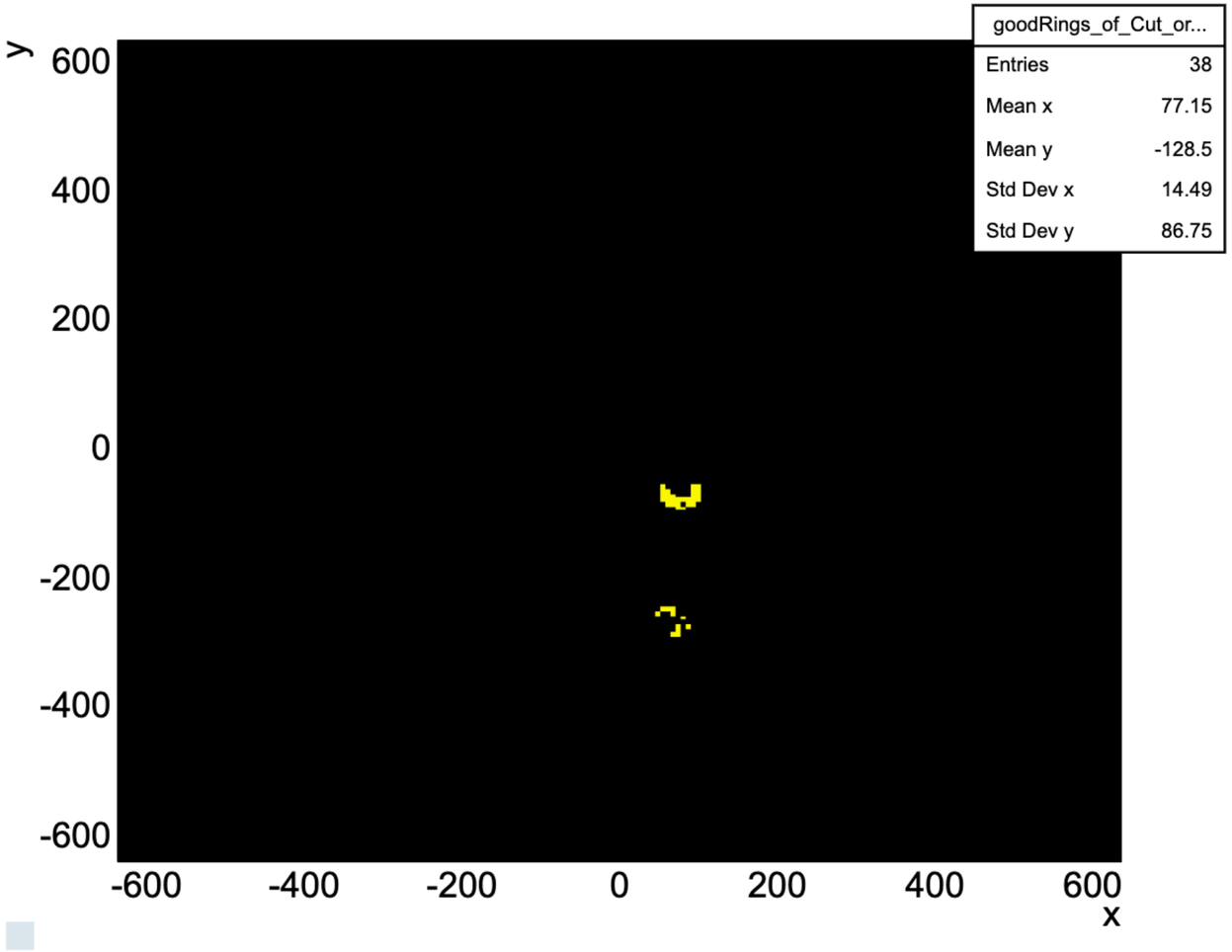


PMT hits in RICH plane (Au+Au @ 800 A MeV)

PMT hits (Wide time cut)

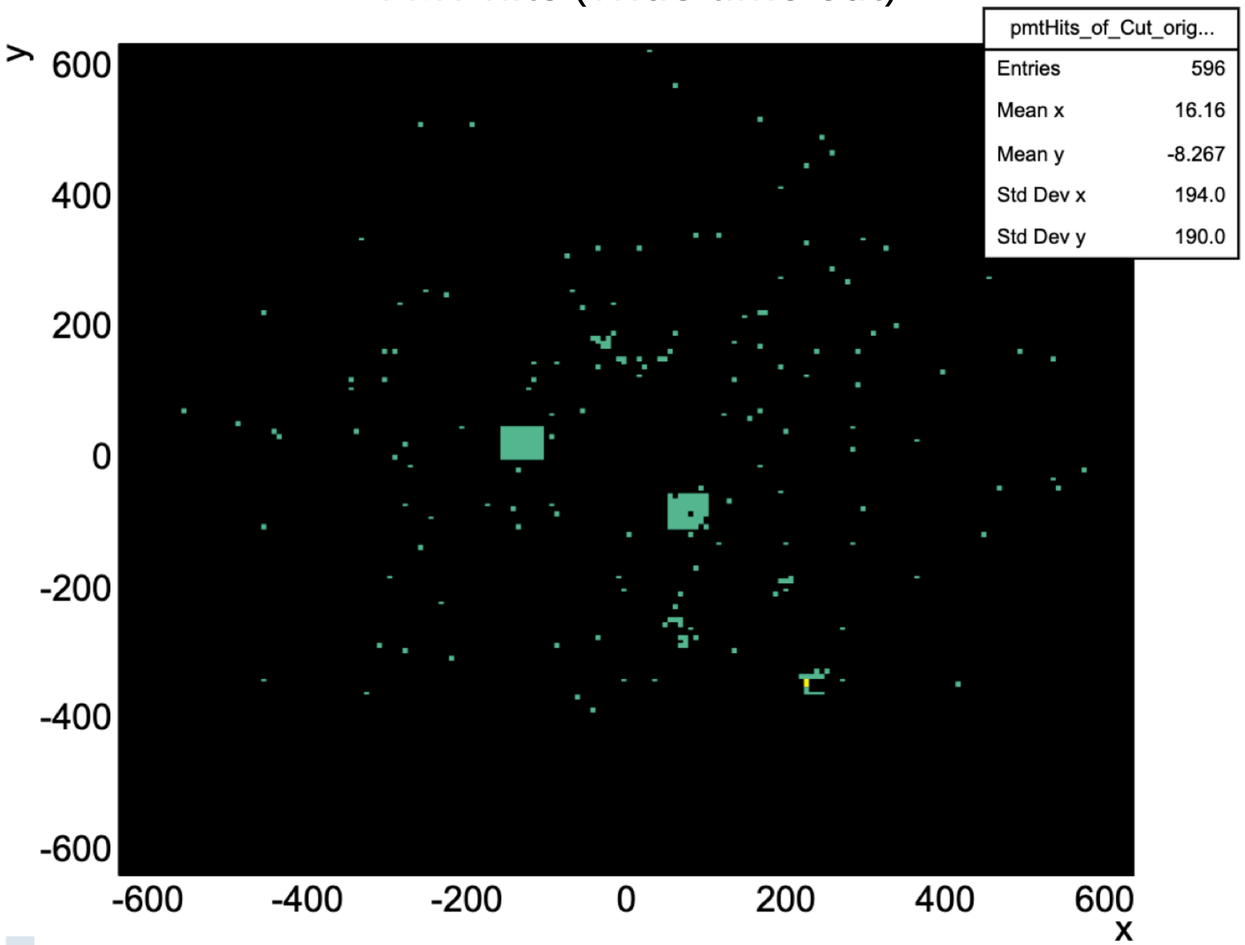


Rings Reconstructed : 2

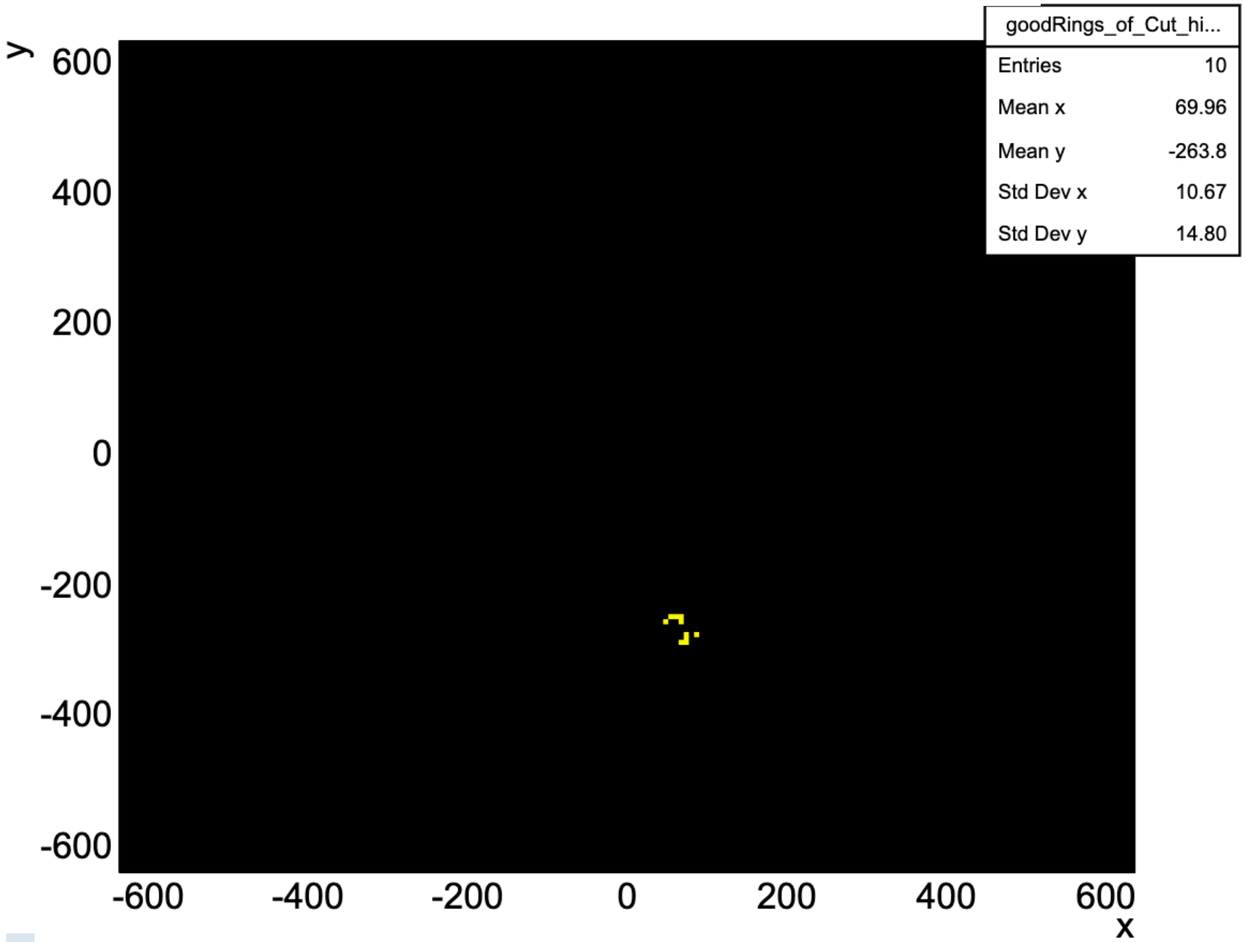


PMT hits in RICH plane (Au+Au @ 800 A MeV)

PMT hits (Wide time cut)



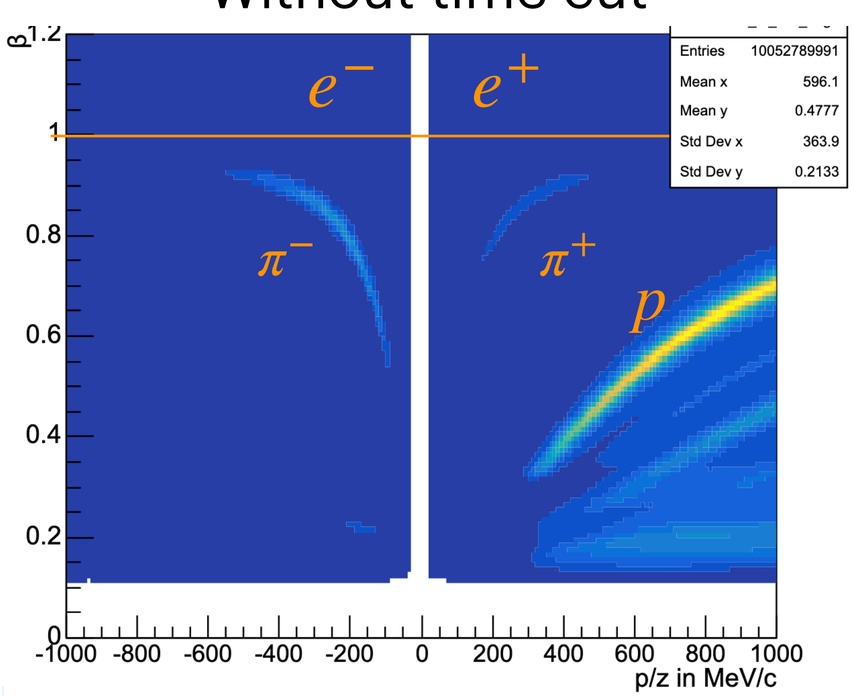
1 Ring left after applying narrow time cut



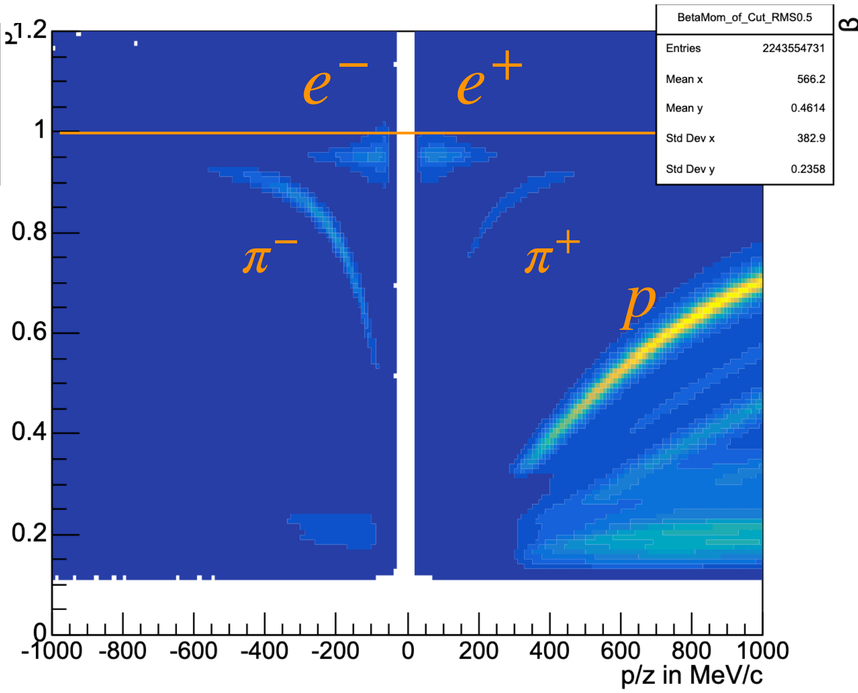
➡ Channel individual sharp time cut needed

Overview of RICH time calibration for Au+Au Feb 24

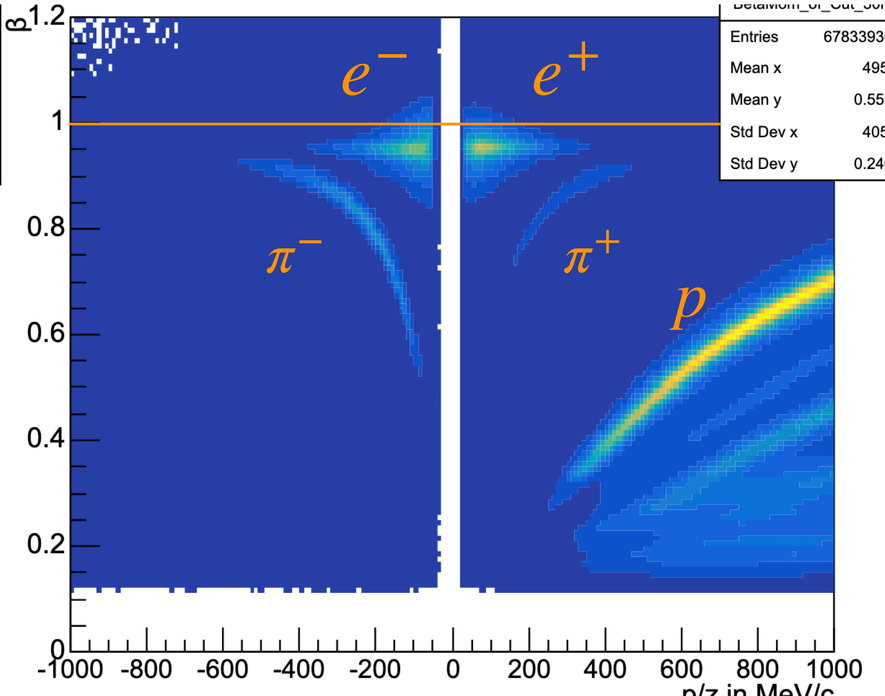
Without time cut



80 ns time cut (current standard)



30 ns time cut

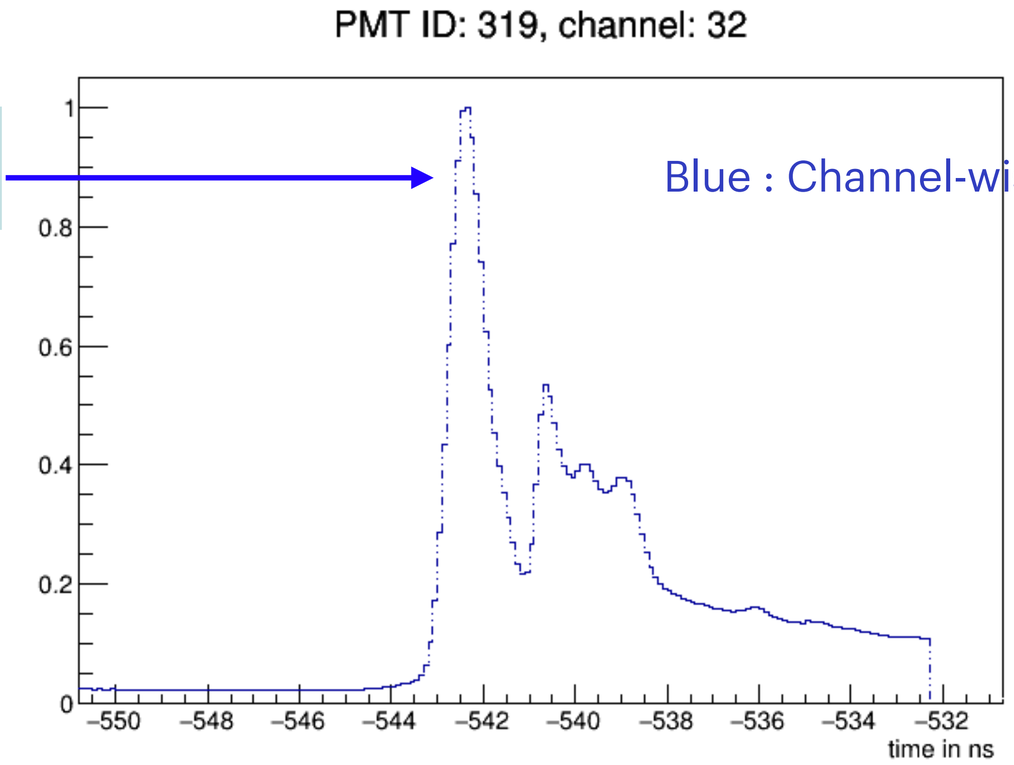


- In recent AuAu data: “Wide" time cuts (average 80 ns) applied
- Narrowing the time cut range from 80 -> 30 ns already removes hadrons
- Next step : going even narrower (3 ns)

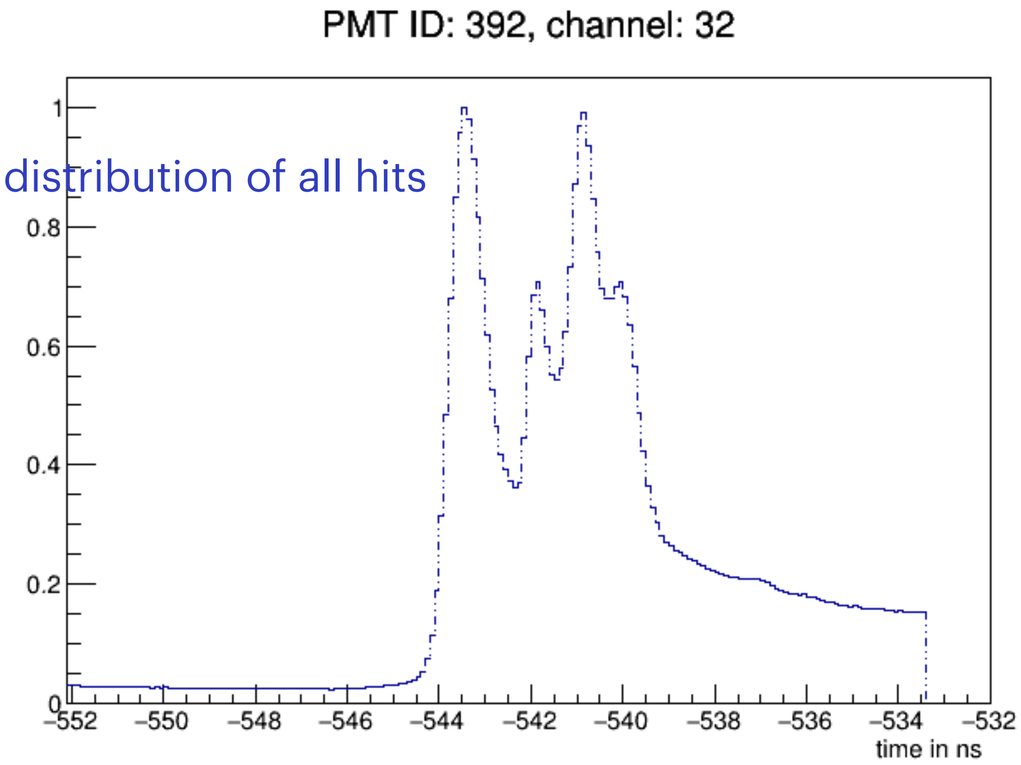
“Narrower” time cuts remove back-scattered pions

plots scaled by the maximum value

Back-scattered pions



Blue : Channel-wise time distribution of all hits

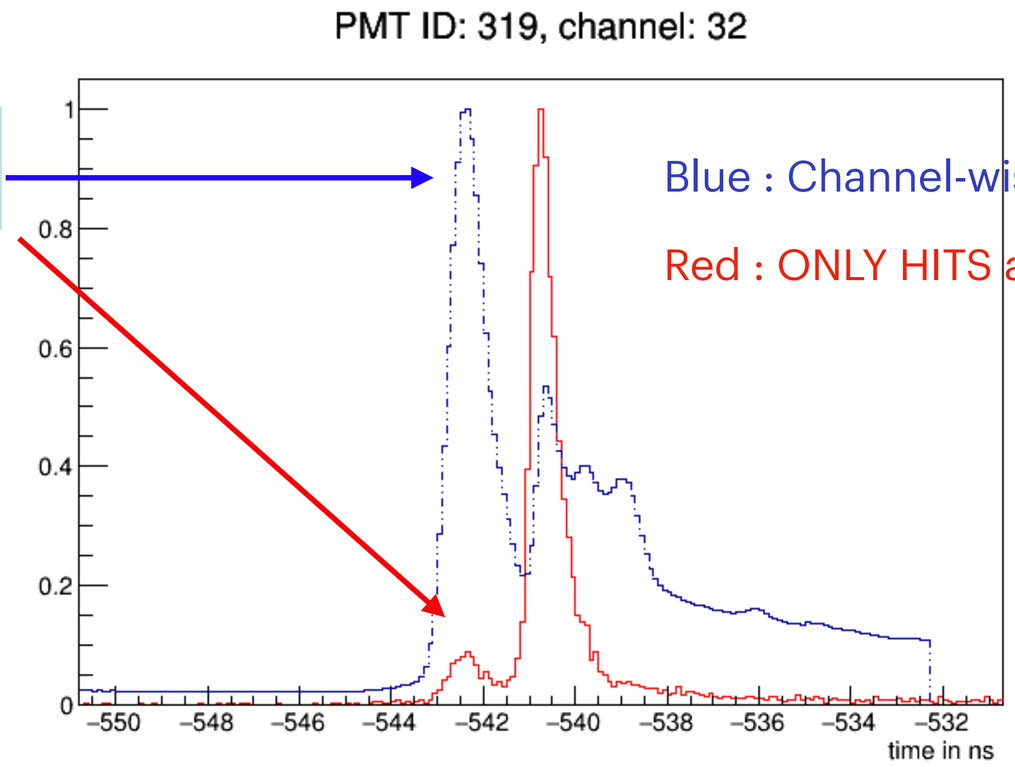


“Narrower” time cuts remove back-scattered pions

- Red : ONLY HITS assigned to “electron rings”

plots scaled by the maximum value

Back-scattered pions



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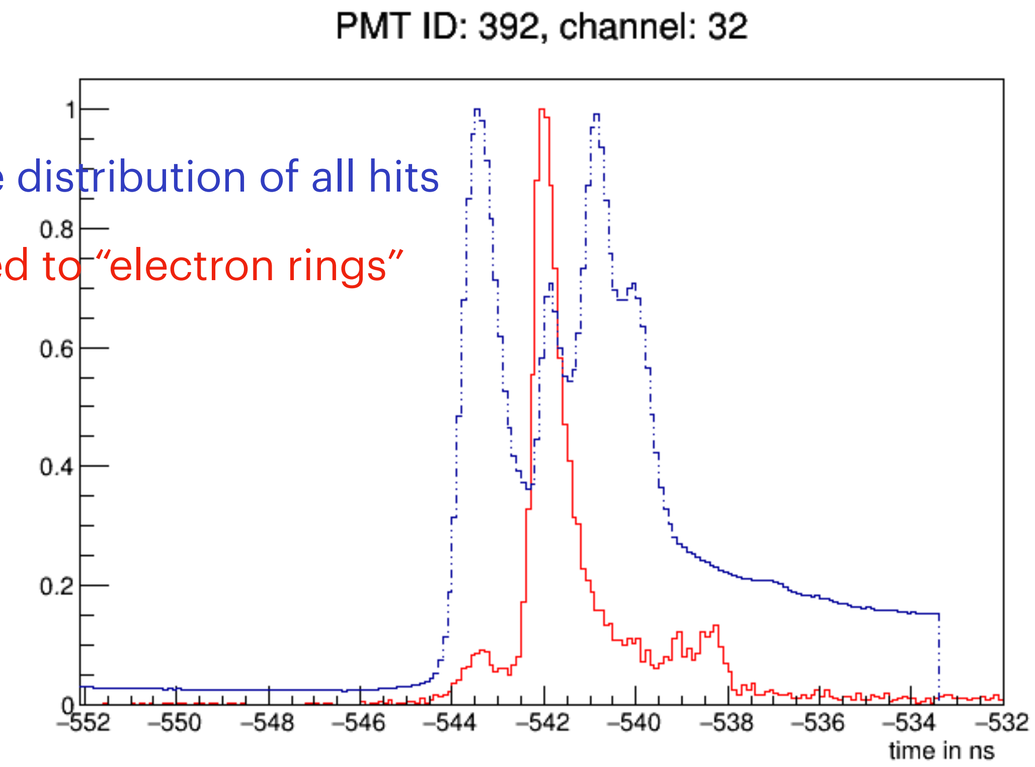
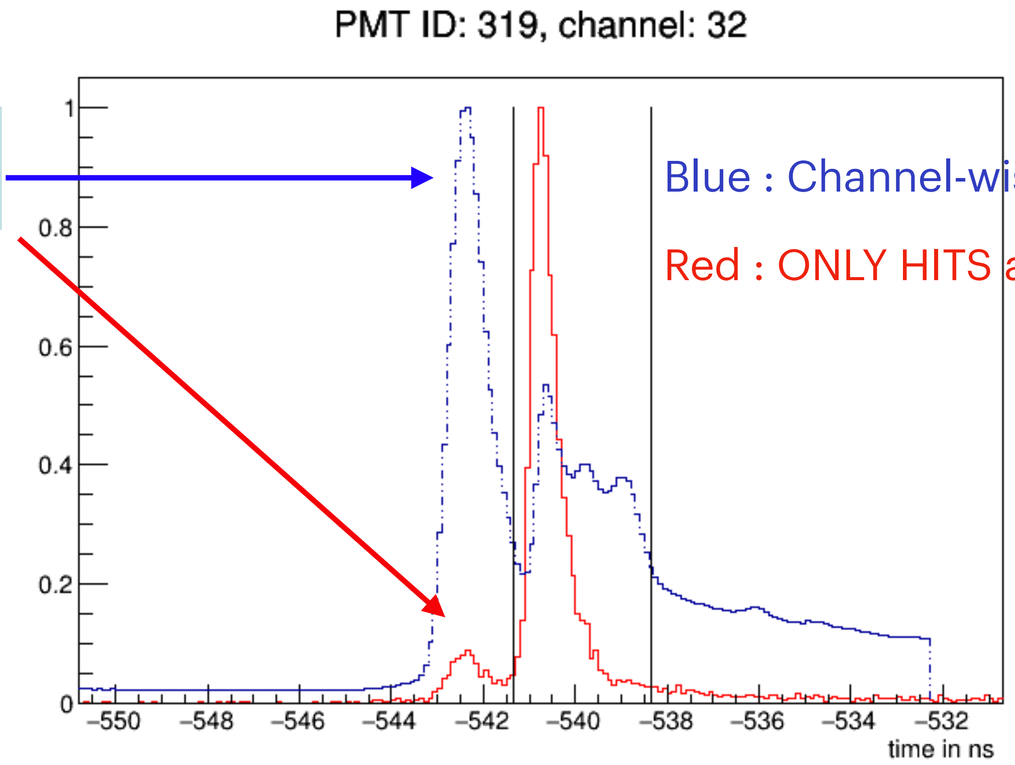


“Narrower” time cuts remove back-scattered pions

- Red : ONLY HITS assigned to “electron rings”
- Time window: (black vertical lines)
  - start = 10 % of the red peak
  - end = start + 3 ns (or 6 ns if there is another bump after the major peak)
- No time cut derived / applied if channel has < 350 hits (total 2770 channels)

plots scaled by the maximum value

Back-scattered pions



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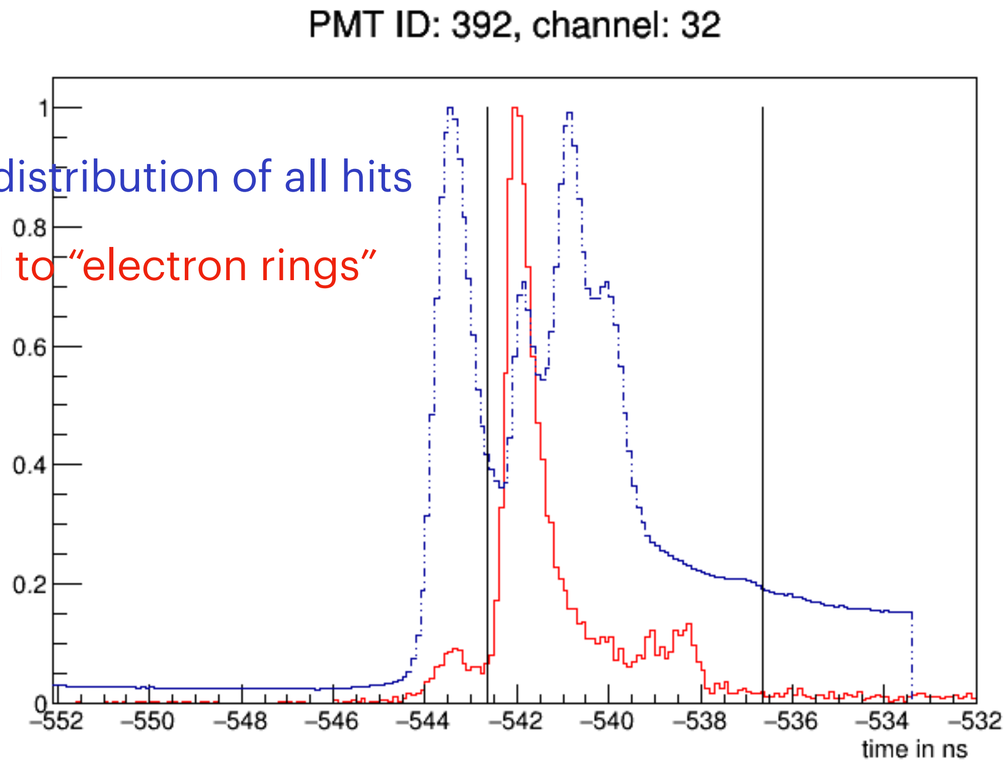
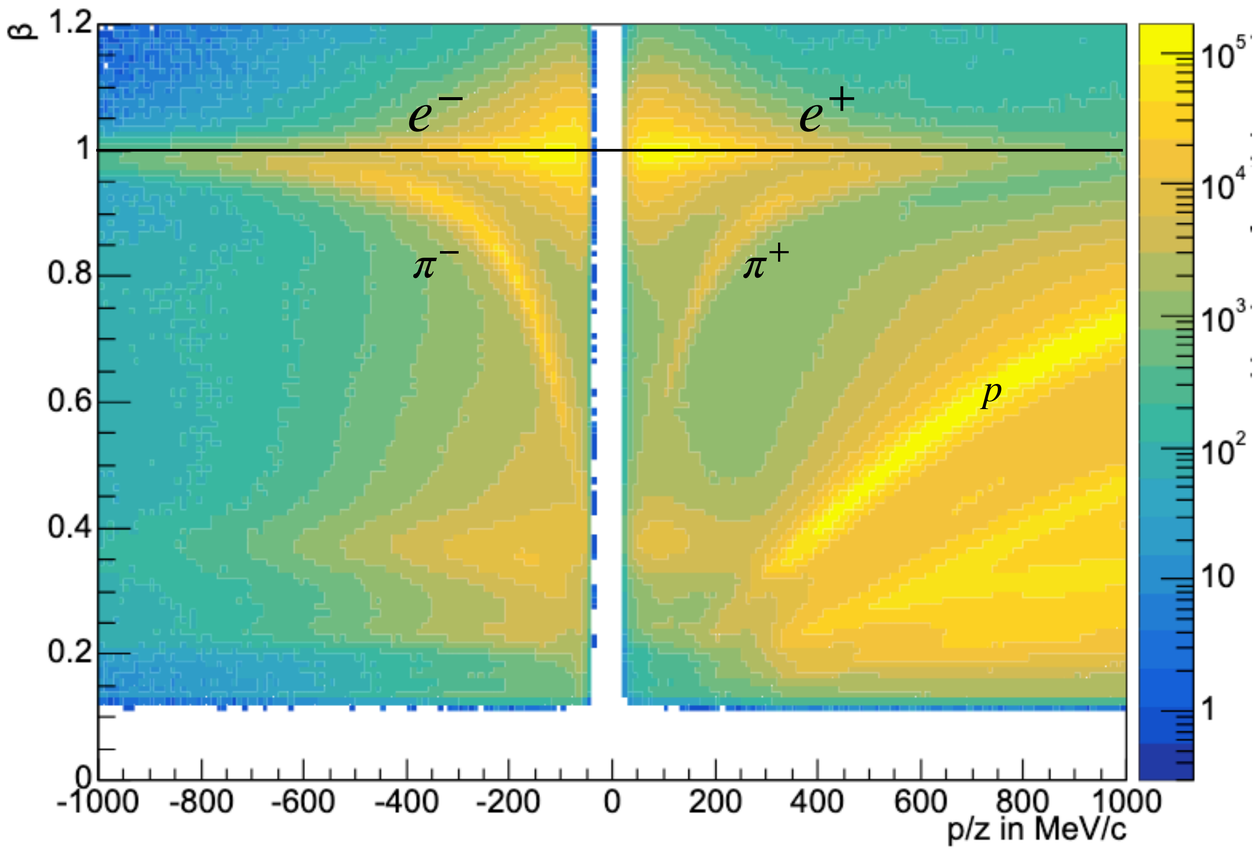
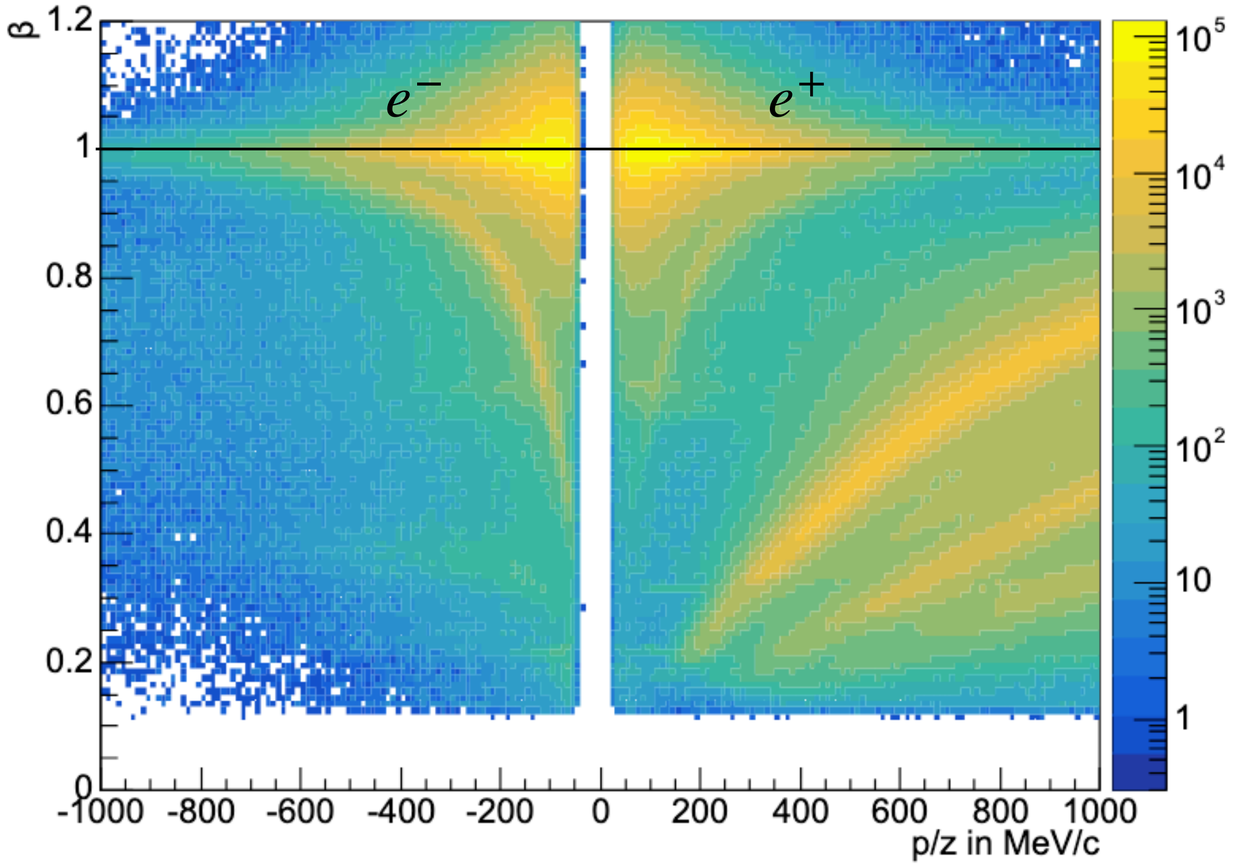


Beta-Momentum of particle candidates matched to RICH rings

Wide Time Cut



Narrow Time Cut



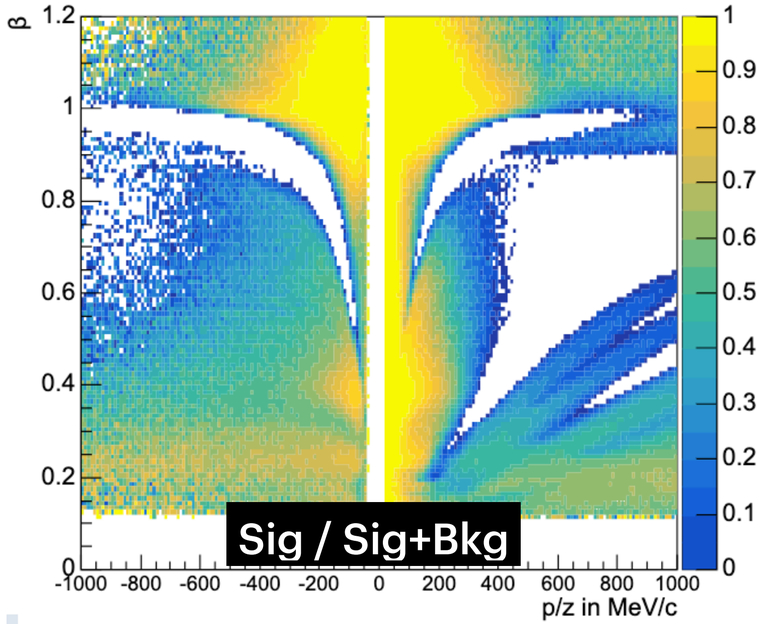
Sig + Bkg

Agenda: take Sig to Noise ratio for each and take divide one another

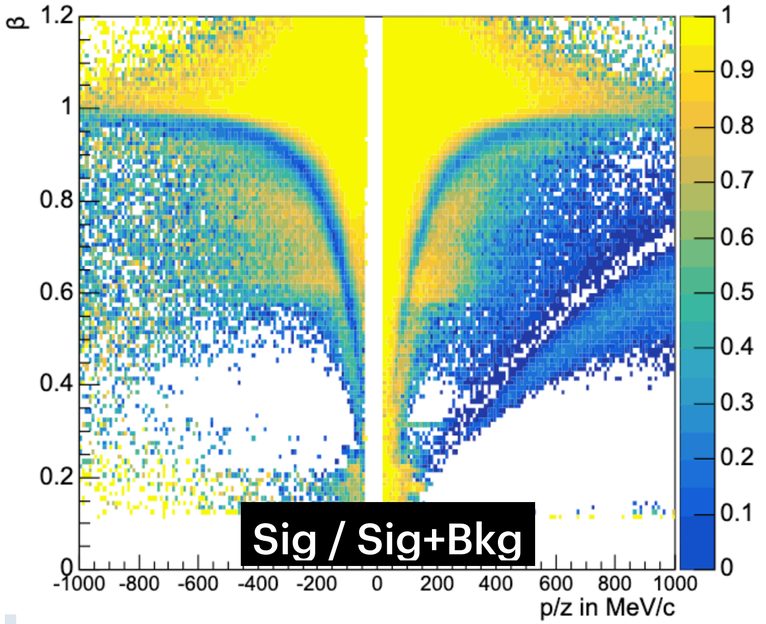
Clear improvement in electron S/B ratio in Beta-Mom plot with narrow time cuts

Background estimation:
Event-Mixing
(Rings and Tracks)

Wide Time Cut



Narrow Time Cut



Clear improvement in electron S/B ratio in Beta-Mom plot with narrow time cuts

Background estimation:
Event-Mixing
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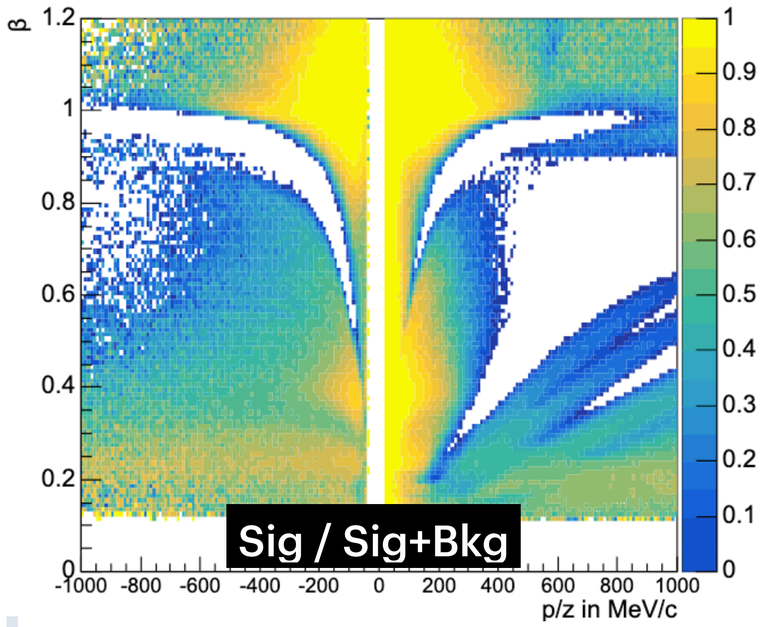
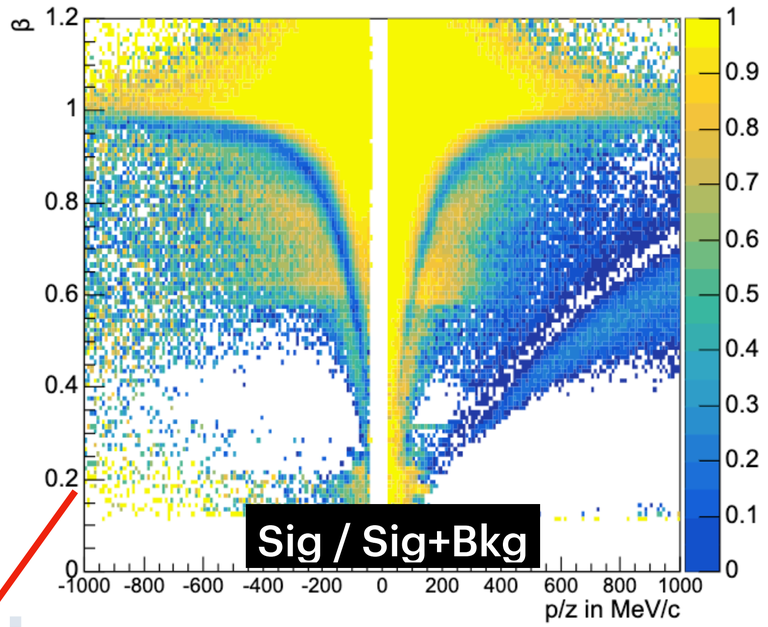
- In the ratio: S / S+B plot, yellow region represents suppressed background

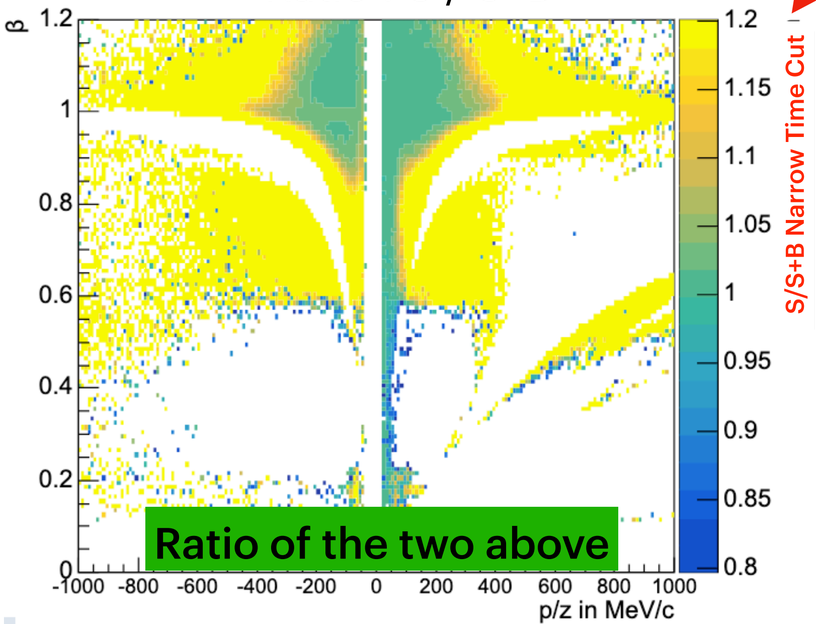
Wide Time Cut



Narrow Time Cut



Ratio : S / S+B



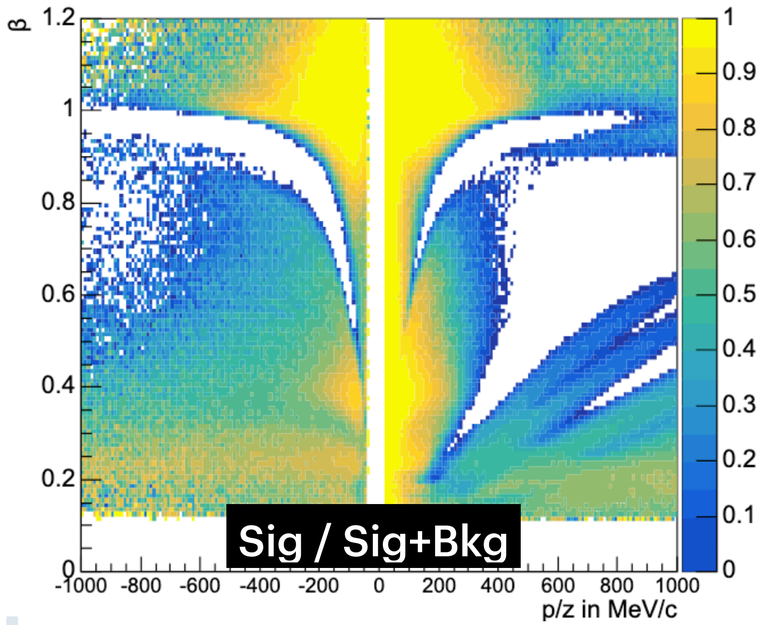
S/S+B Narrow Time Cut / S/S+B Wide Time Cut

Clear improvement in electron S/B ratio in Beta-Mom plot with narrow time cuts

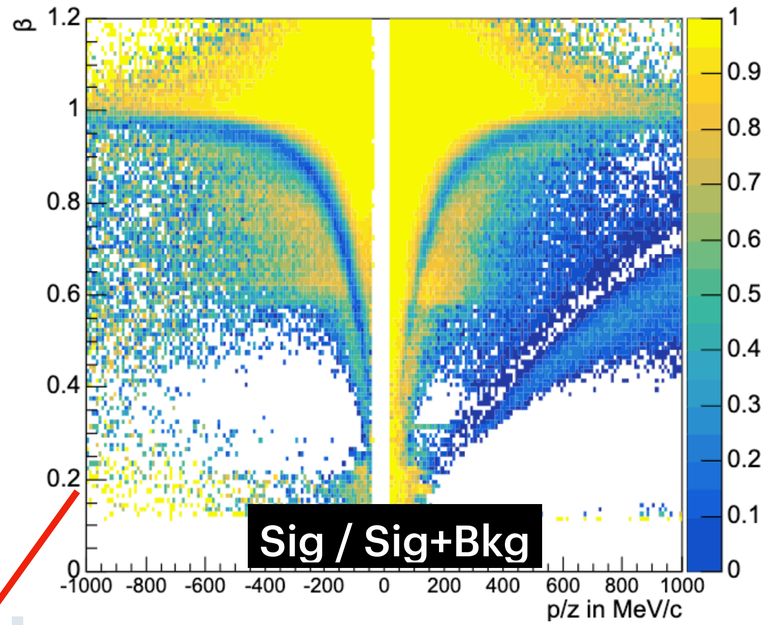
Background estimation:
Event-Mixing
(Rings and Tracks)

- In the ratio: S / S+B plot, yellow region represents suppressed background
- In the signal ratio plot, electron signal is nearly completely conserved

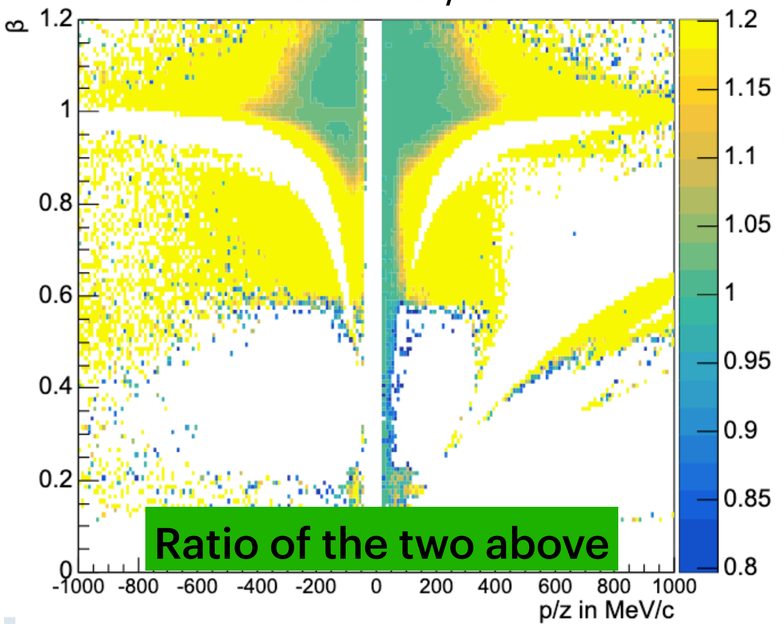
Wide Time Cut



Narrow Time Cut

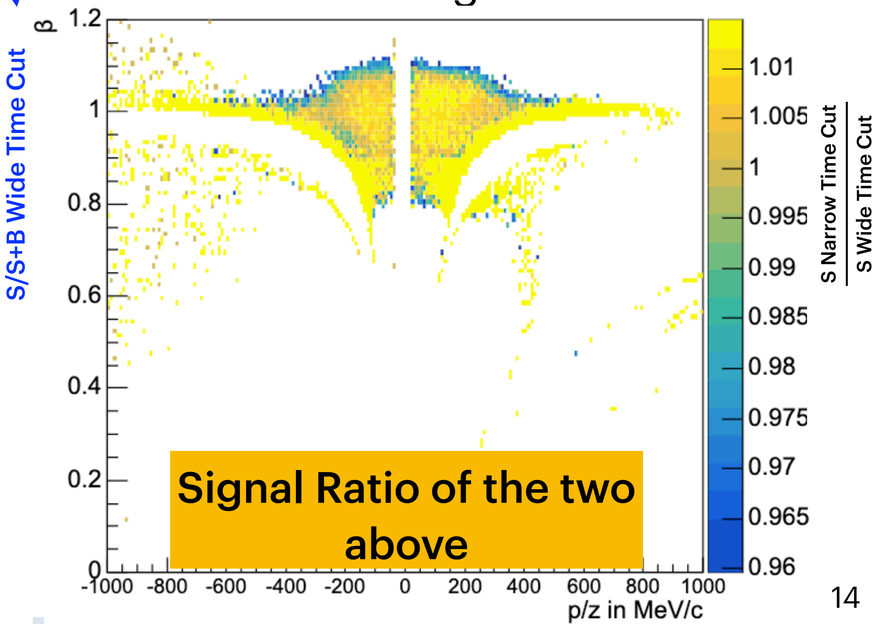


Ratio : S / S+B



S/S+B Narrow Time Cut / S/S+B Wide Time Cut

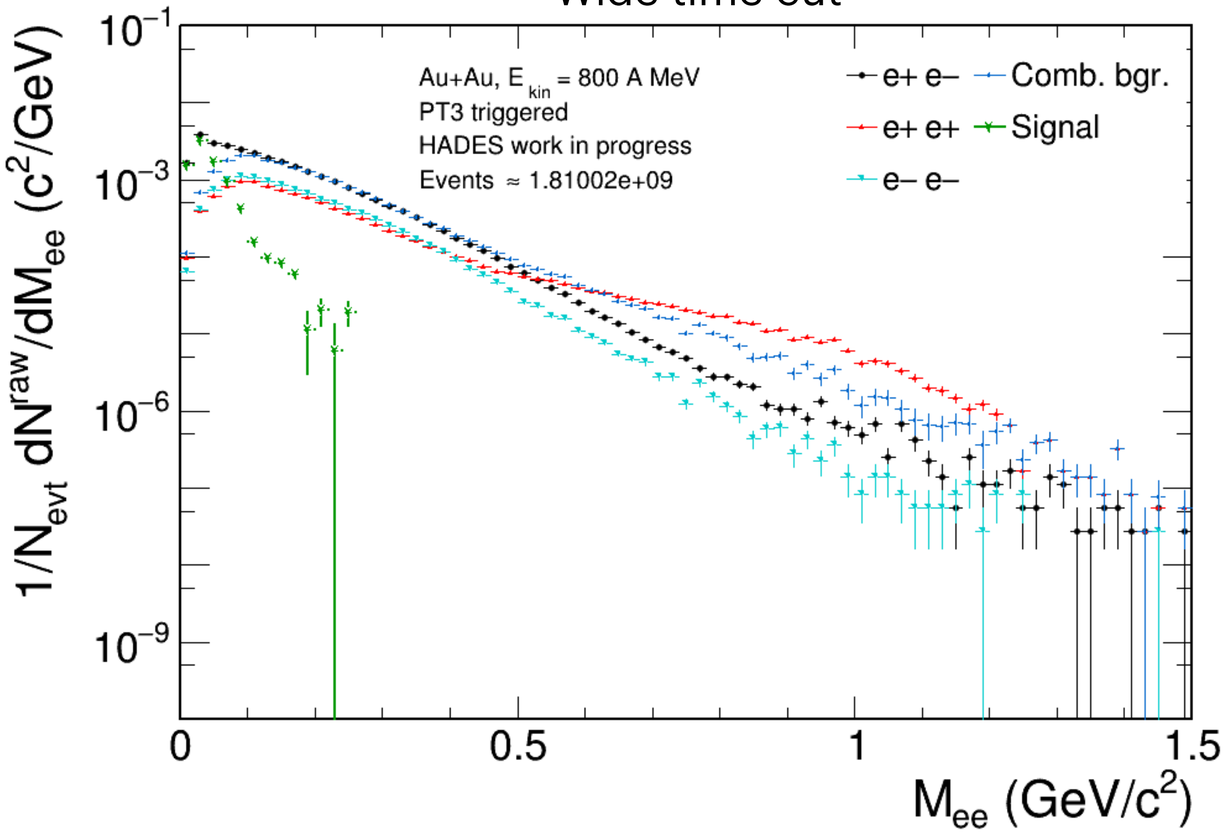
Ratio : Signal



Invariant mass spectra reconstructed after the narrow time cut

$0.9 < \beta < 1.1,$
$|p/z| < 2000\ MeV/c$

Wide time cut



- Wide time cut over-estimates background, thus invariant mass spectrum is not derivable

Combinatorial background

fg : mixed-event spectra
FG : same-event spectra

$$\langle BG_{+-} \rangle = \frac{\langle fg_{+-} \rangle}{2\sqrt{\langle fg_{++} \rangle \langle fg_{--} \rangle}} 2\sqrt{\langle FG_{++} \rangle \langle FG_{--} \rangle} = k2\sqrt{\langle FG_{++} \rangle \langle FG_{--} \rangle}$$

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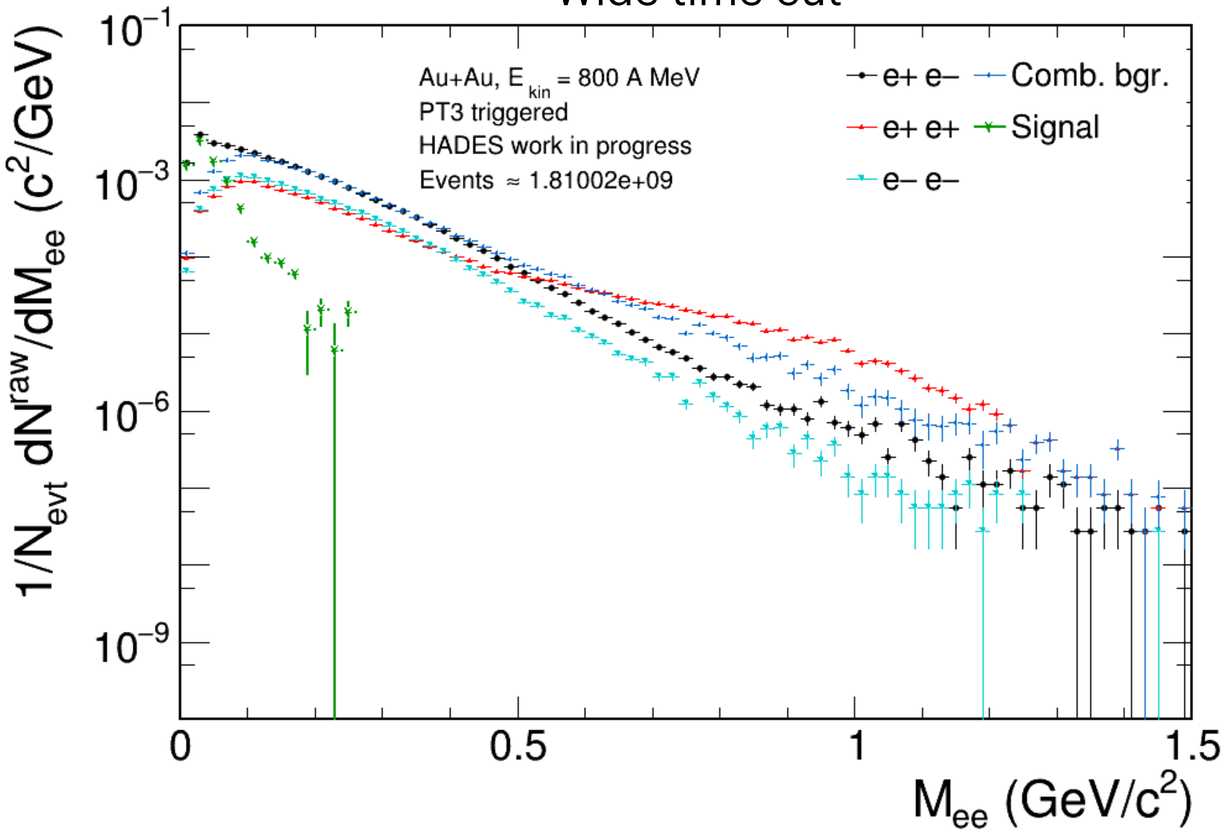
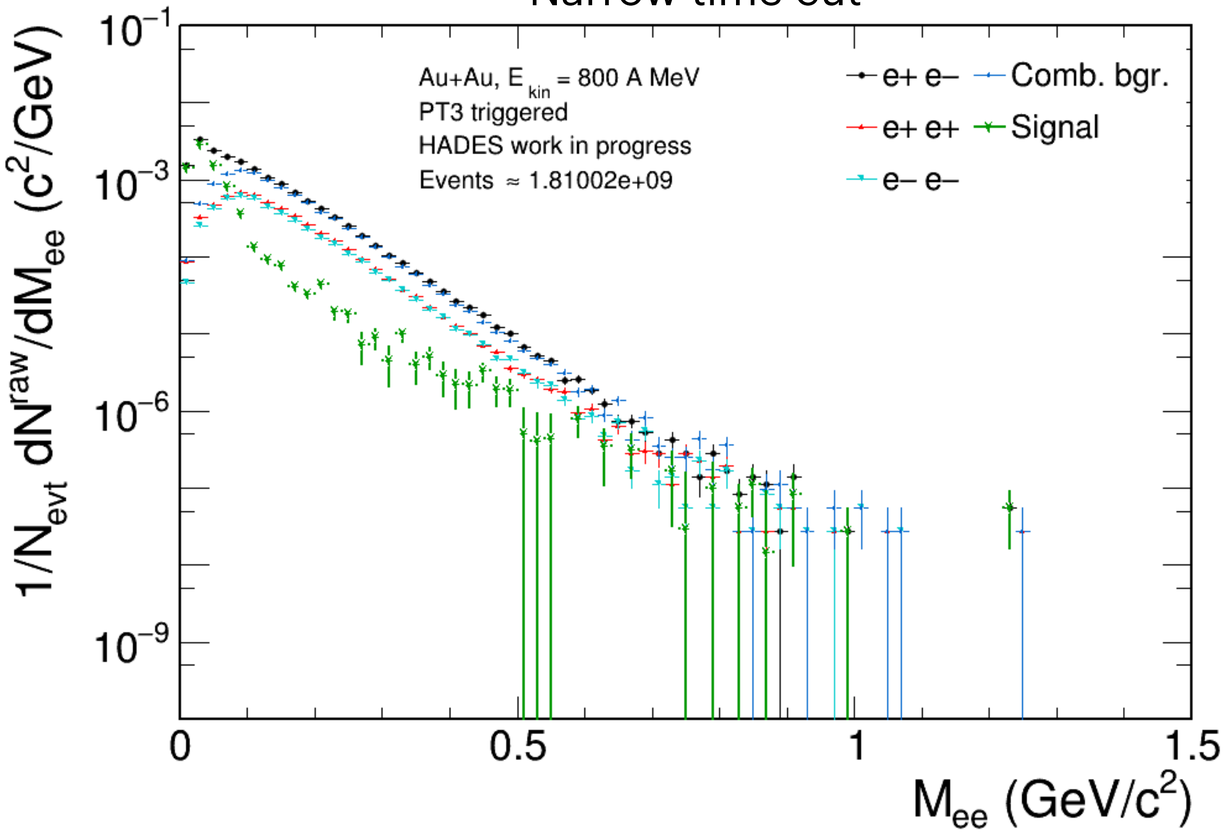
Wide time cut



Narrow time cut



- Wide time cut over-estimates background, thus invariant mass spectrum is not derivable

Summary & Outlook

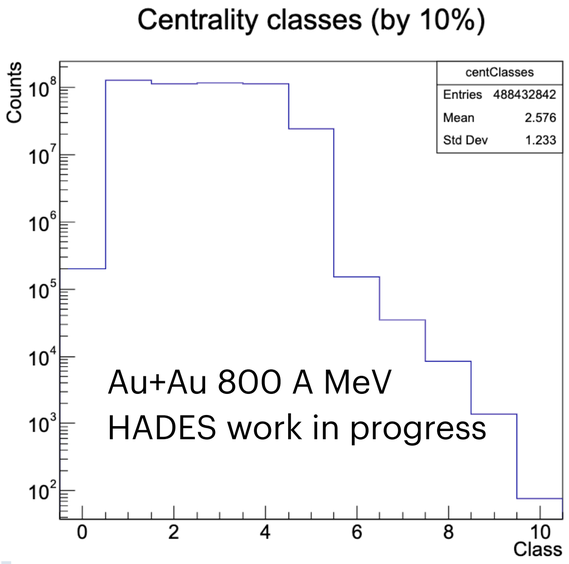
- For the Au+Au @ 800 A MeV run, the new RICH narrow time cut (3ns)
  - suppresses background (back-scattered pions, hadrons), but still conserving the efficiency
  - enables di-electron pair reconstruction

Next steps

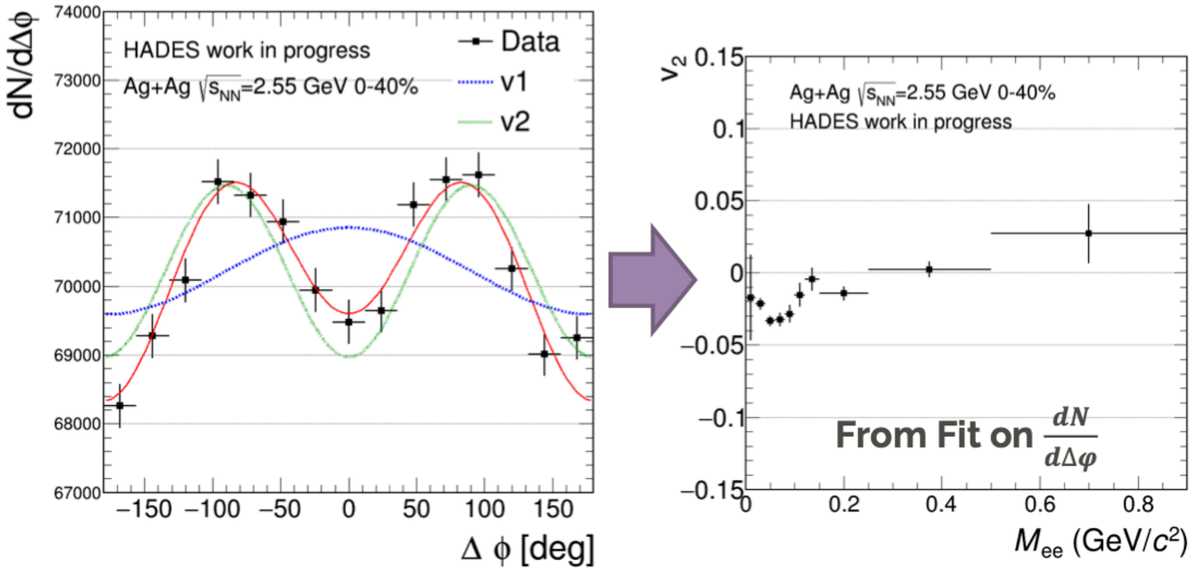
➡ Finalize the time cut

➡ Look into dilepton flow (SMASH simulation and data)

➡ Already started : event plane reconstruction



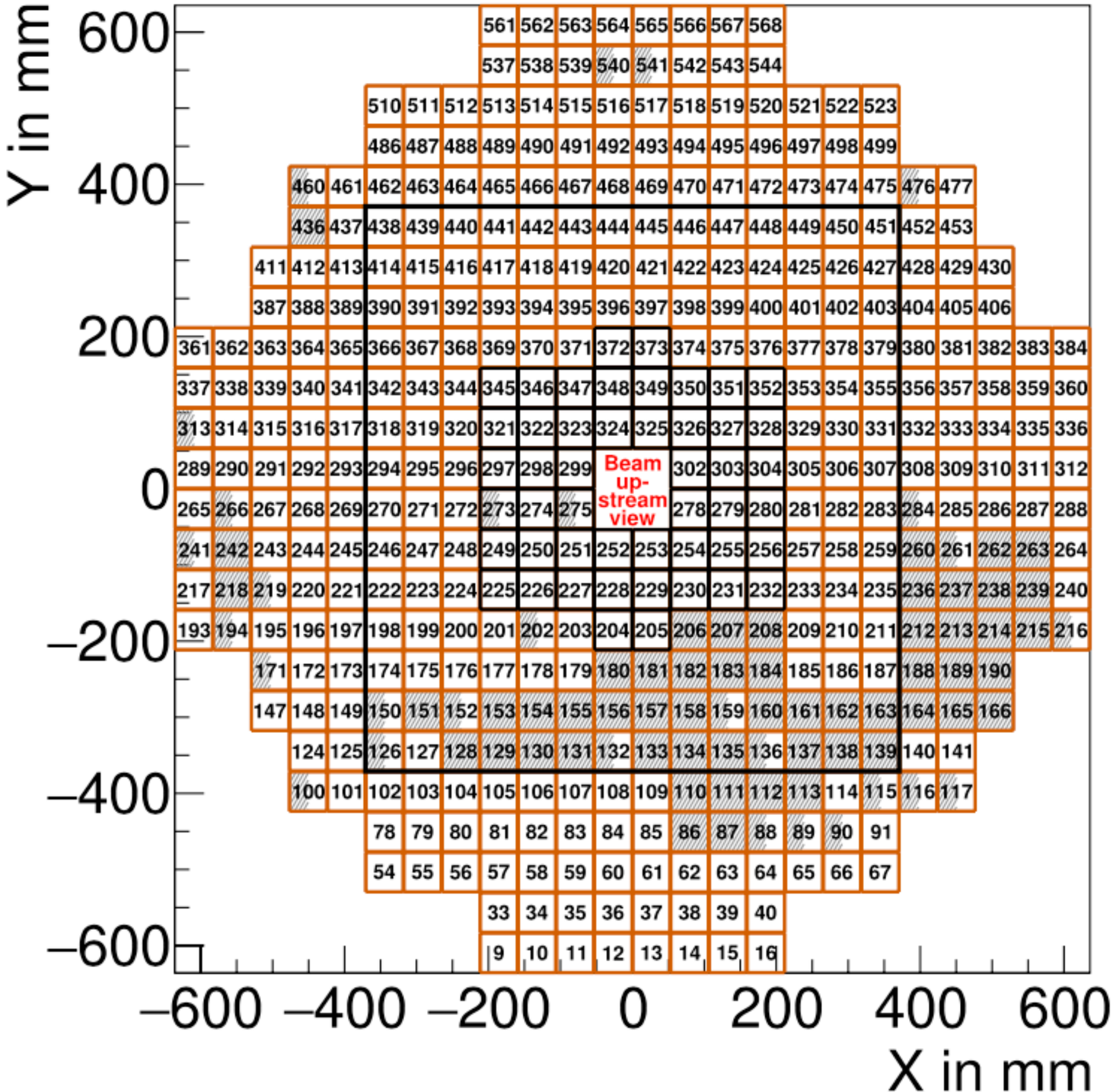
Fit $\Delta\varphi$ Distributions



Niklas Schild @ HADES CM Mar.2023

Thank you for your attention!

Backup


Y in mm
600
400
200
0
−200
−400
−600
−600 −400 −200 0 200 400 600
X in mm
Beam up-stream view

HADES beam time

Previous beam times

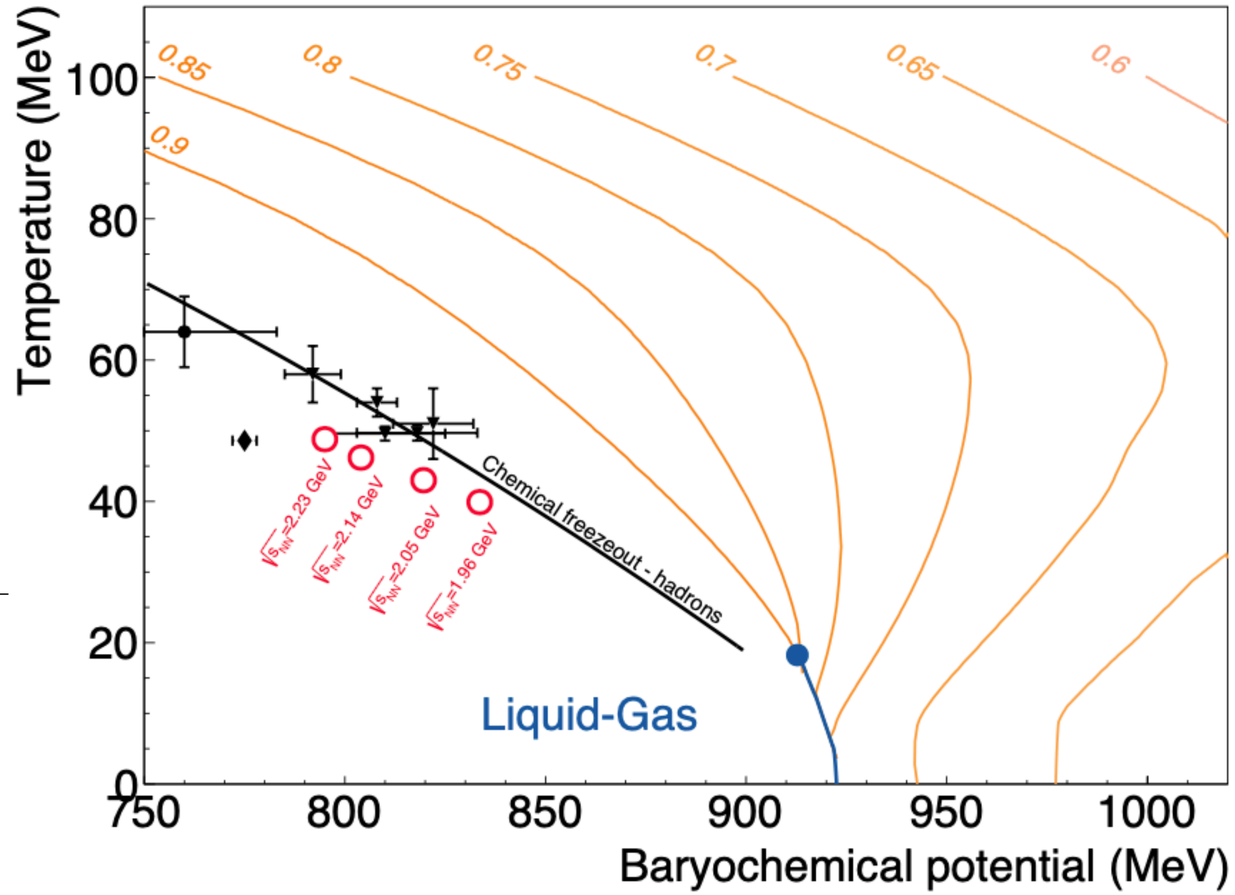
- Au+Au @ 1.23 A GeV (2012) → 2.55 / 2.42 GeV
- Ag+Ag @ 1.58 A / 1.23 A GeV (2019)
- p+p @ 4.5 GeV (2022)

Beam time 2024

- End of Feb - Mar → 2.23 GeV
- Au+Au @ 800 A MeV → 3 days
- 2.5×10^9 events collected (with/without magnetic field combined)

Beam time 2025 (Au+Au)

- 200, 400, 600 A MeV → 2.5 days each → 1.96, 2.05, 2.14 GeV
- 800 A MeV → 3 days

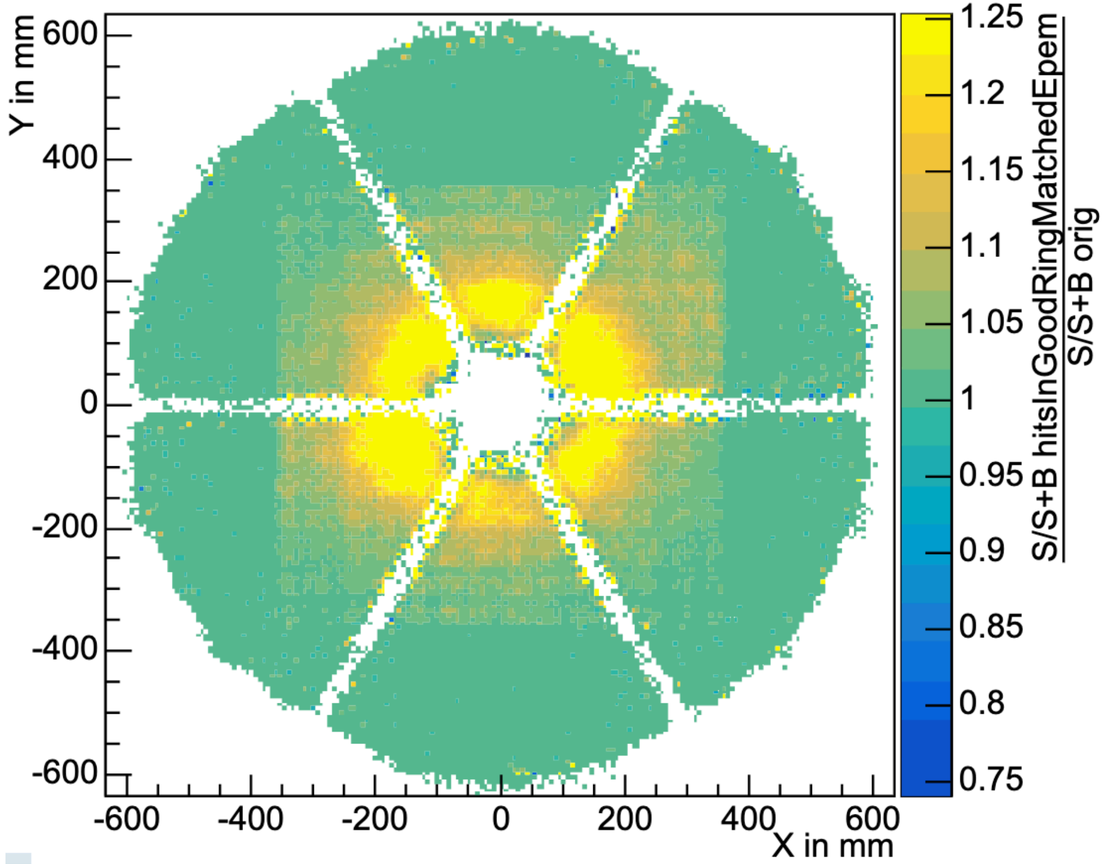


Hits removed in the inner part and near the beam pipe area

Ratio of S/S+B with/without time cuts

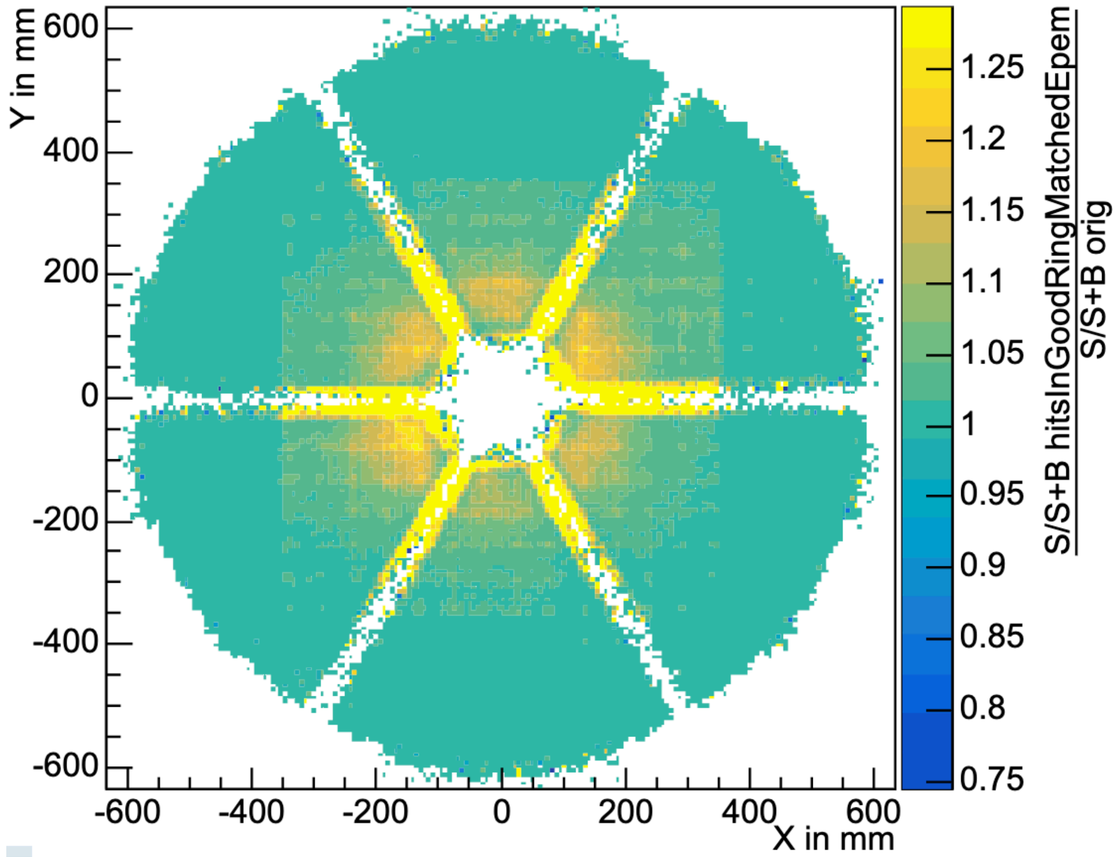
$0.9 < \beta < 1.1,\ |p/z| < 2000\ \text{MeV}/c$
$\text{Mass} < 1000\ \text{MeV}/c^2$

Hits in the electron cand area with matched rings



➡ Hits are mostly removed near the beam pipe area

Good ring centre positions with matched electron tracks

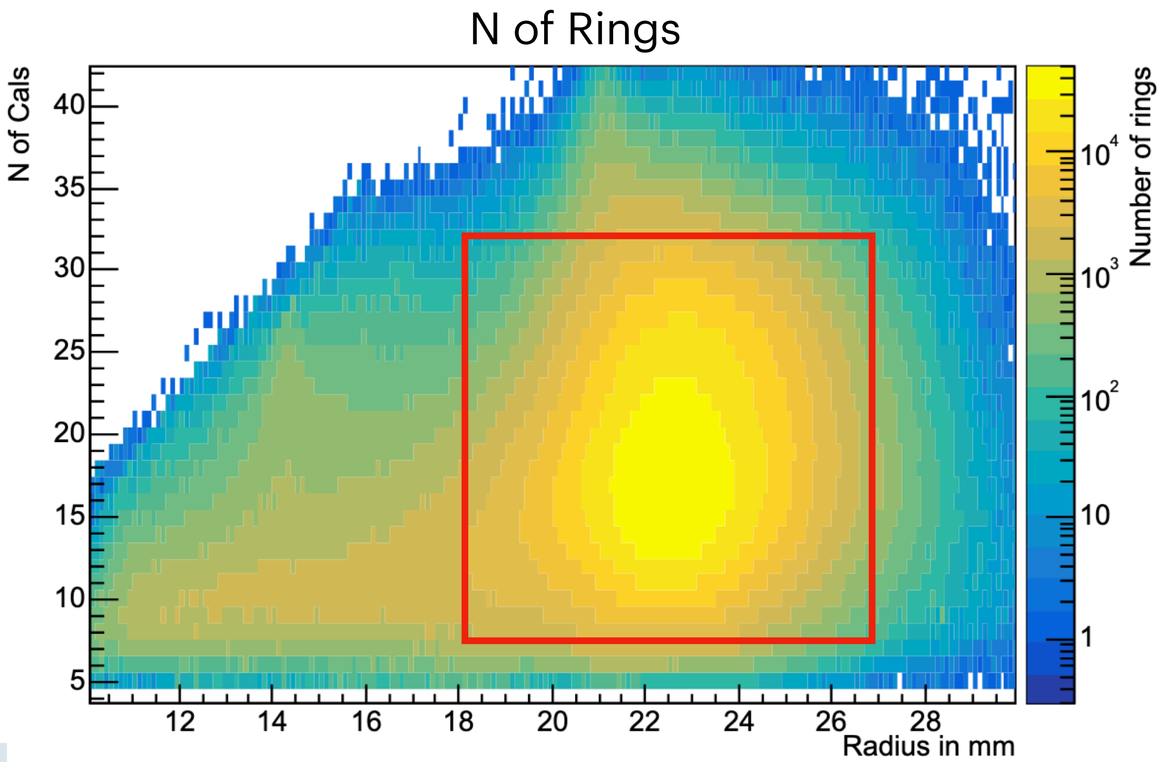


➡ Removing those hits also affect ring reconstruction but suppresses fake rings especially in the inner part

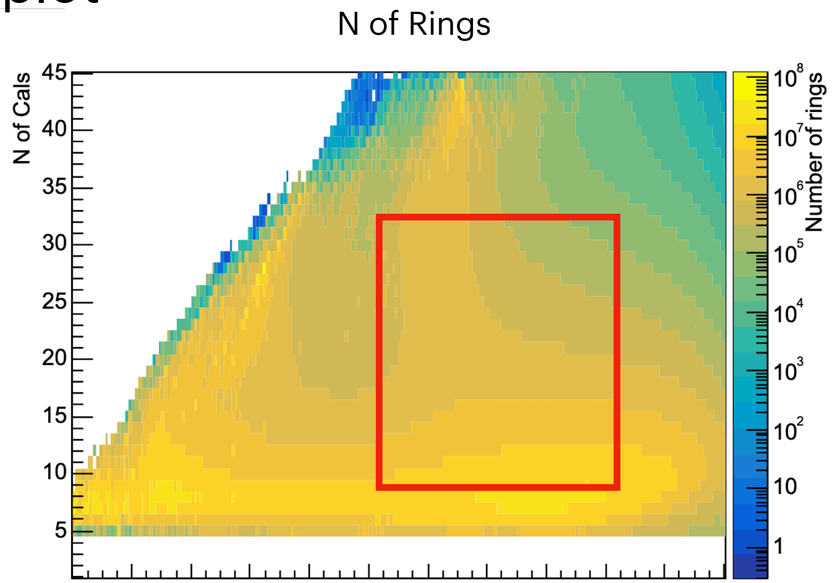
Determining Additional Ring cuts

with Number of Rings (z scale) vs Radius plot

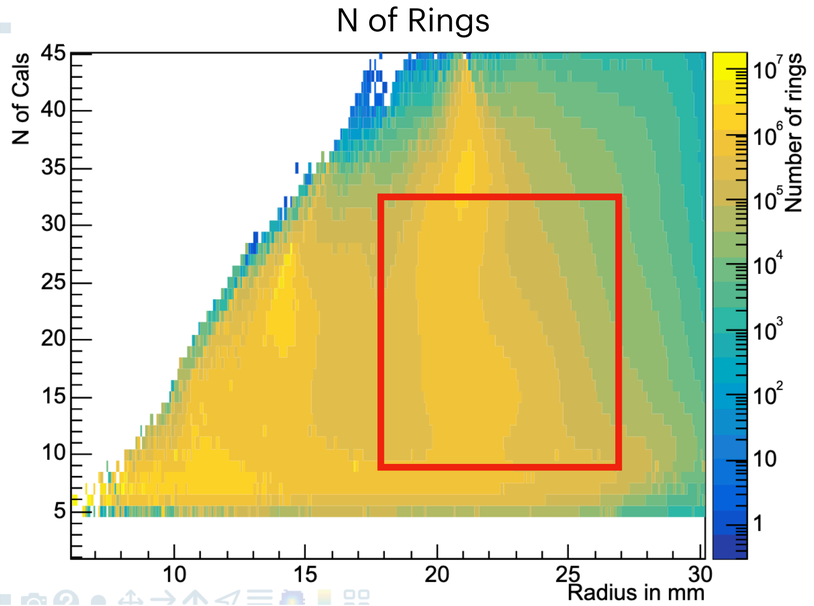
+ Narrow time cuts,
$e^{\pm}$ Track matching
$0.9 < \beta < 1.1$,
$|p/z| < 250\,MeV/c$,
Mass $< 100\,MeV/c^2$



Before applying any cuts



+ Narrow time cuts



This will be the new “Good Ring” cut

The effect of the good ring cut only visible in wide time cut case

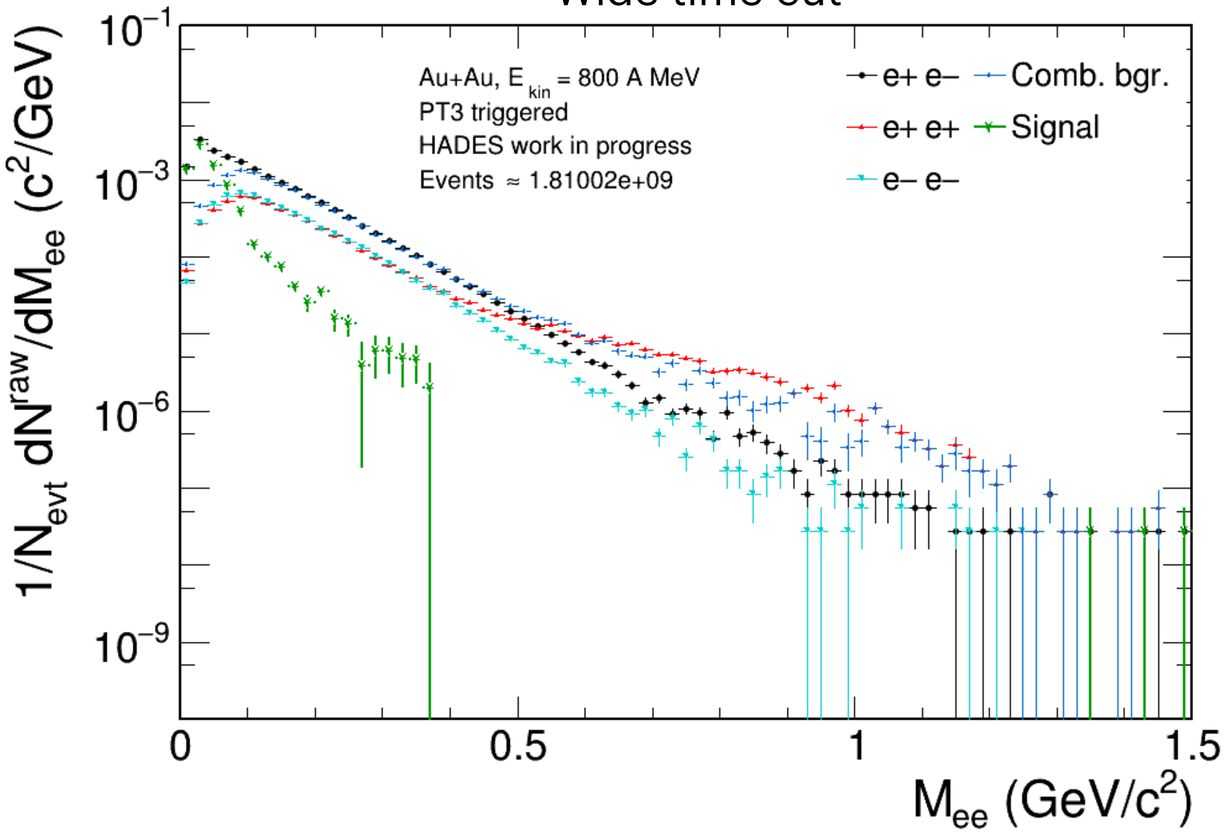
With the new "Good Ring" cut

- Ring-track matching : 2°
- $18 <$ Ring radius < 27
- $8 <$ Hits in good rings < 32

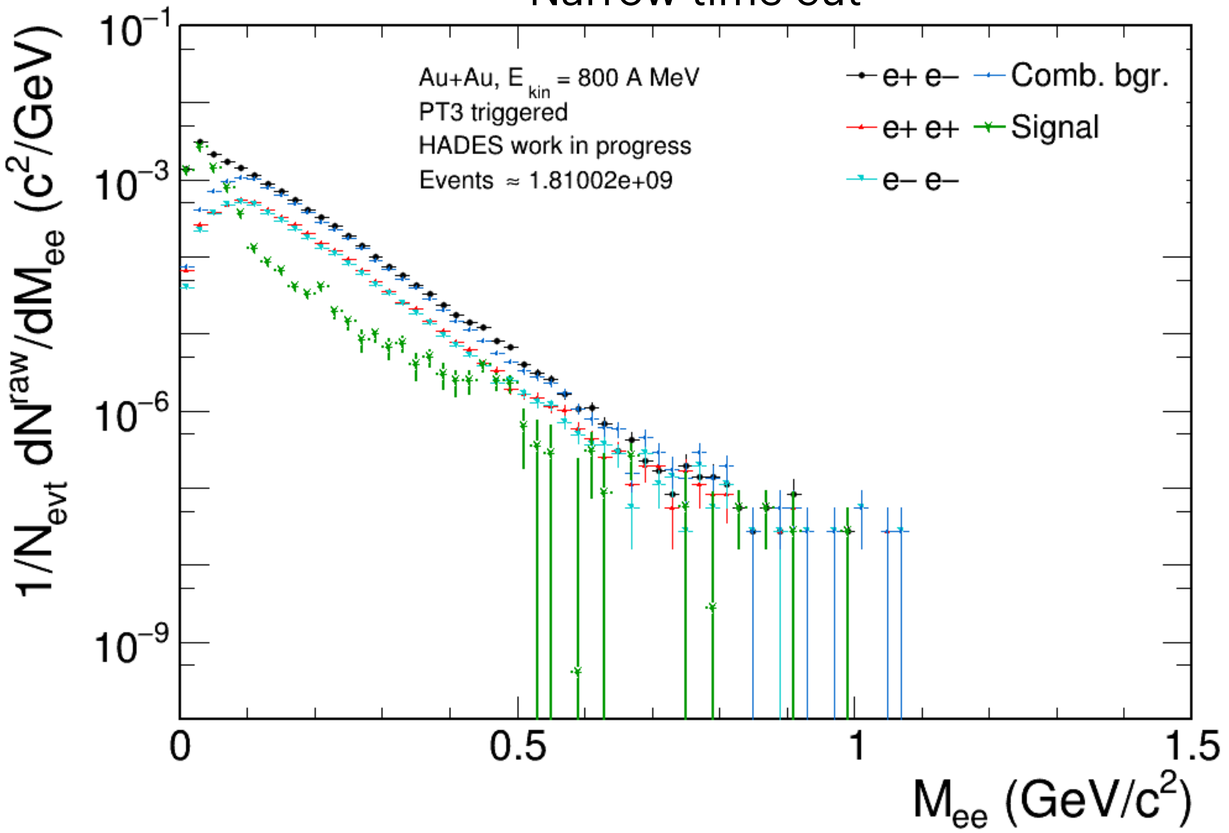
Beta-Momentum cut

- $0.9 < \beta < 1.1,\ |p/z| < 2000\ MeV/c$

Wide time cut



Narrow time cut



- "Good Ring" cut slightly improves di-electron pair reconstruction
- In the context of narrow time cuts, the "Good Ring" criterion has minimal impact

One track or multiple tracks per ring?

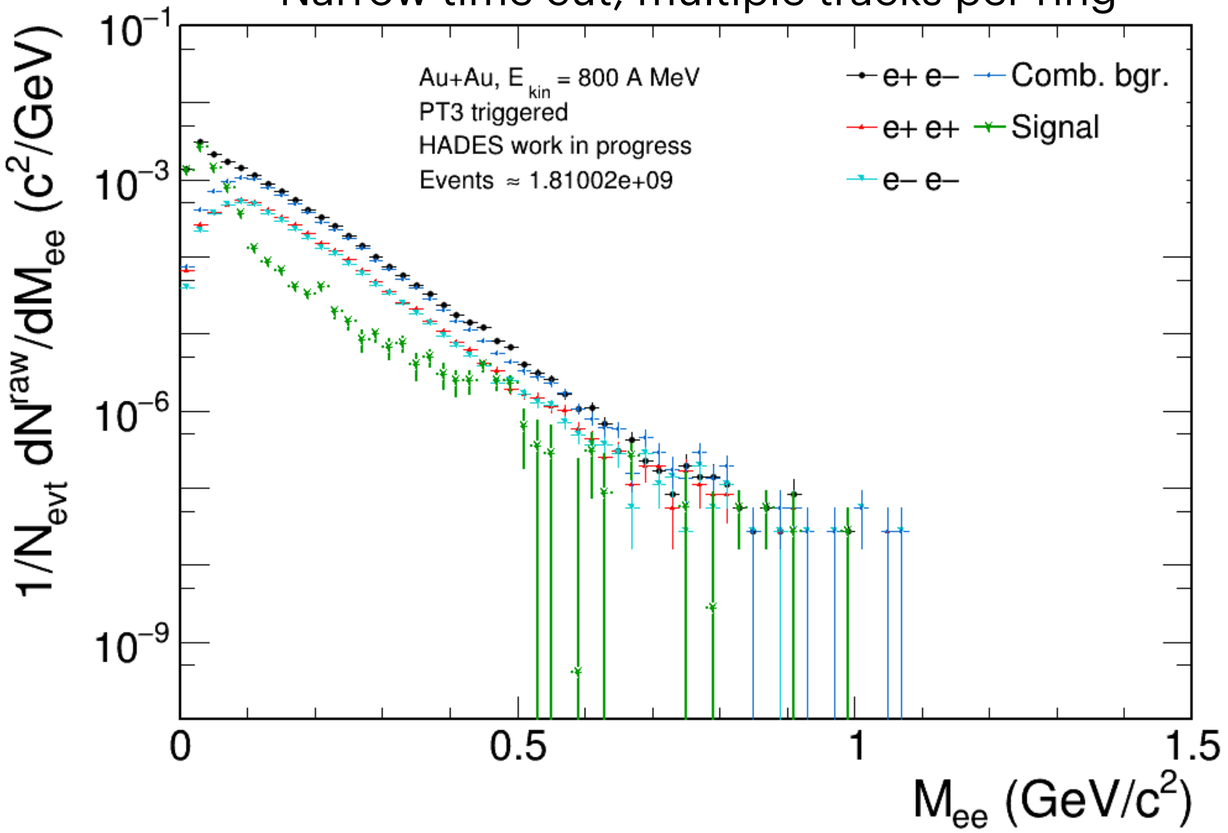
With the new "Good Ring" cut

- Ring-track matching : 2°
- $18 <$ Ring radius < 27
- $8 <$ Hits in good rings < 32

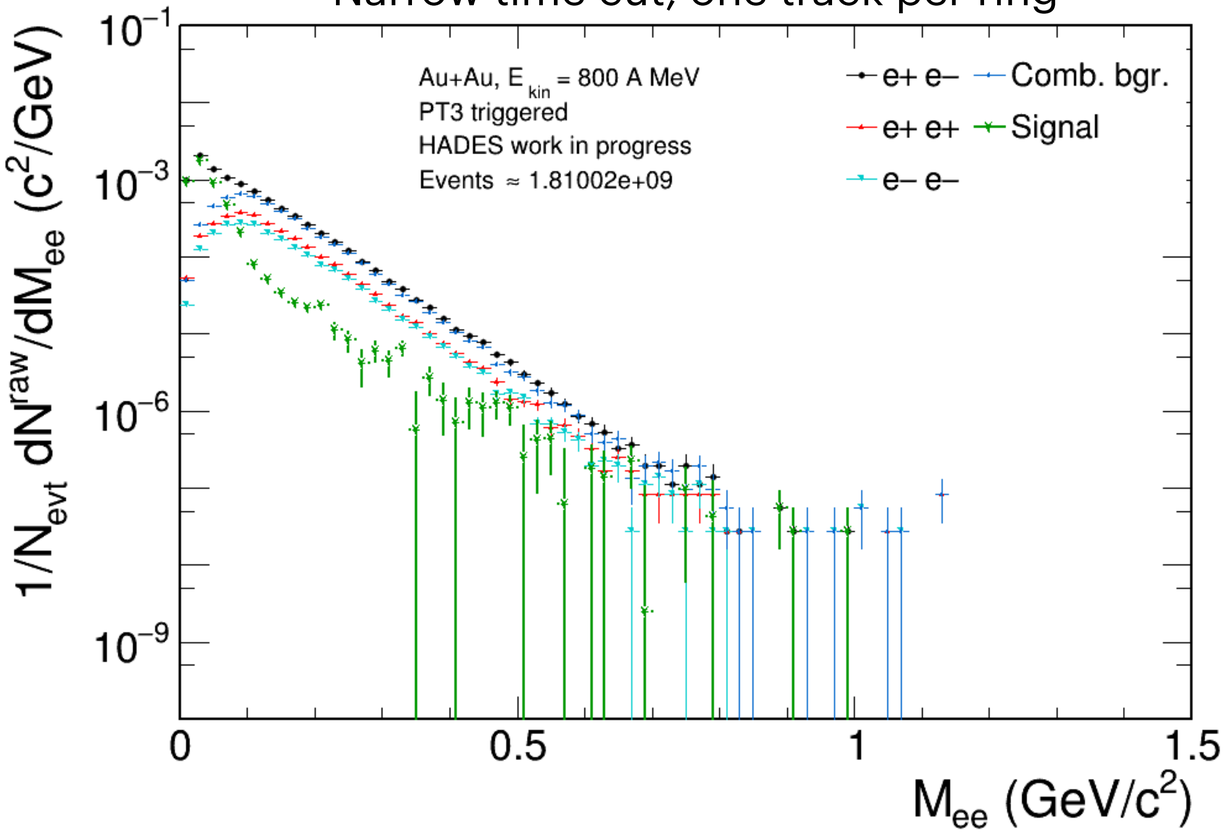
Beta-Momentum cut

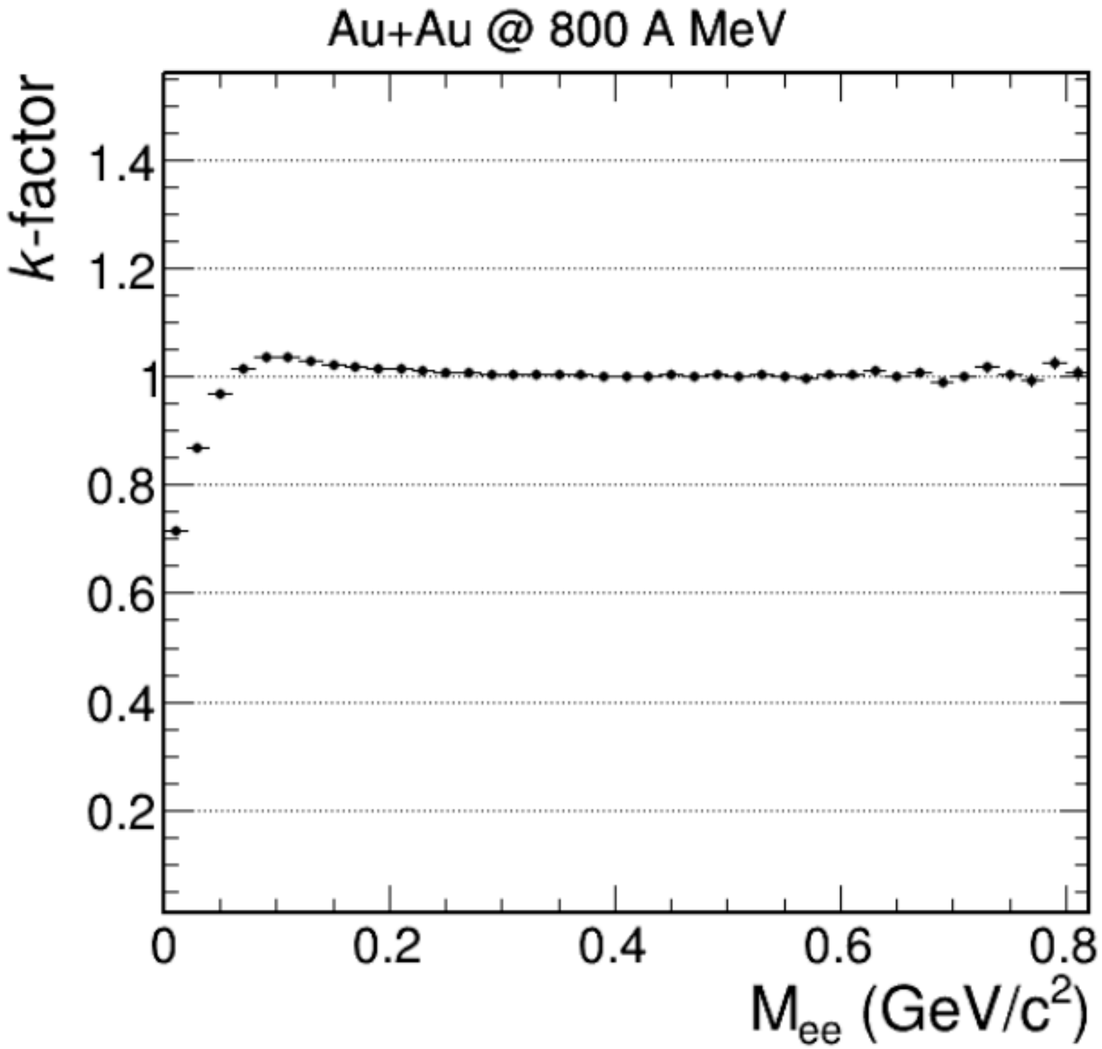
- $0.9 < \beta < 1.1,\ |p/z| < 2000\ MeV/c$

Narrow time cut, multiple tracks per ring



Narrow time cut, one track per ring




Au+Au @ 800 A MeV
k-factor
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.2
0.4
0.6
0.8
M_ee (GeV/c^2)