Endcap Time-of-Flight in the STAR experiment

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Brookhaven National Lab

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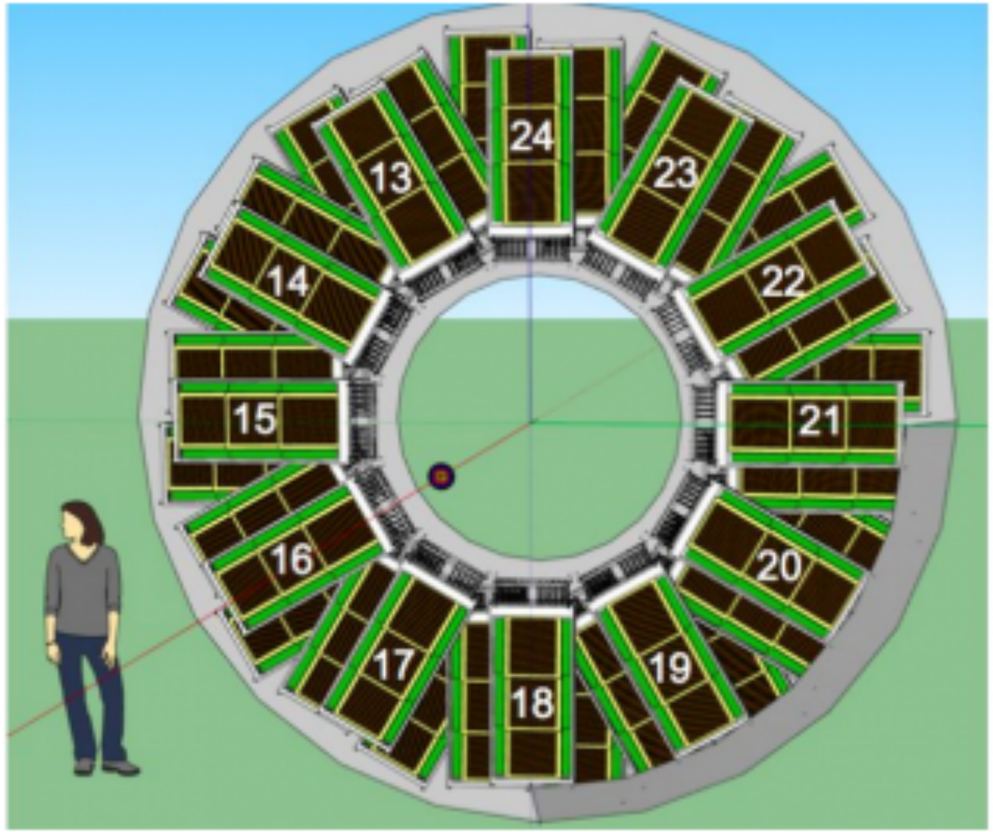
Supported in part by

Outline

1. Motivation for eTOF
2. Important techniques used in analysis with eTOF
3. Some physics results with eTOF

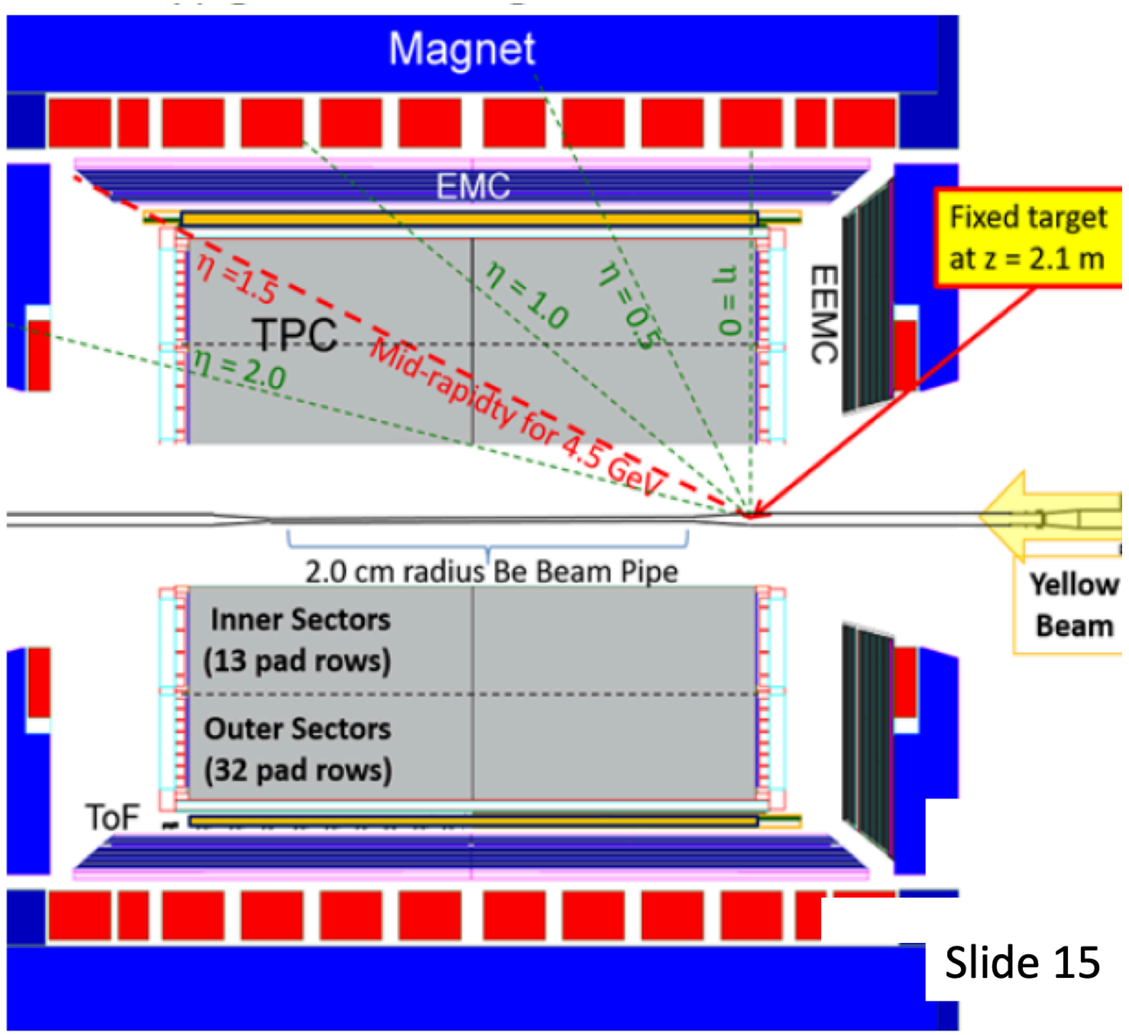


STAR fixed-target program

- Collider mode can achieve collisions as low as $\sqrt{s_{NN}} = 7.7$ GeV
- To more extensively scan the phase diagram, we want to achieve lower energies
- **Solution:** Turn STAR into a fixed-target experiment!

eTOF in BES-II

- FXT mode comes with its own challenges;
  - Mid-rapidity moves out of the barrel time-of-flight acceptance
- Implemented **Endcap Time-of-Flight (eTOF)** in 2018
  - Gives PID for high momentum tracks
  - Extends η coverage from $0 < \eta < 1.5$ to $0 < \eta < 2.2$ in FXT
- A prototype for the CBM experiment



Slide 15

eTOF in BES-II

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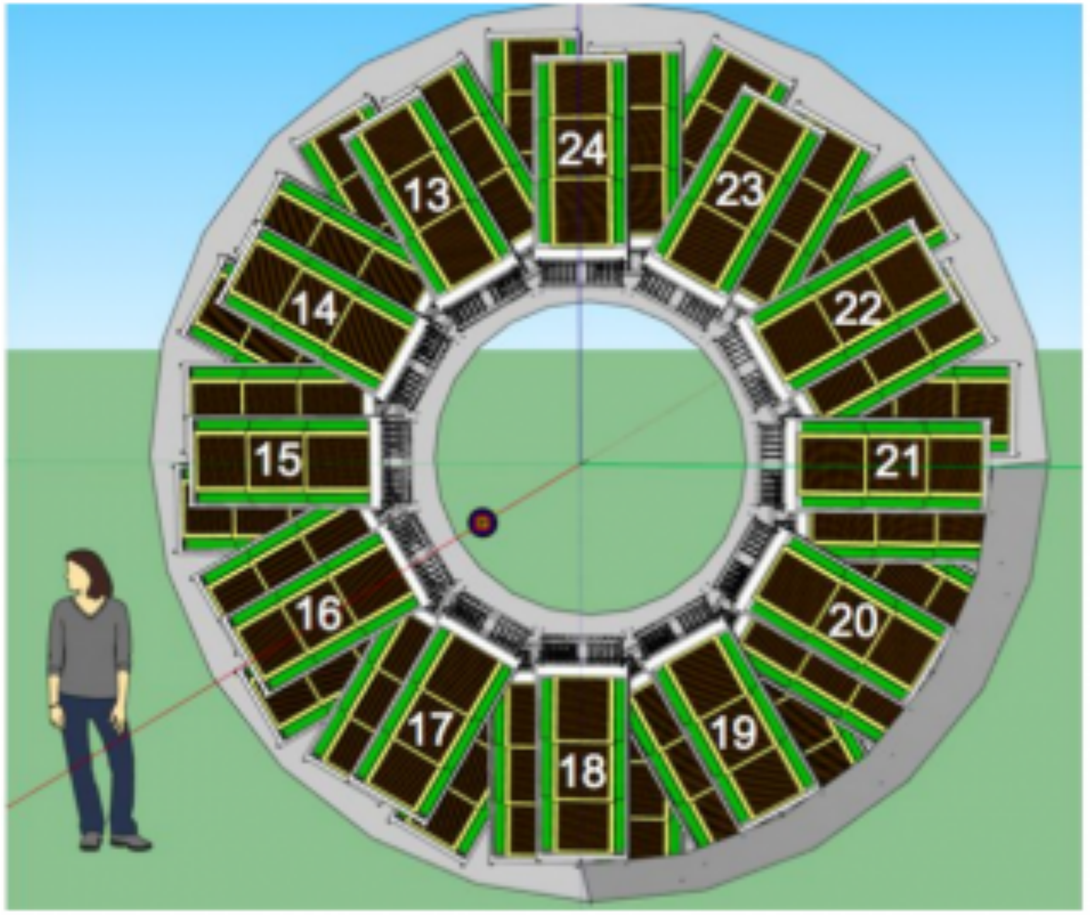
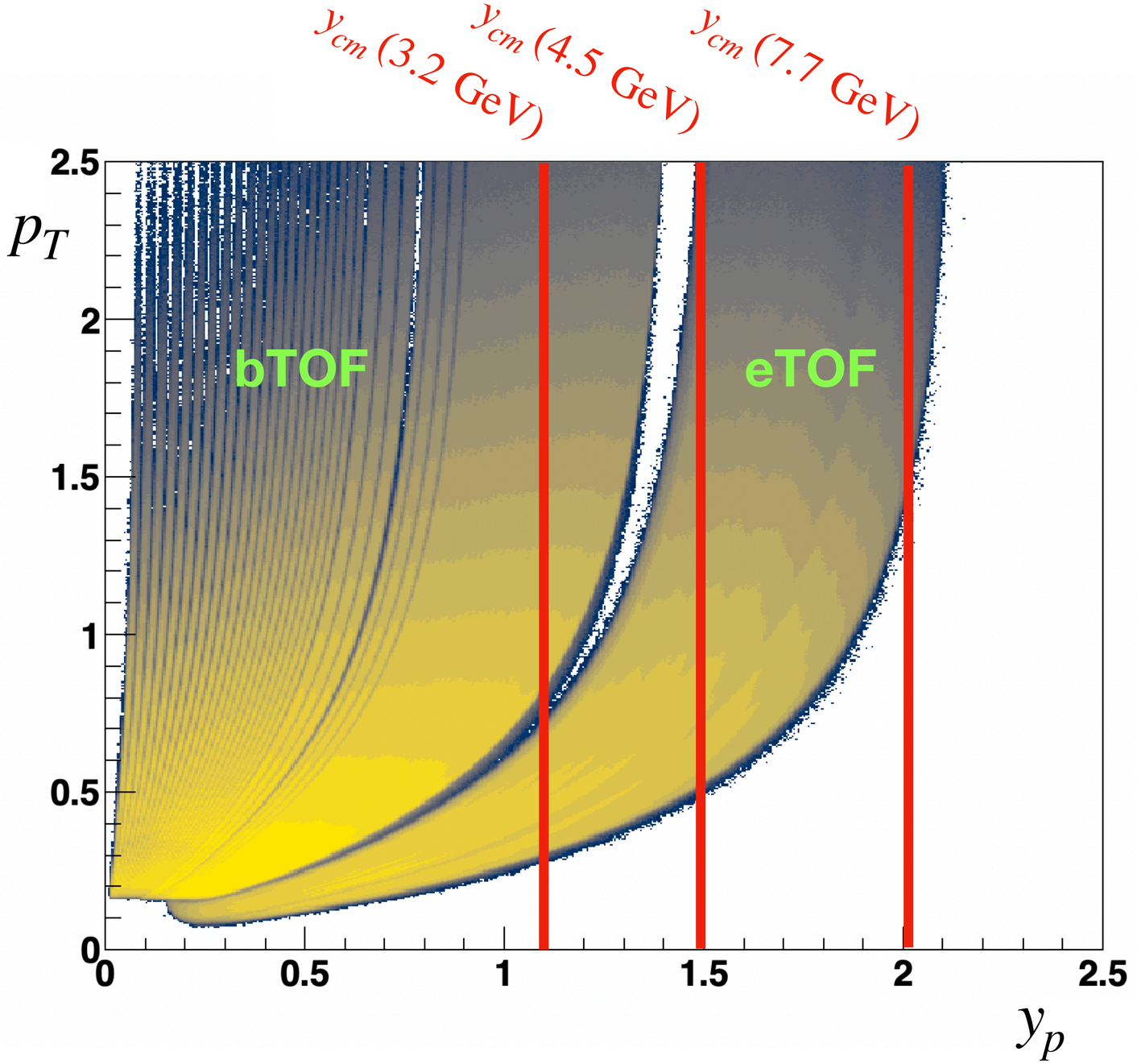


Why use eTOF?

- Extends our acceptance
- **Critical** for FXT
    - Allows us to measure mid rapidity
- Gives us the ability to make extensive cross-checks to collider mode at 7.7 GeV

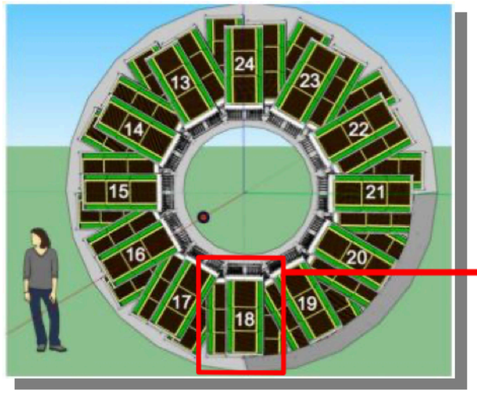


eTOF construction

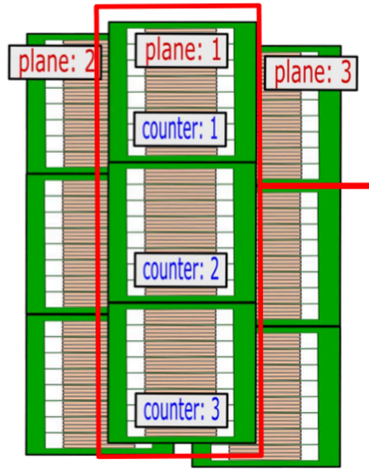
ETOF : Hardware Schematics

Yannick Söhngen , Heidelberg

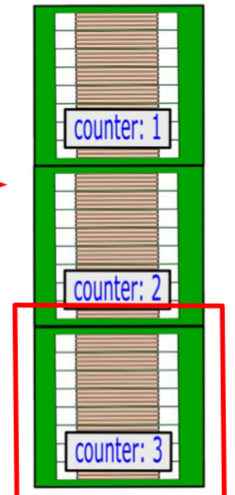
Full ETOF wheel



ETOF sector



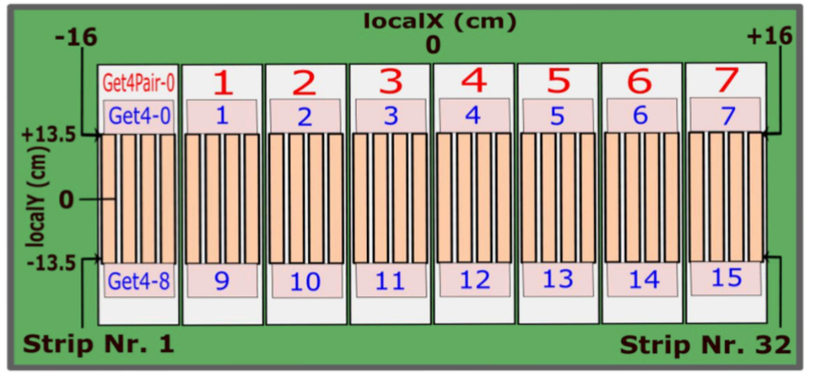
ETOF module



ETOF consists of:

- **12 sectors** made of
- **3 modules** made of
- **3 counters** containing
- **8 Get4-pairs** reading out
- **32 strips**

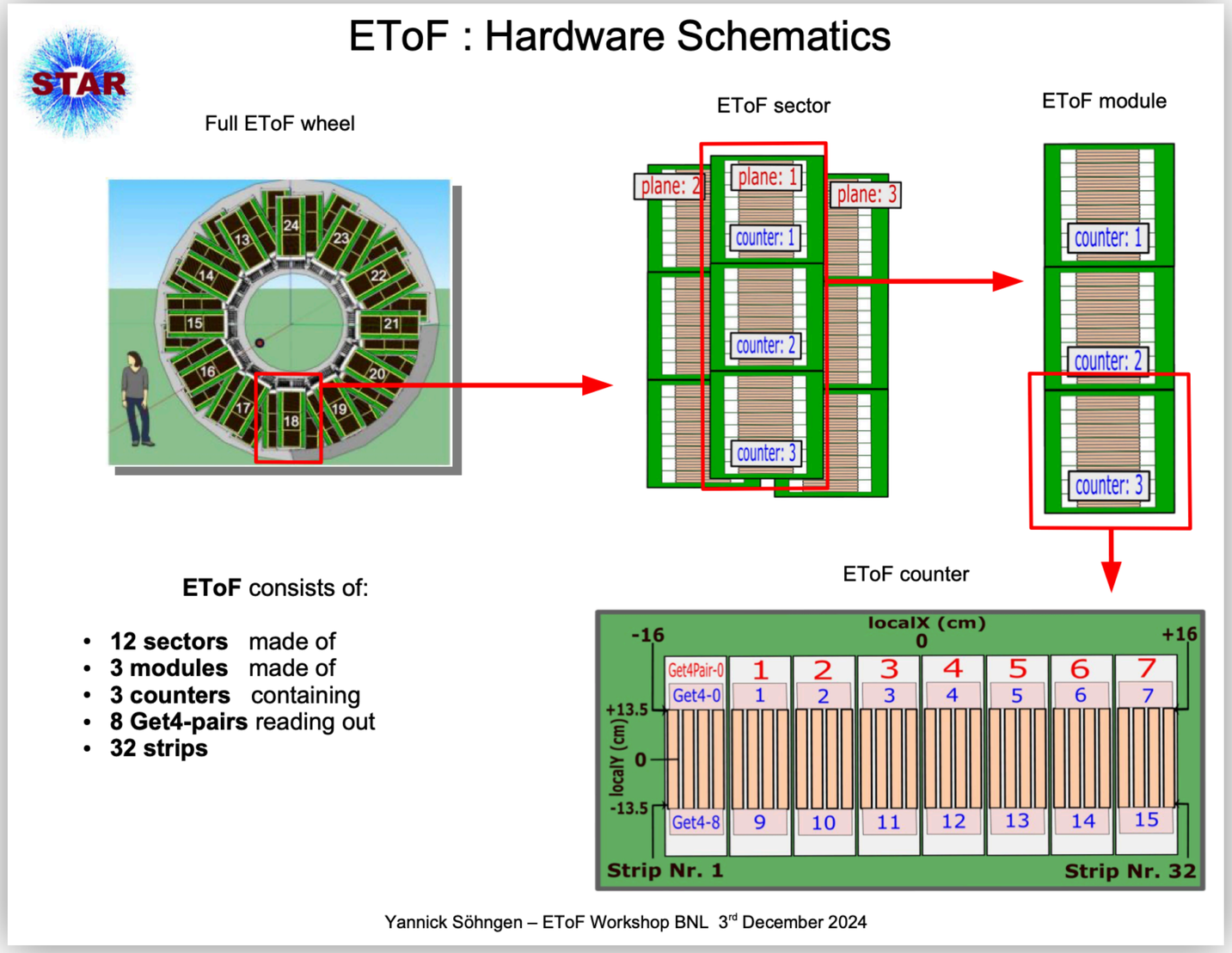
ETOF counter



Yannick Söhngen – ETOF Workshop BNL 3rd December 2024

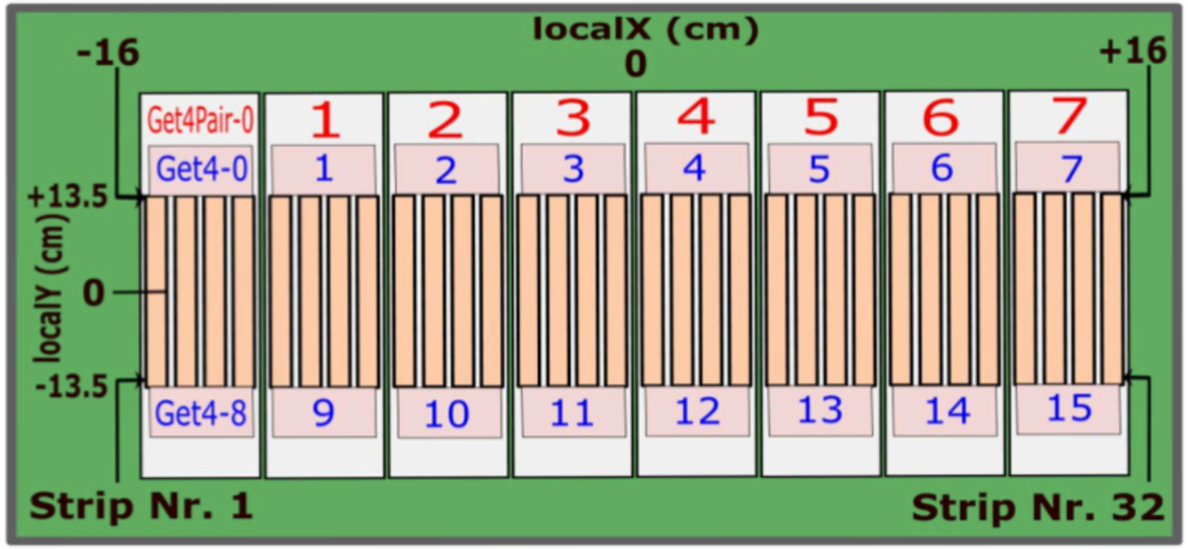
tofMatch flags

- eTOF “twinkles” at the Get4 level
- Changes acceptance event-by-event
- Implement a “Match Flag”, where we can require one or both of the Get-4 are healthy



tofMatch flags

- **If hit is one sided -** the acceptance is more stable, but we get worse timing resolution
    - Ideal for a fluctuations analysis
- **If hit is two sided -** the acceptance is less stable, but we get better timing resolution
    - Ideal for a spectra analysis



tofMatch flags

- To get the best m^2 distributions for spectra, we can use
  Match Flag = 204, 214, and 224
- Double sided, single-hit, single track

Yannick Söhngen

Match-Flag scheme:

Match-Flag = A + B + C

A = 0 → single sided hits only
A = 100 → single and double sided hits
A = 200 → double sided hits only

B = 0 → no hits from overlap region
B = 10 → only hits from overlap
B = 20 → mixture of both

C = 0 → no valid match
C = 1 → multi-hit, multi-track
C = 2 → single-hit, multi-track
C = 3 → multi-hit, single-track
C = 4 → single-hit, single-track

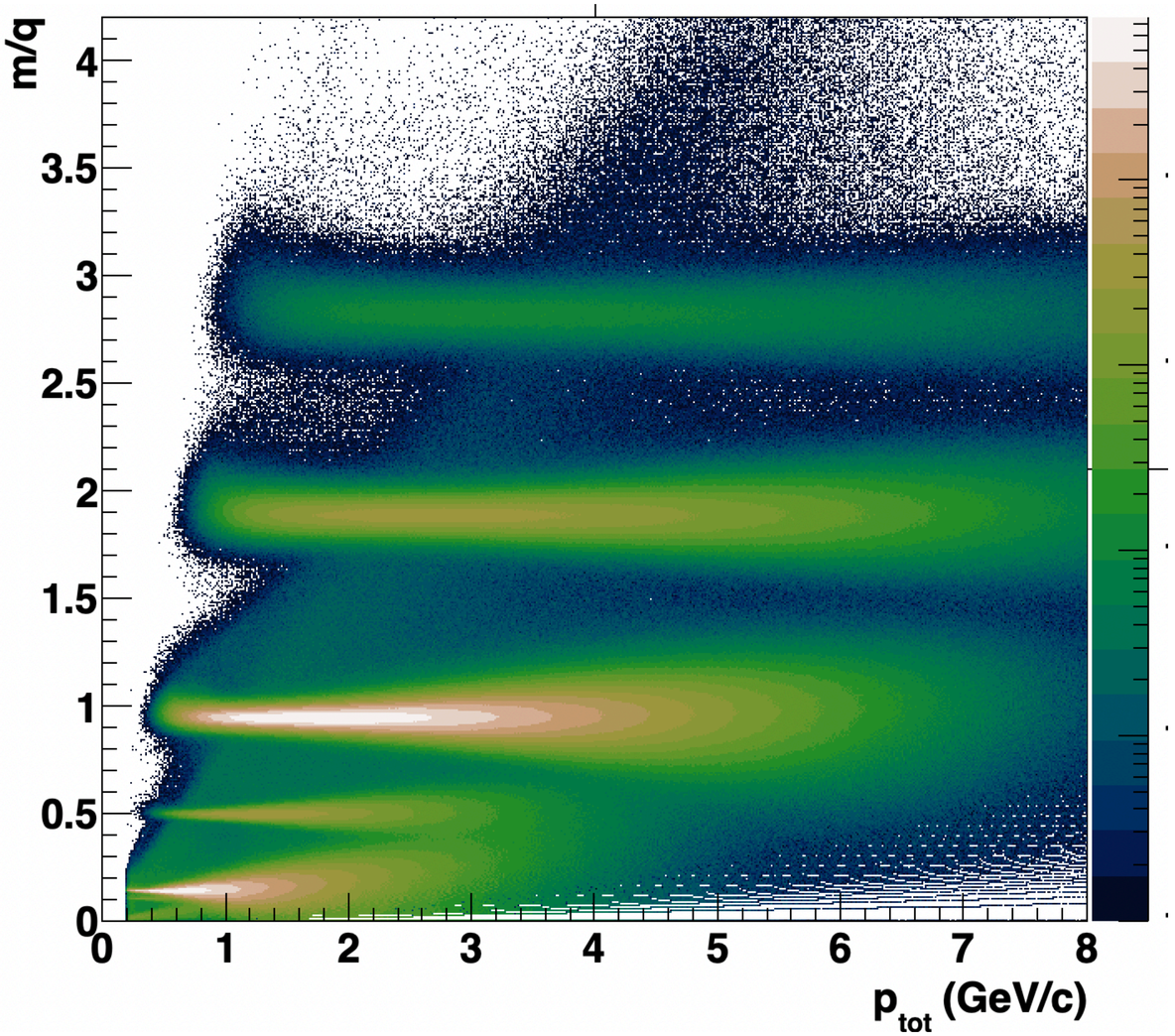
Example :

Match-Flag = 204

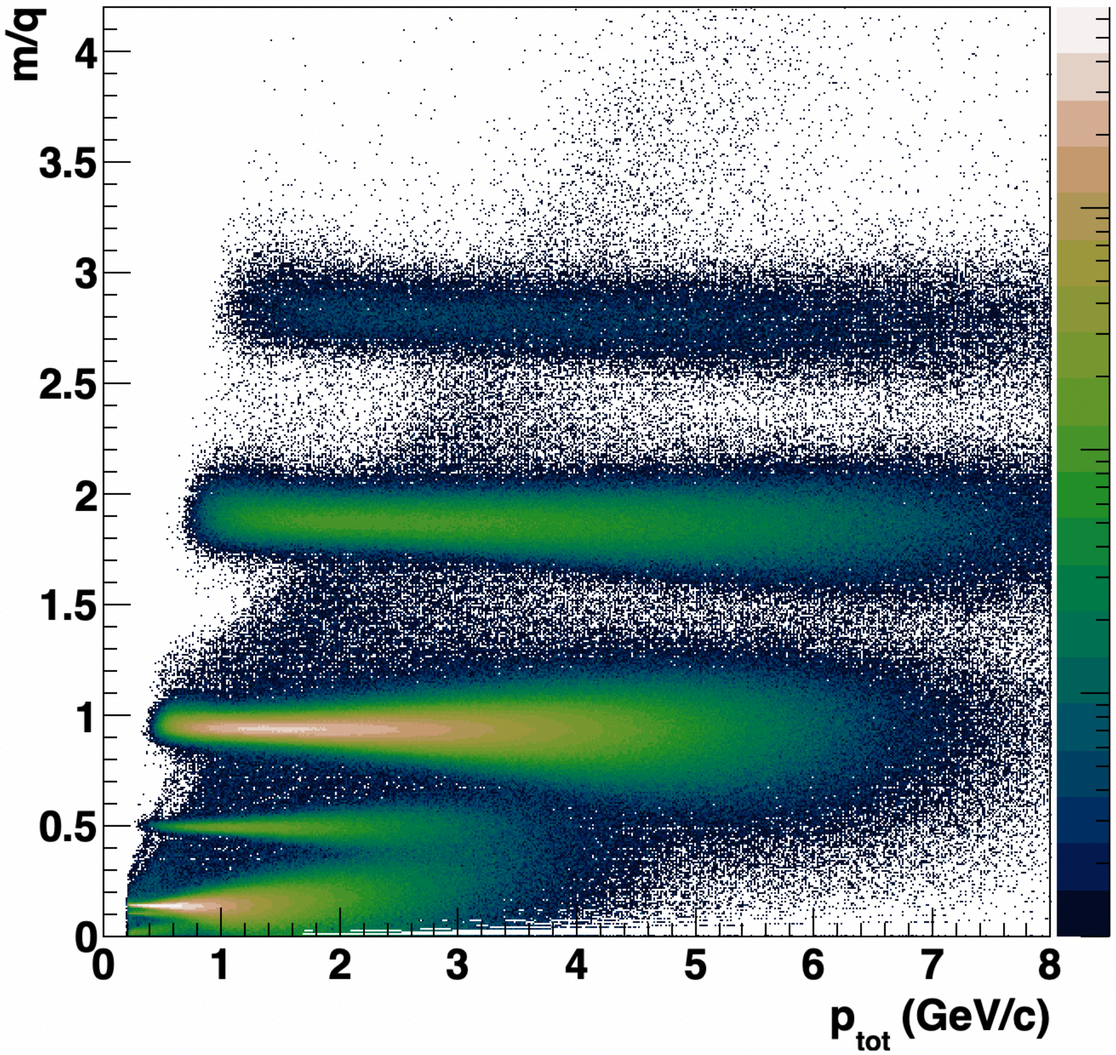
- 200 → only double sided hits
- + 0 → no contribution from overlap
- + 4 → single-hit, single-track match

tofMatch flags

No double-sided hit

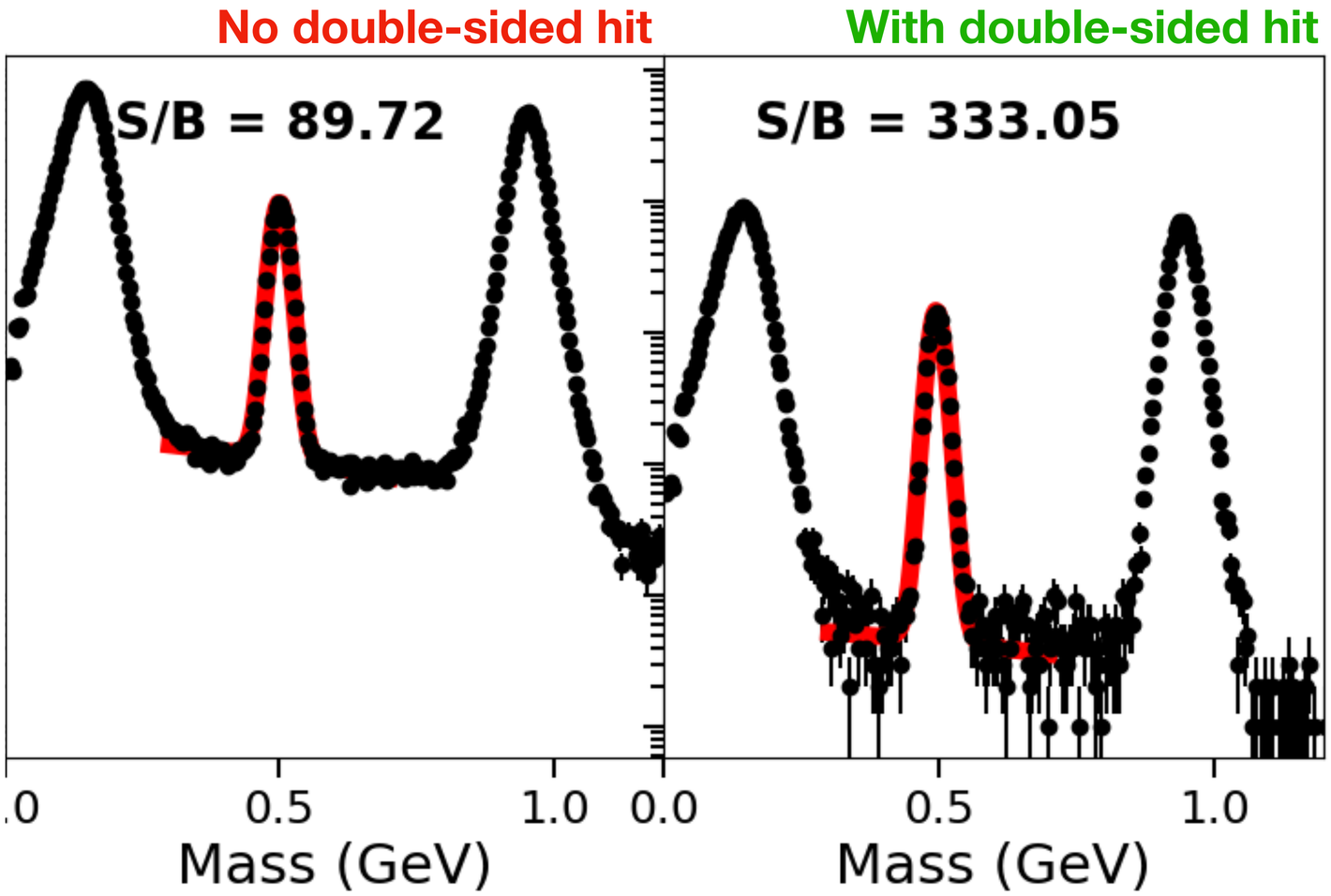


With double-sided hit



Signal to background ratio

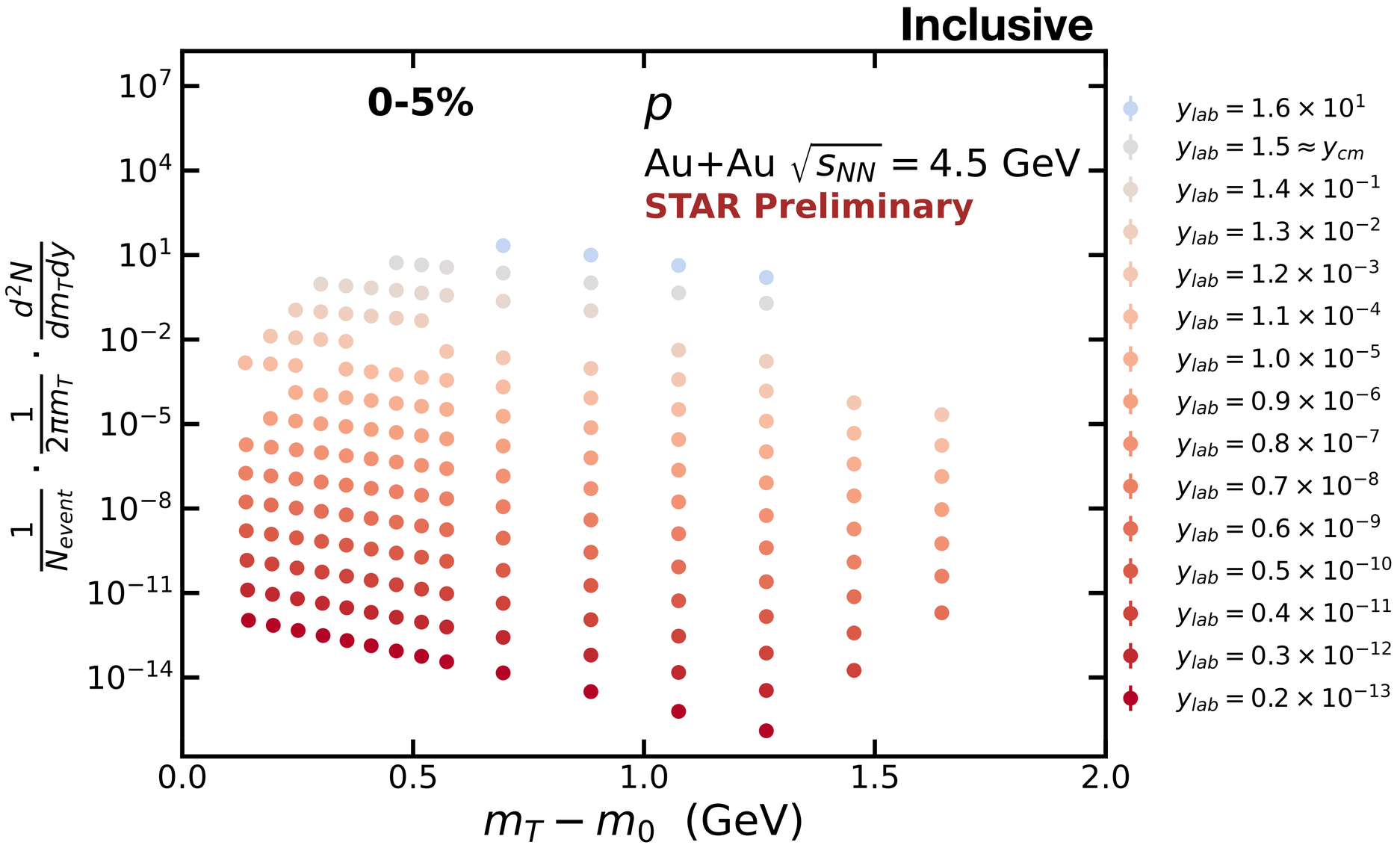
Projection (p = 1 GeV)



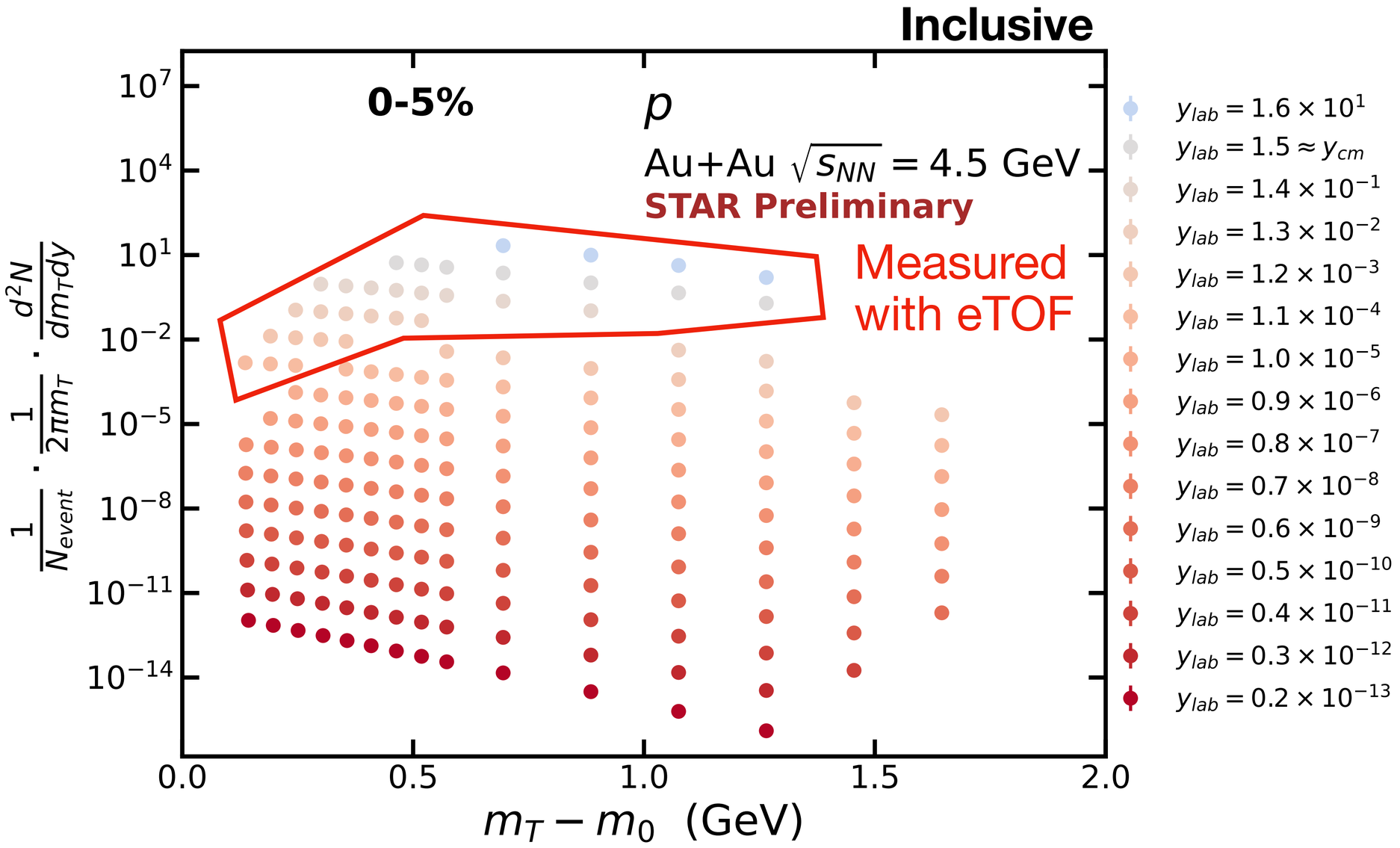
Spectra with eTOF

- Spectra measurements are a key measurement in BES-II
    - Thermal modeling can give μ_B, T at chemical freeze-out
    - Study baryon stopping with proton dN/dy
- eTOF is critical for a spectra analysis in FXT
- Allows us to measure midrapidity
- Allows us to constrain dN/dy measurements

Spectra with eTOF



Spectra with eTOF



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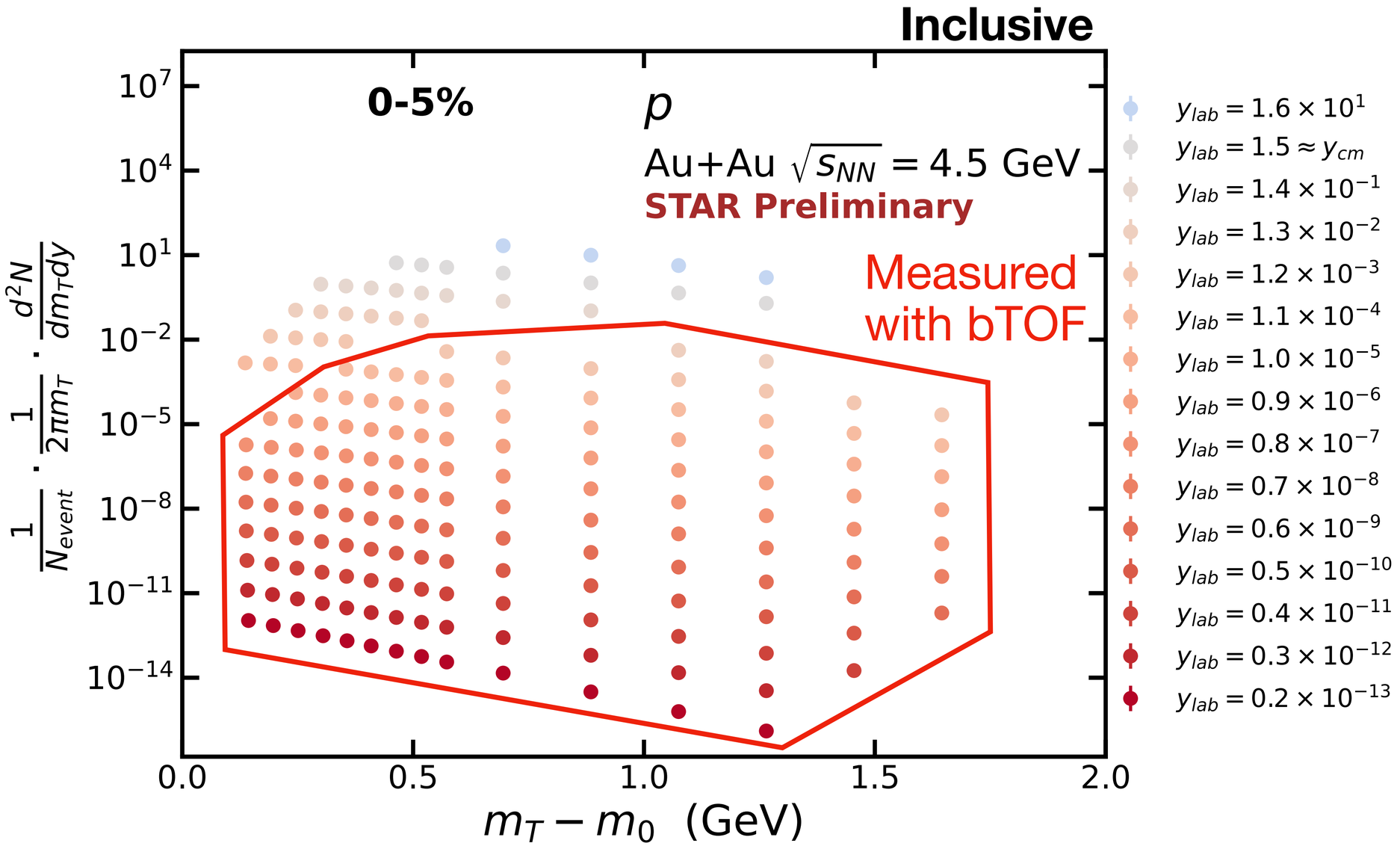

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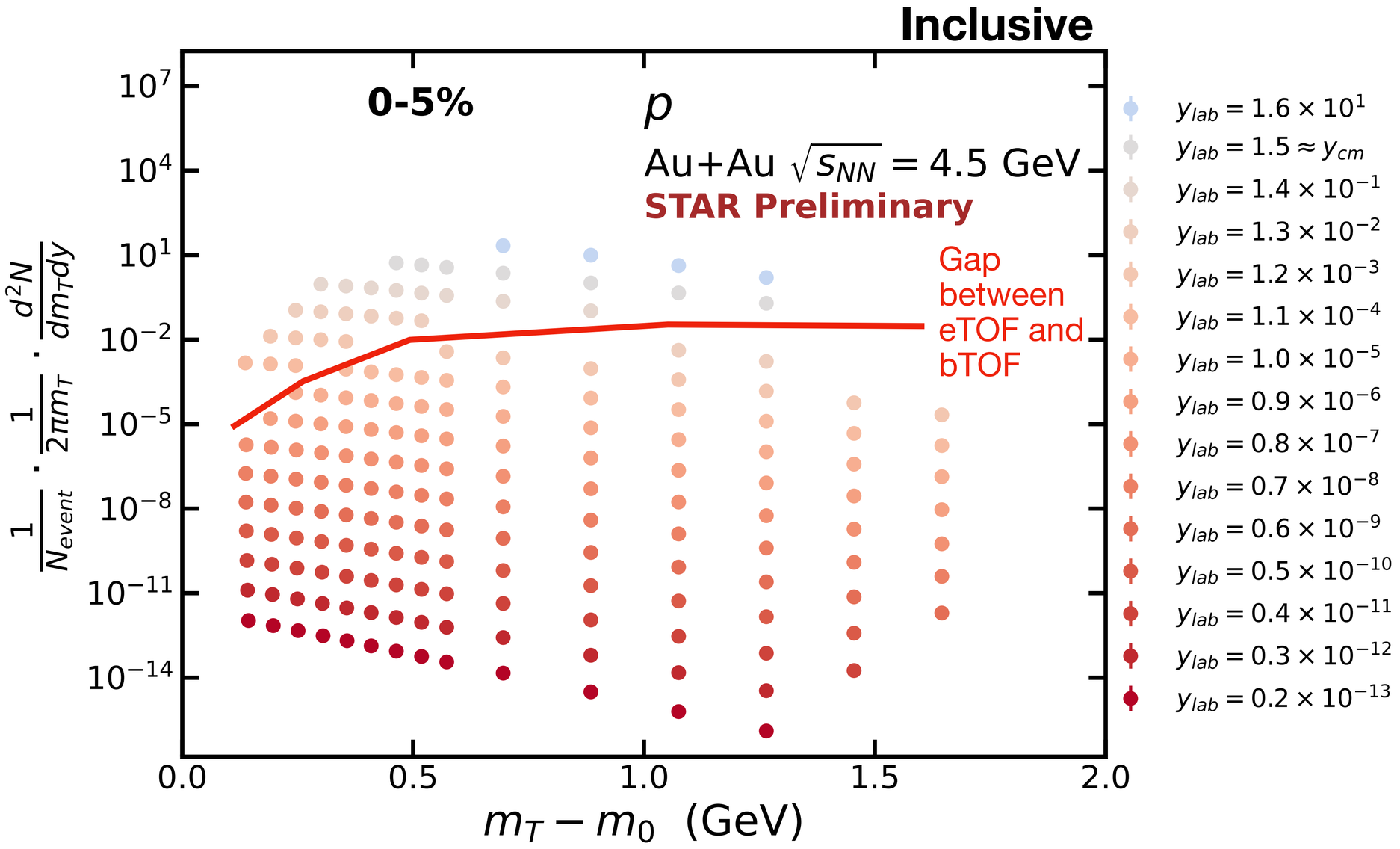
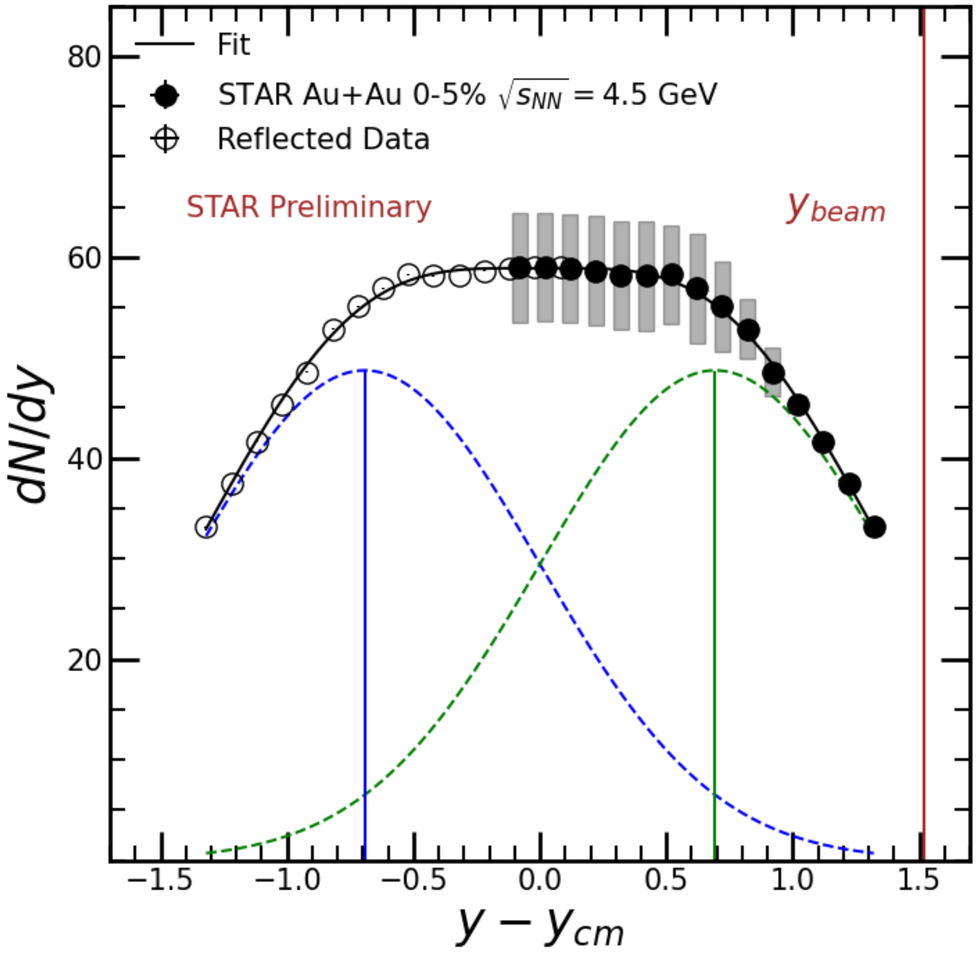
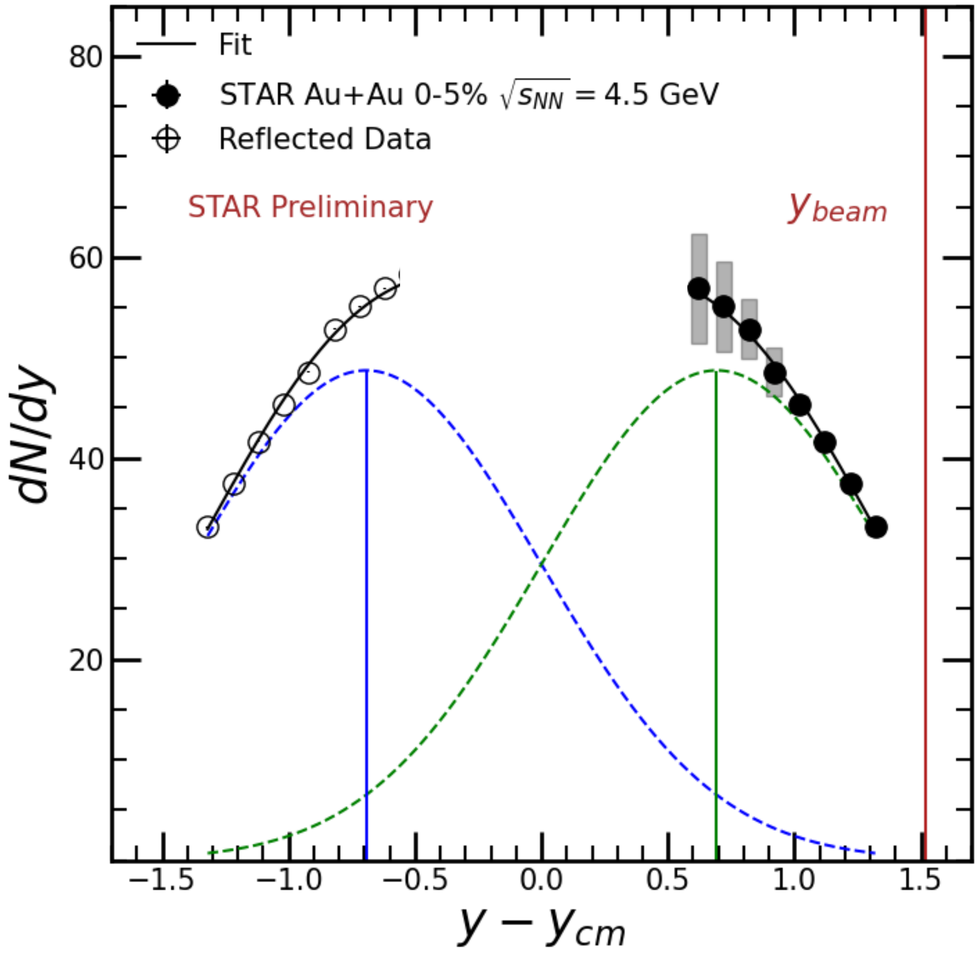


Proton dN/dy

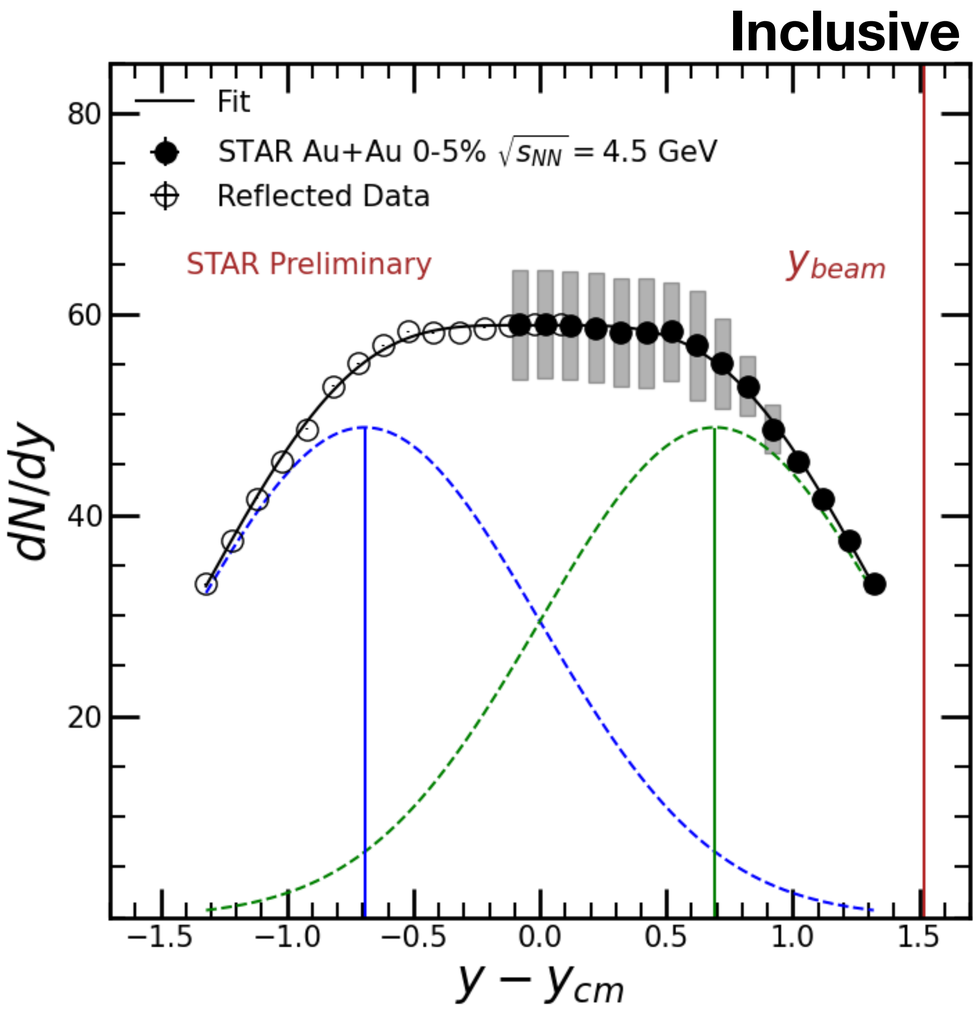
With eTOF **Inclusive**



No eTOF **Inclusive**



Proton dN/dy



- eTOF allows us to constrain the shape of the dN/dy distribution near midrapidity
- Very important in the context of baryon stopping
- Also important in light nuclei ratios

Conclusion

- Time-of-flight detector on the STAR endocarp
- Extends the phase space accessible for physics analysis
- **Critical for FXT -** allows for the recovery of midrapidty
- eTOF is already giving us results!
    - Recently at Quark Matter 2025: QCD critical point search, π, K, p spectra