Analysis Status of S490

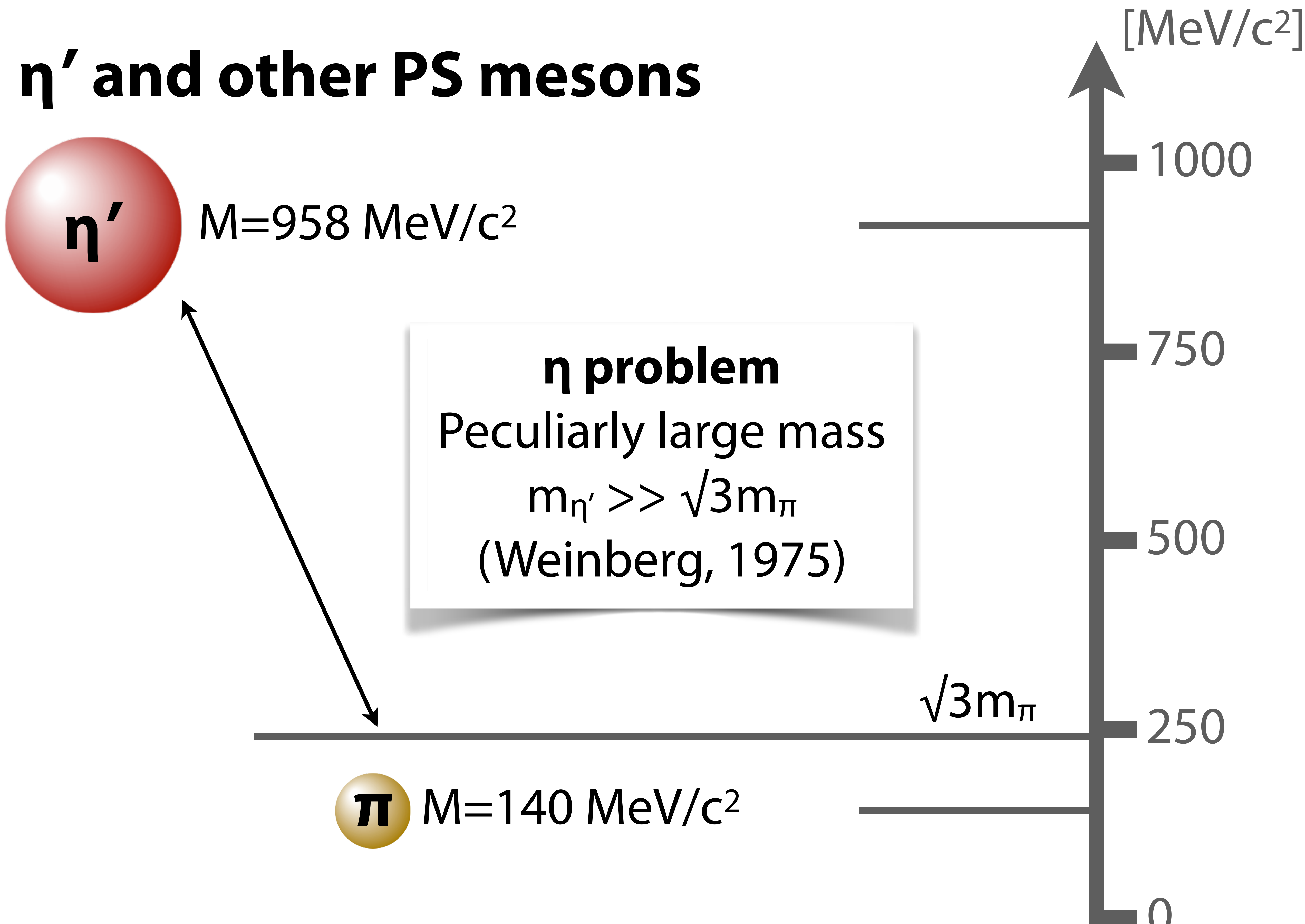
Experimental Search for η′-mesic Nuclei

Kenta Itahashi

on behalf of

EtaPrime Collaboration

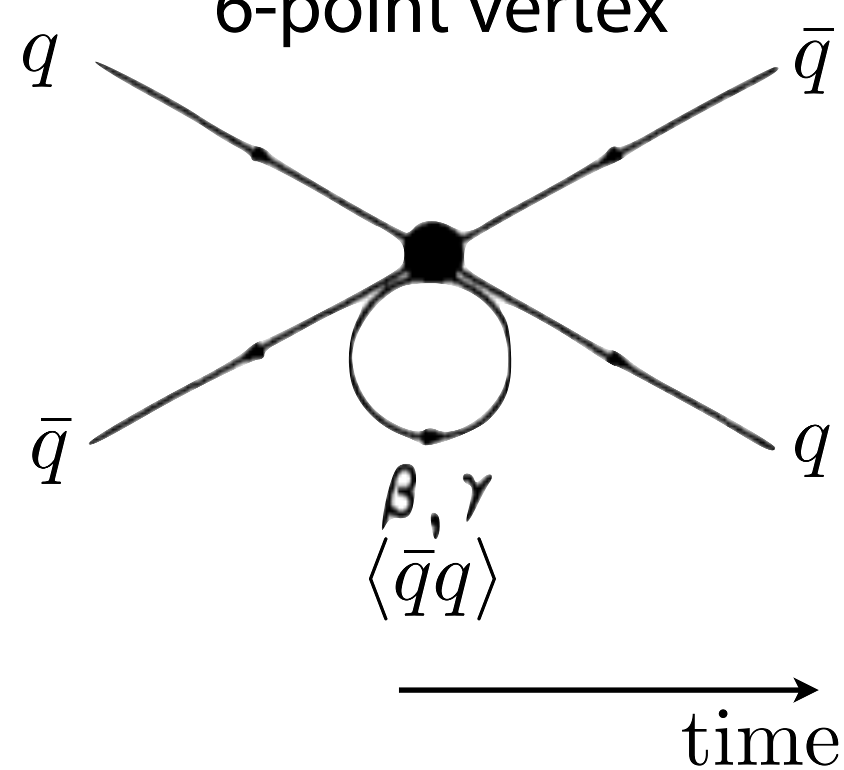
η′ and other PS mesons



η′ = axial U(1) anomaly × chiral condensate

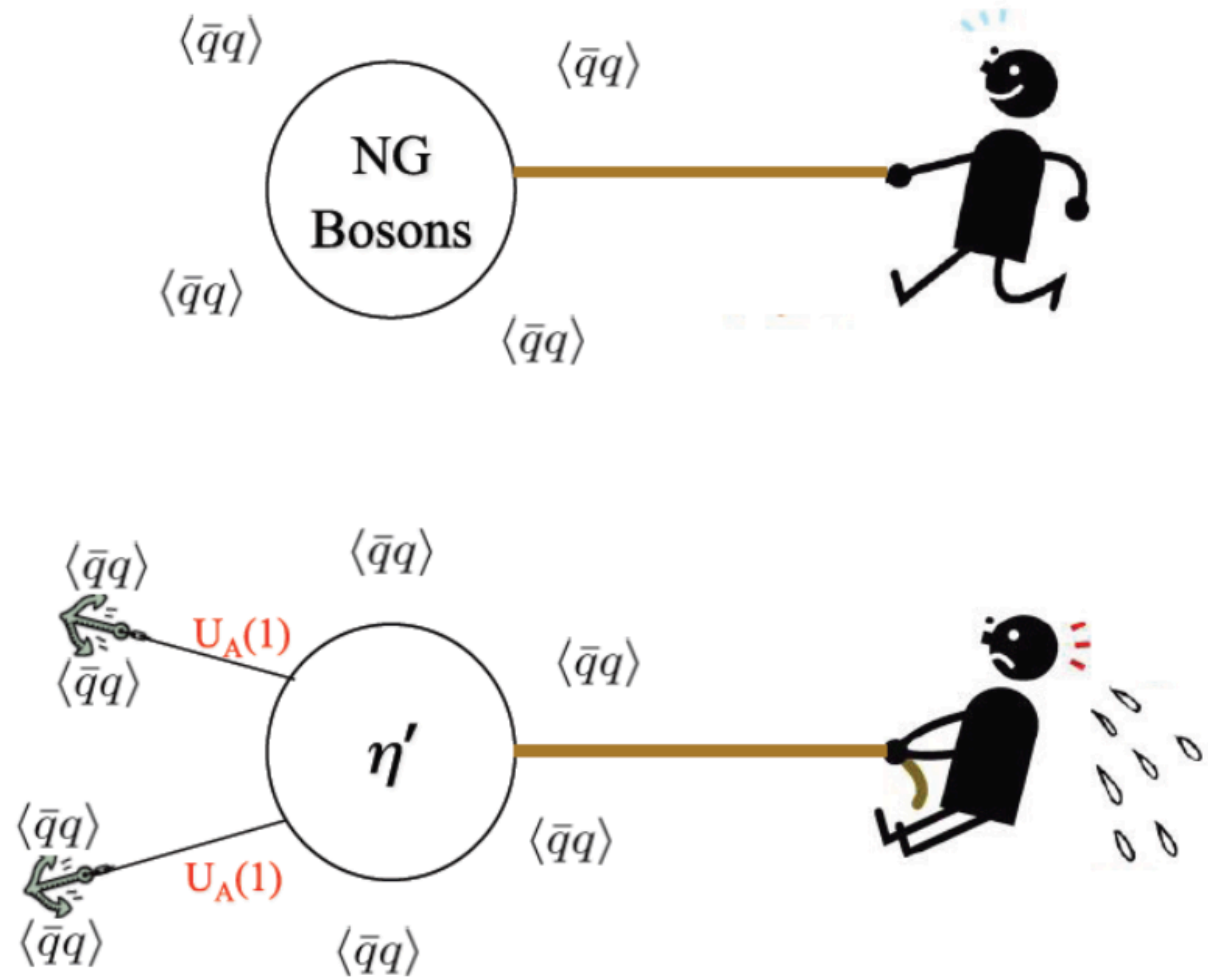
$U_A(1)$ symmetry breaking term of effective Lagrangian

6-point vertex



Kobayashi-Maskawa-'t Hooft interaction

Kobayashi, Maskawa, PTP44(70)1422
't Hooft, PRD14(76)3432.
T. Kunihiro, Phys. Lett. B219(89)363.
Klimt, Lutz, Vogl, Weise, NPA516(90)429.



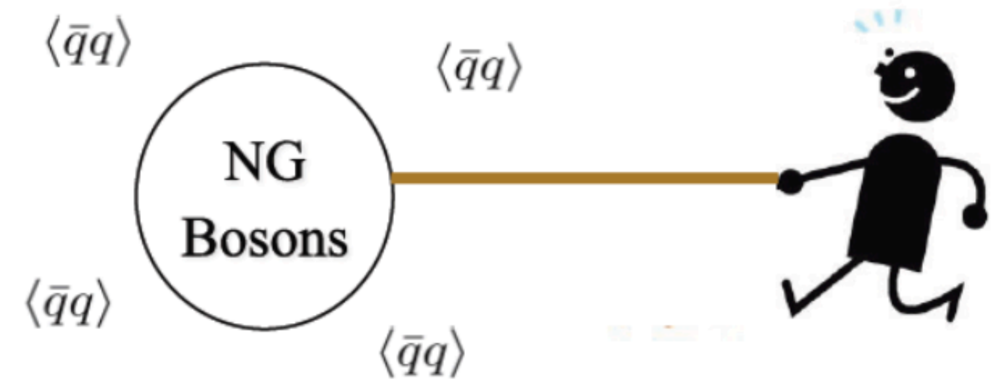
Hirenzaki

40% reduction of <qq> leads to considerably large η′ mass drop
→ Attractive potential
→ Existence of bound states

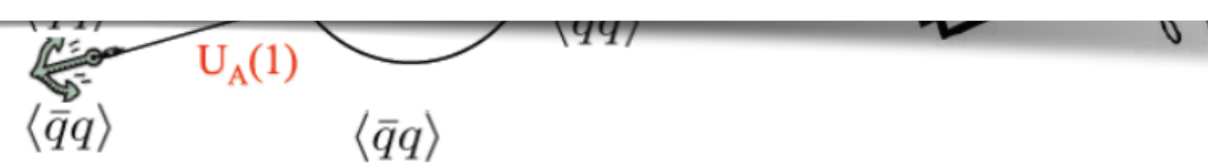
η′ = axial U(1) anomaly × chiral condensate

$U_A(1)$ symmetry breaking term of effective Lagrangian

6-point vertex



η′-mesic nuclei will give us a hint of understanding the structure of the vacuum



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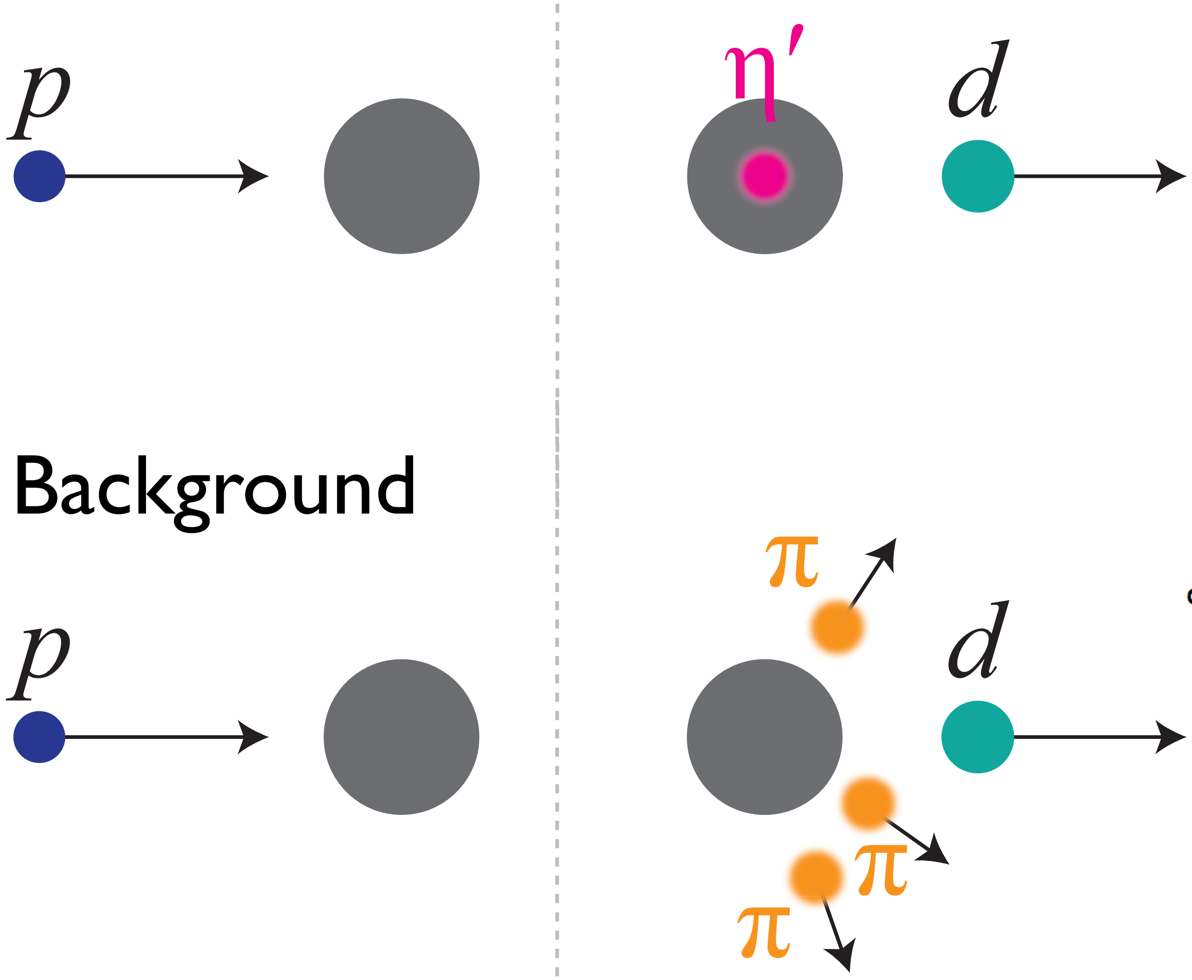
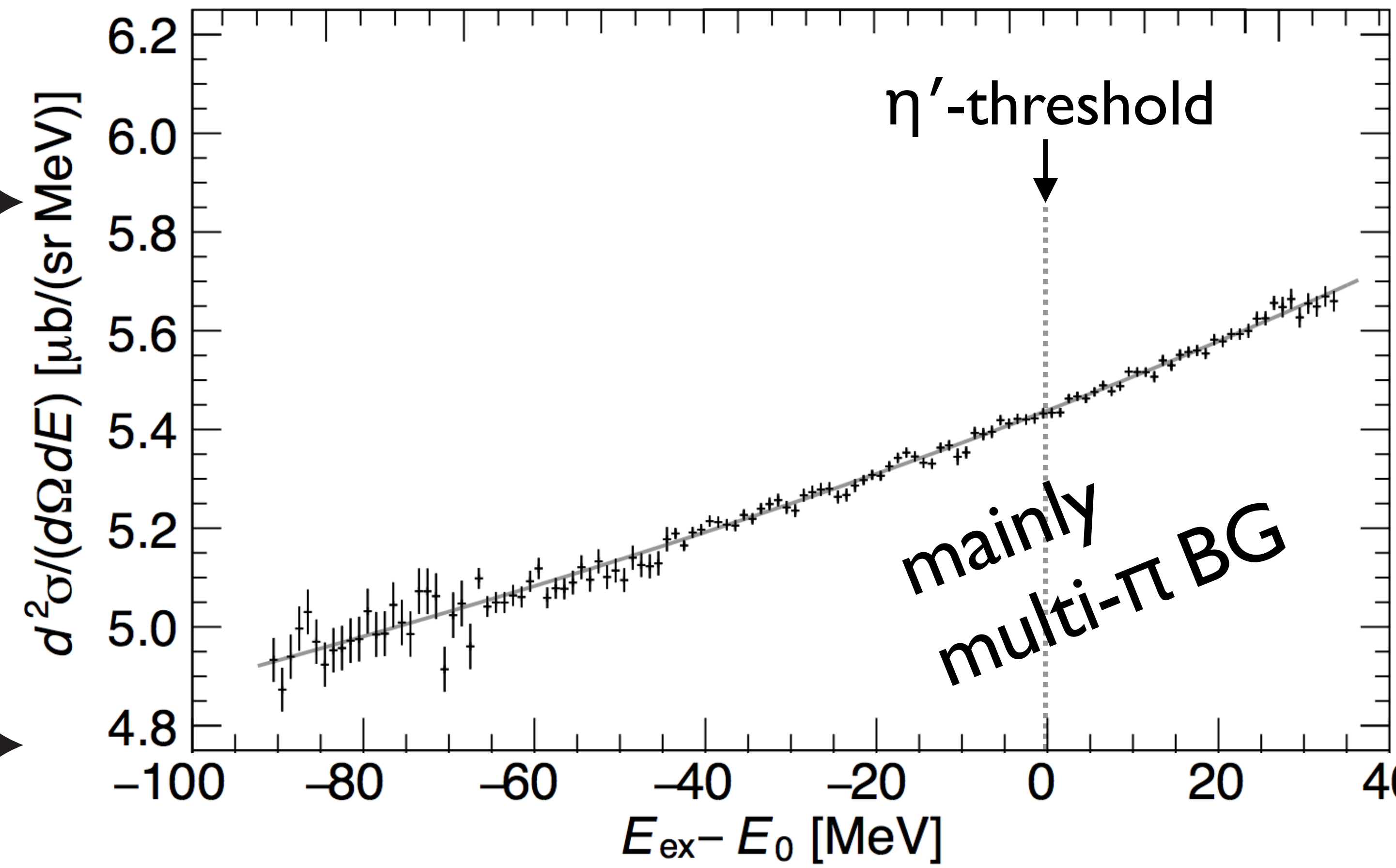
Step1: Missing-mass of (*p*,*d*) inclusive measurement



S437 ^{12}C(*p*,*d*) in 2014 at FRS/GSI

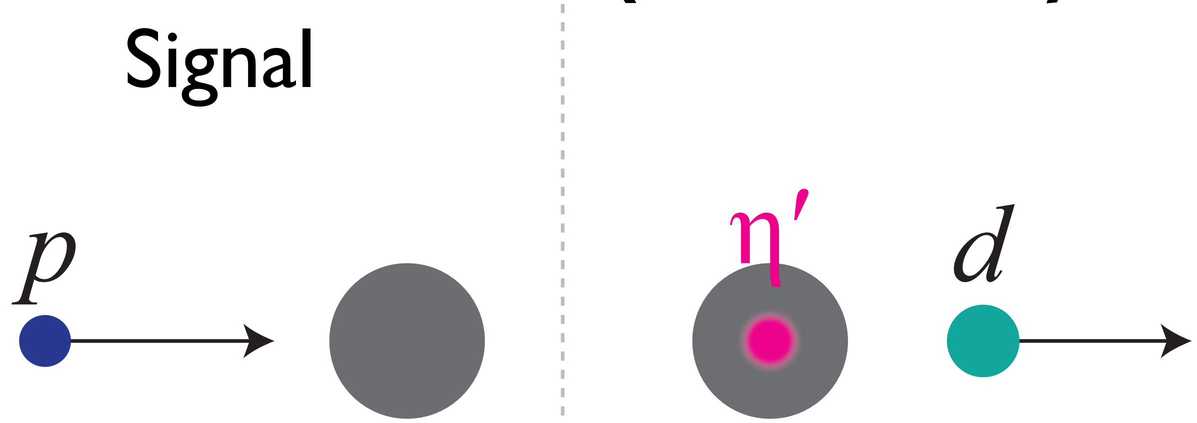


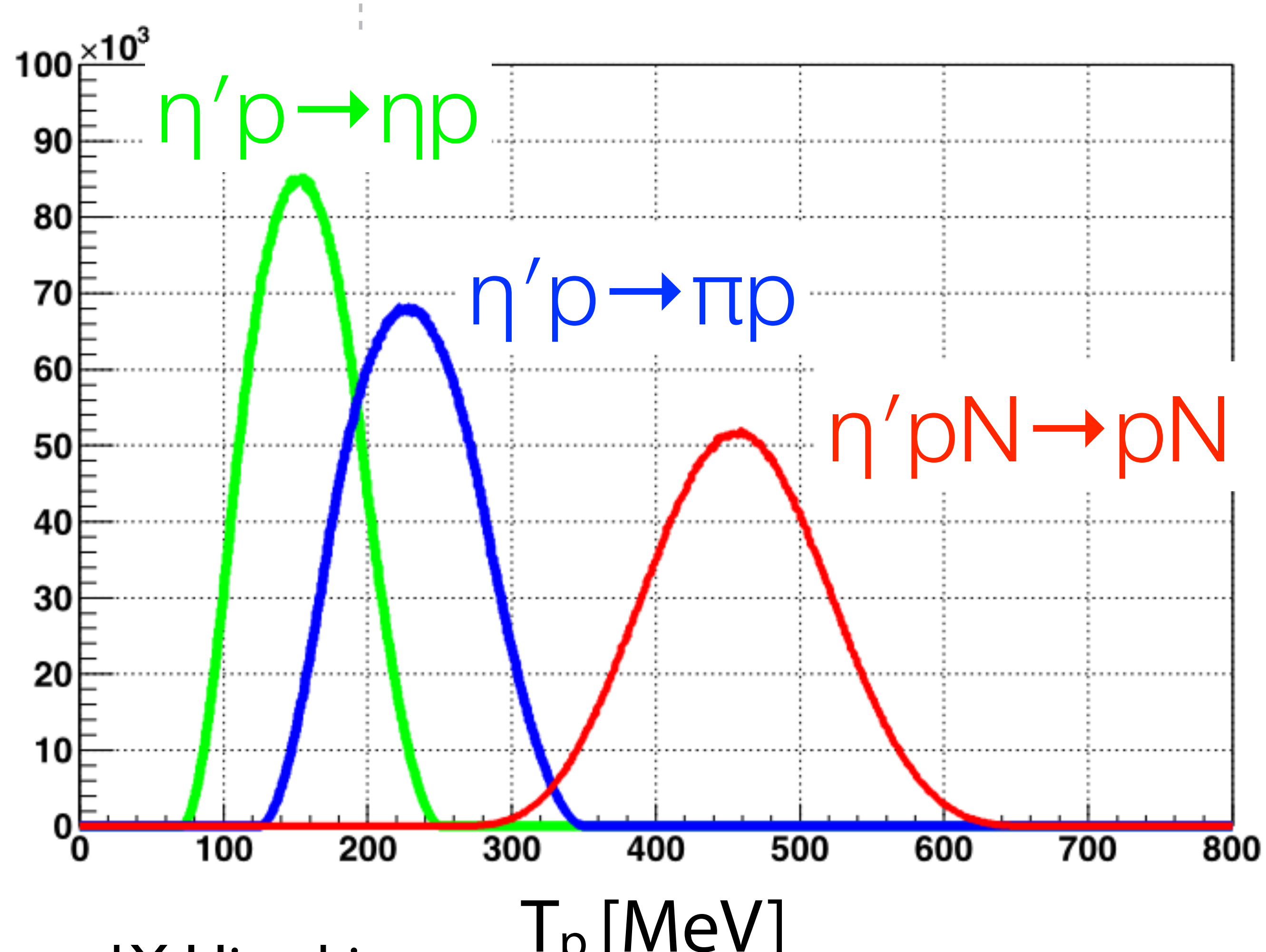
Y.K. Tanaka et al., Phys. Rev. Lett. **117**, 202501(2016)

We achieved extremely high statistical sensitivity demonstrating very good performance of FRS.
But, no peak was observed. Major BG=multi π.
S/BG cross sections must be ~ 1/100

NiSHiNA CENTER

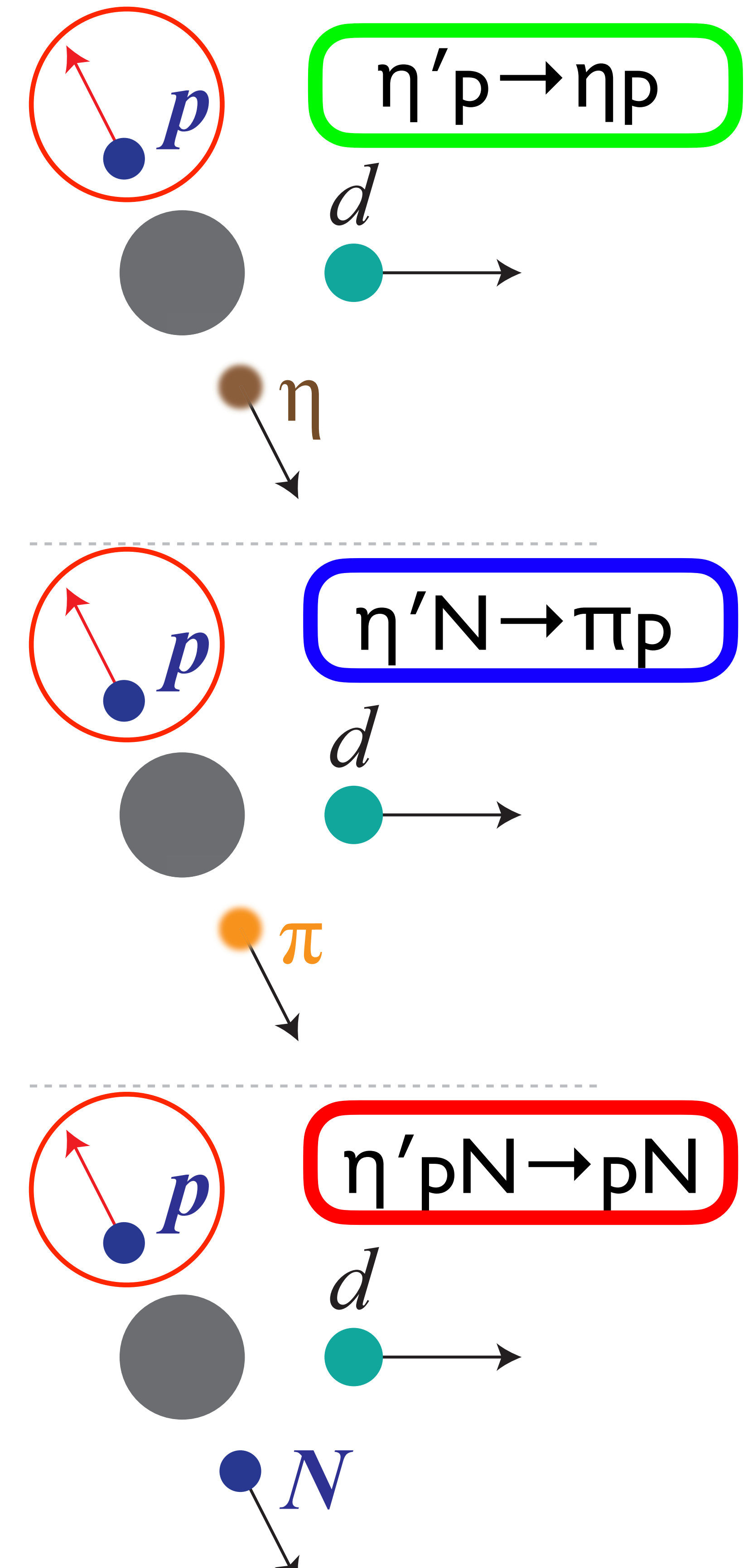
Step 2: Semi-exclusive measurement of $^{12}C(p,dp)$ reaction (GSI-S490, 2022)





Y.K. Tanaka and Y. Higashi

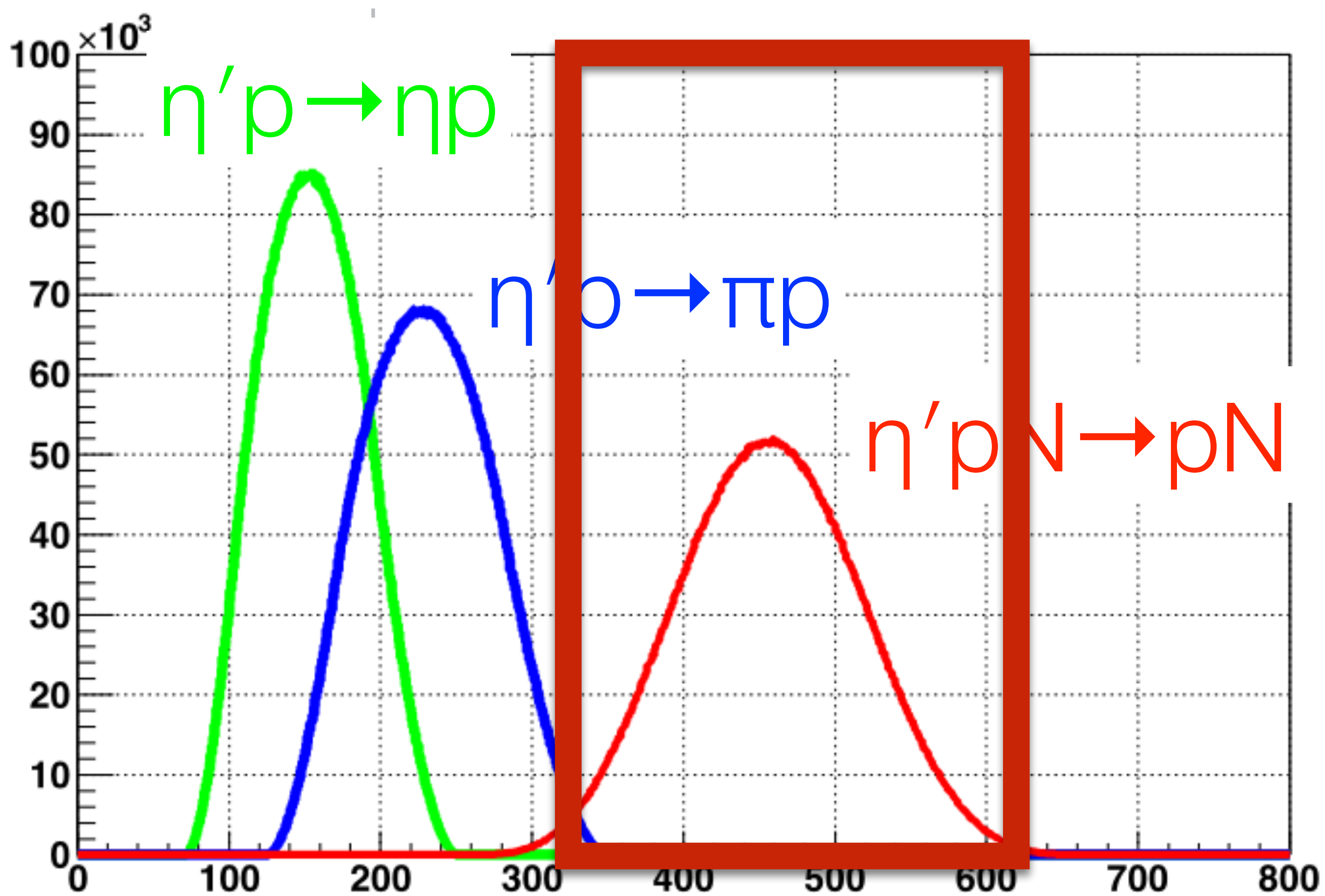
3 major decay modes of η′-mesic nuclei



Other candidate channels: ωp or KΛ

Step 2: Semi-exclusive measurement of $^{12}C(p,dp)$ reaction (GSI-S490, 2022)

Detect *p* (300-600 MeV) emitted in the decay of η′-nuclei for semi-exclusive measurement.
f ~ 100 improvement in S/BG



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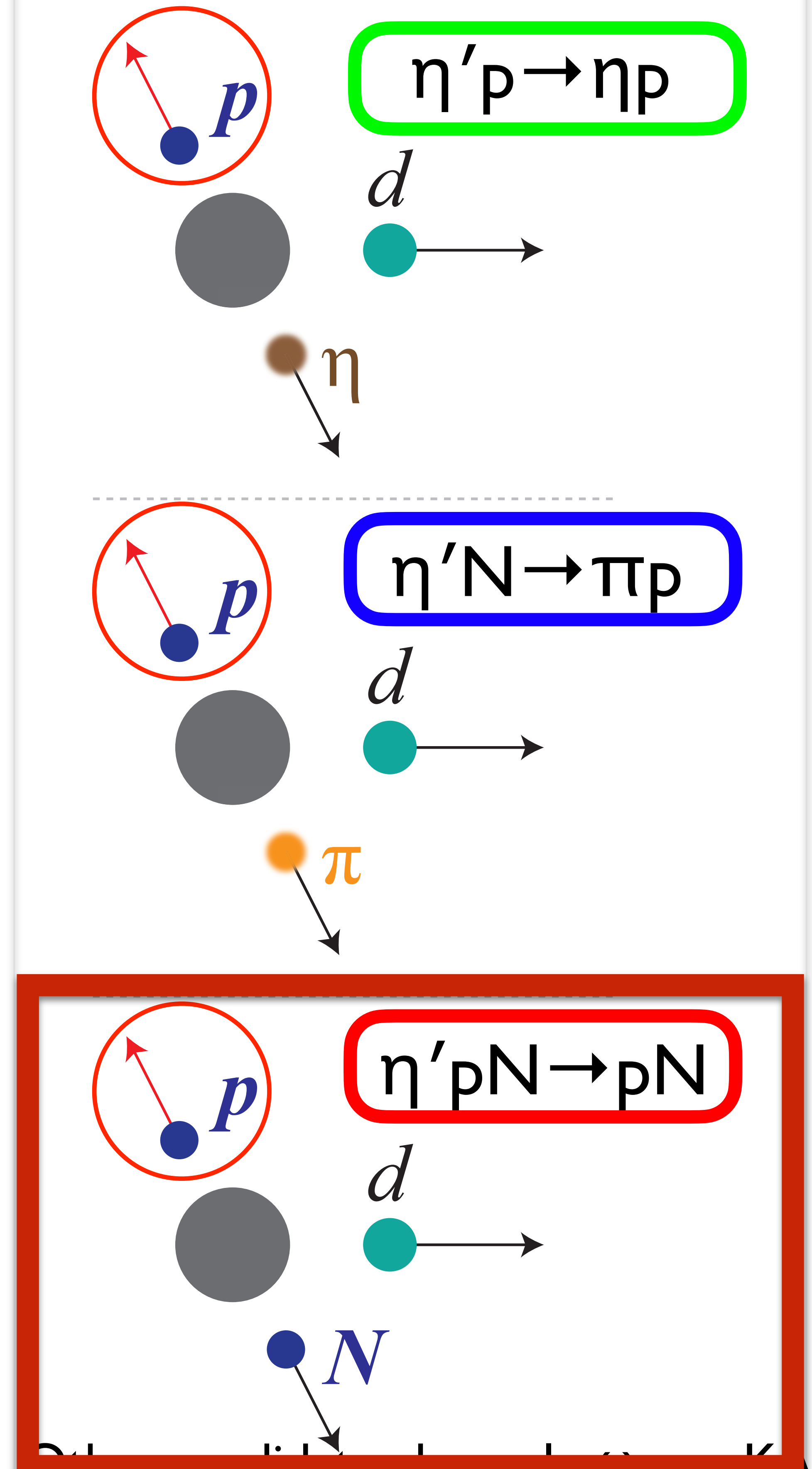
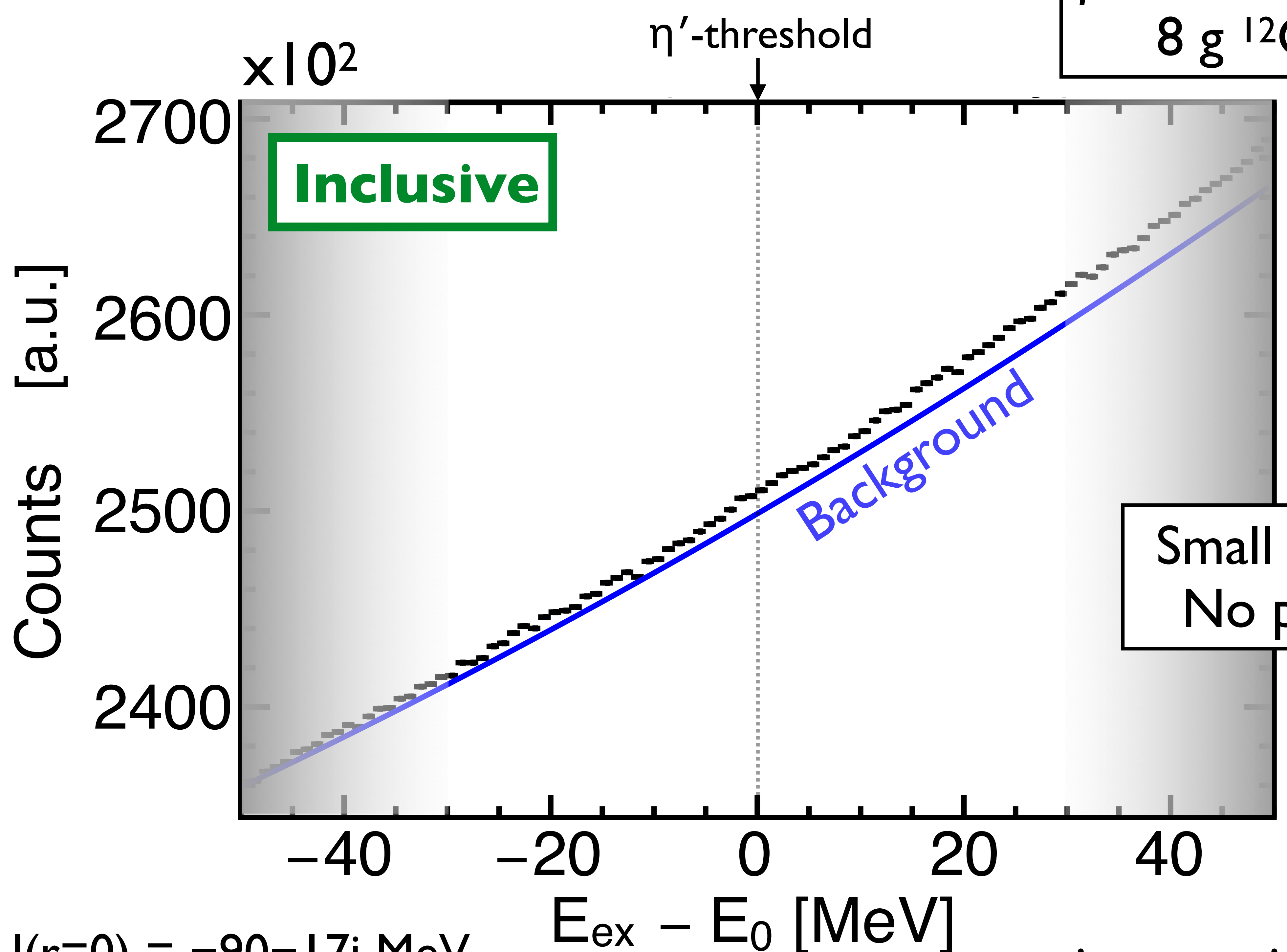


Expected spectrum in 4 days of DAQ at FRS

T_p = 2.5 GeV, ^{12}C(*p*,*d*)

p 2.5 GeV, 2.5x10^8/s,
8 g ^{12}C target



Small S/BG
No peak

U(r=0) = −90−17i MeV

microscopic transport simulation

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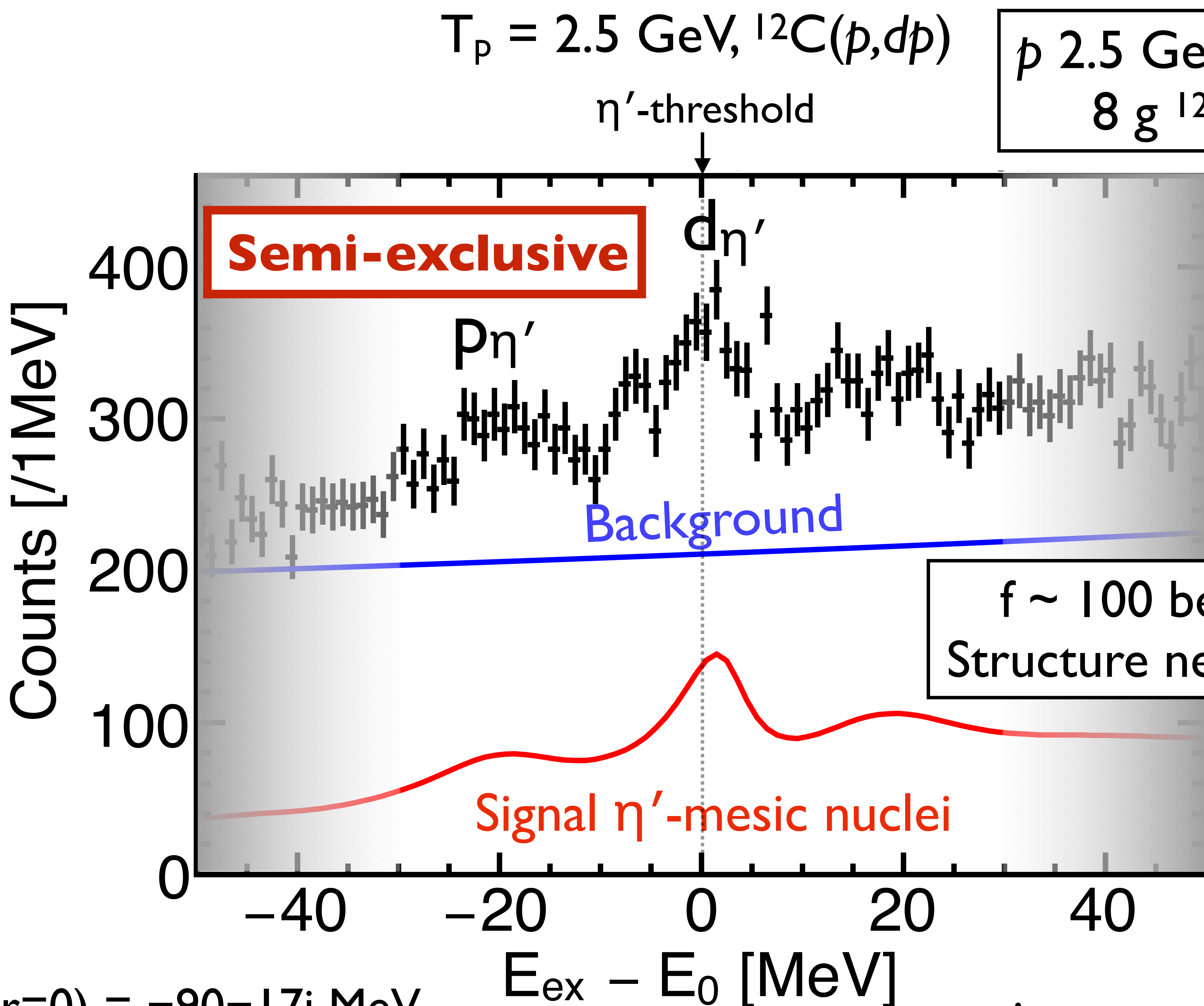
Expected spectrum in 4 days of DAQ at FRS



p 2.5 GeV, 2.5x10⁸/s, 8 g ¹²C target

f ~ 100 better S/BG
Structure near threshold

U(r=0) = −90−17i MeV

microscopic transport simulation

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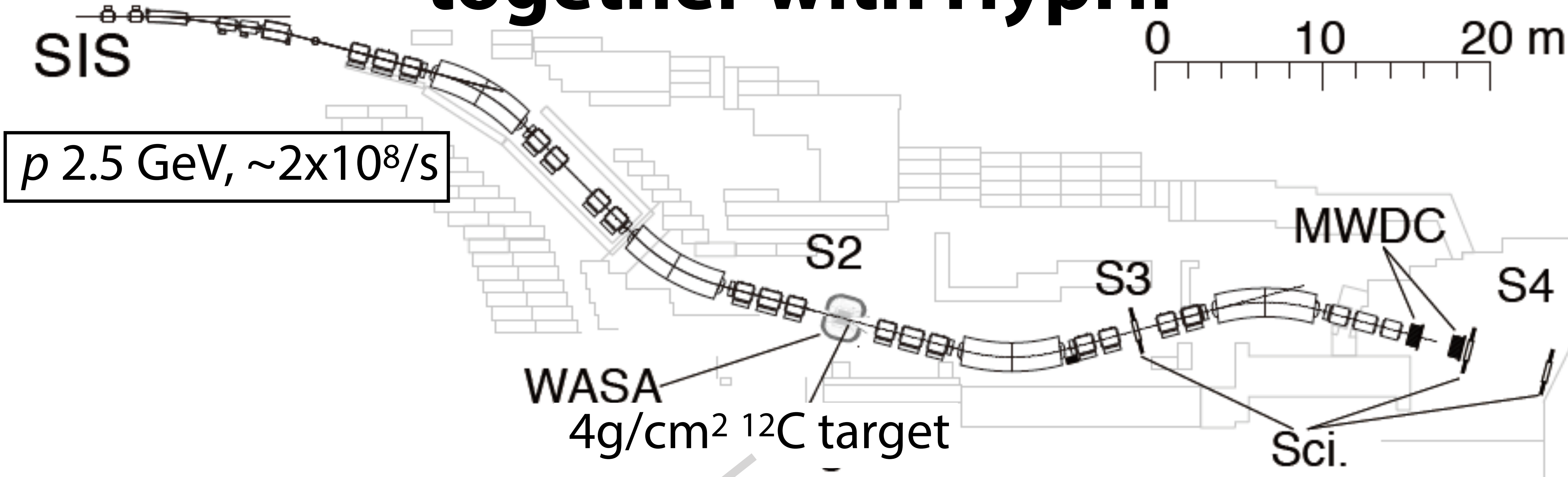
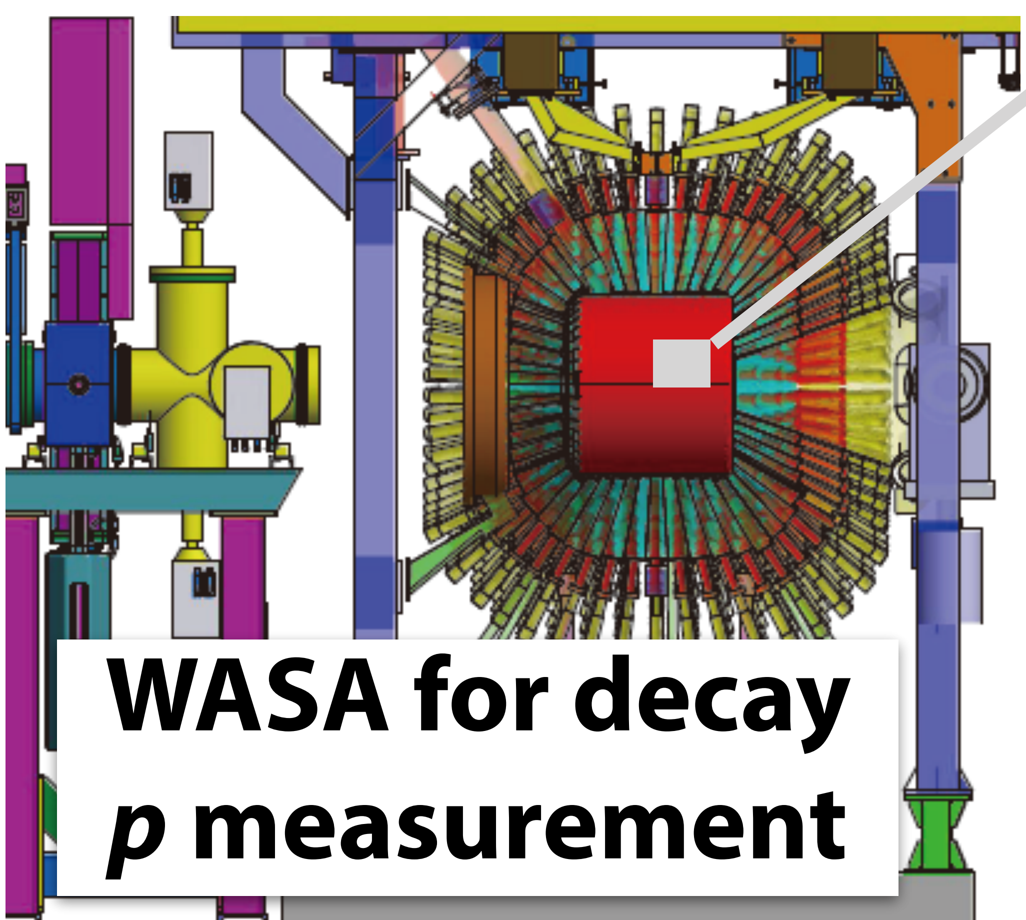
Experimental setup : ^{12}C(*p*,*dp*) in Feb. 2022 together with HypHI



Momentum analysis of (*p*,*d*) for Missing Mass Spectroscopy

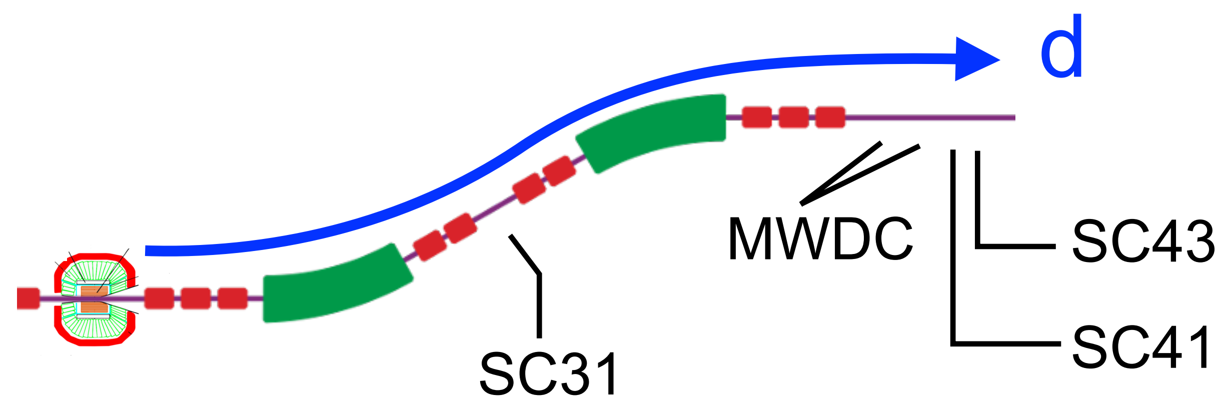


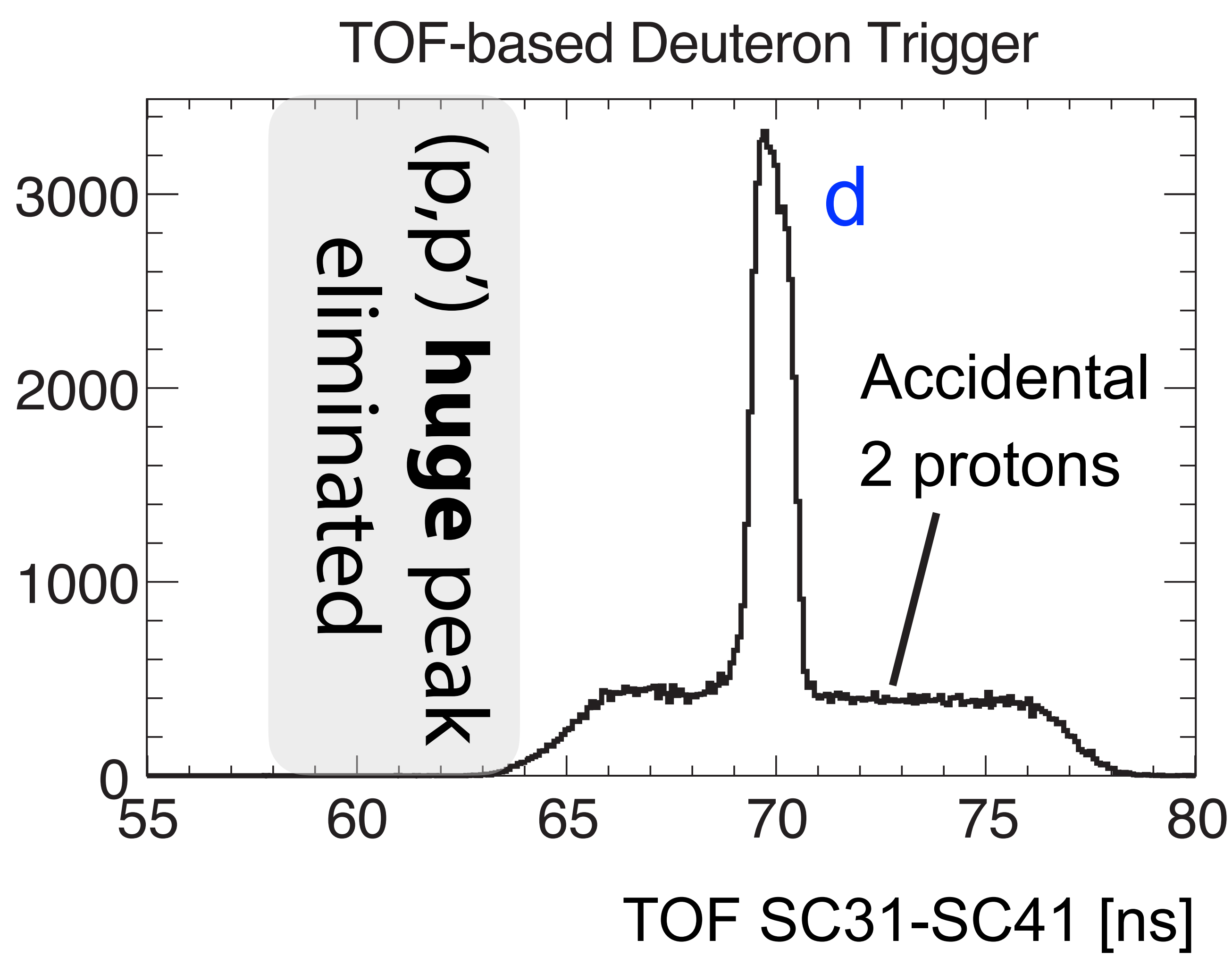
WASA for decay *p* measurement

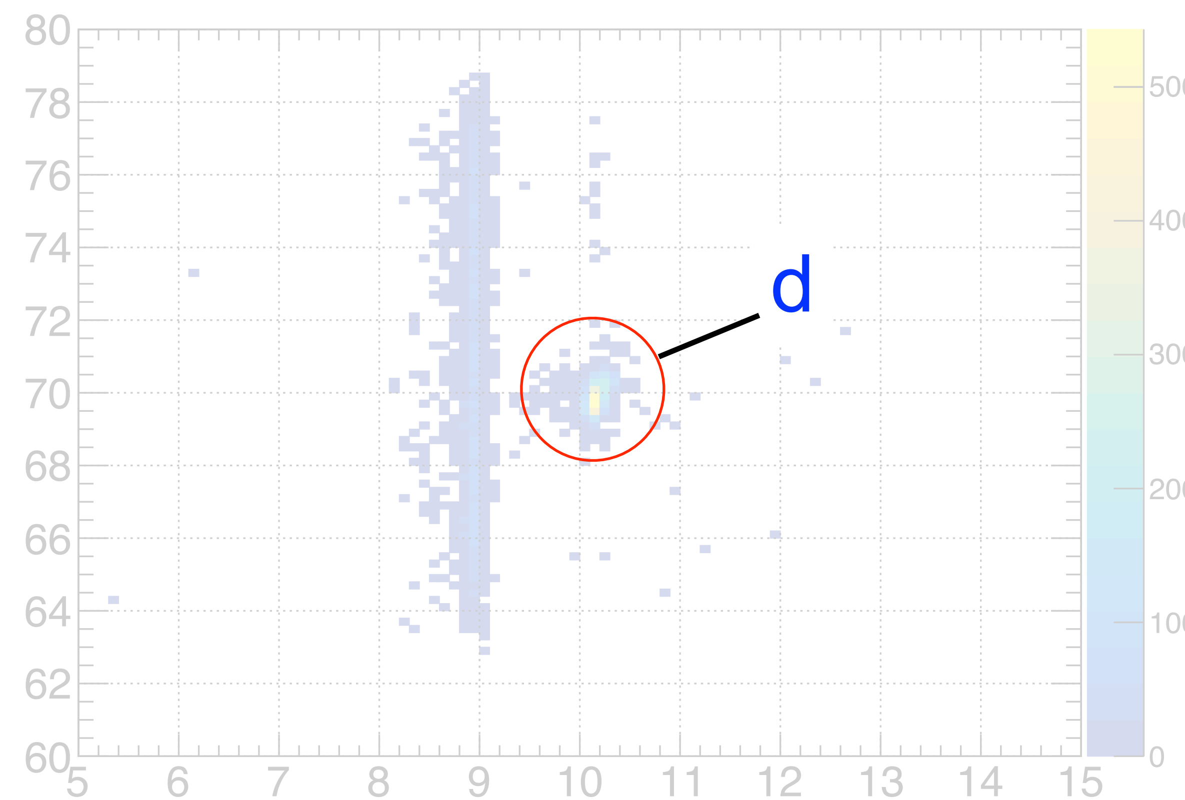
Combination of forward high-res. spectrometer and large solid angle detector

FRS S2-S4 PID Analysis

p/d **ratio at S4 >1000**
SC31-SC41 TOF trigger
→ *p/d* ratio ~10







Y.K. Tanaka

FRS S2-S4 PID Analysis

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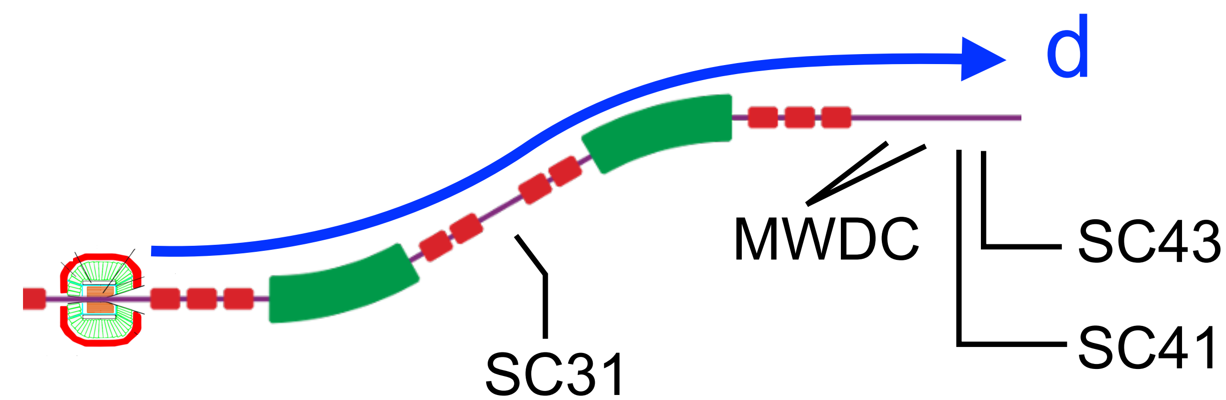
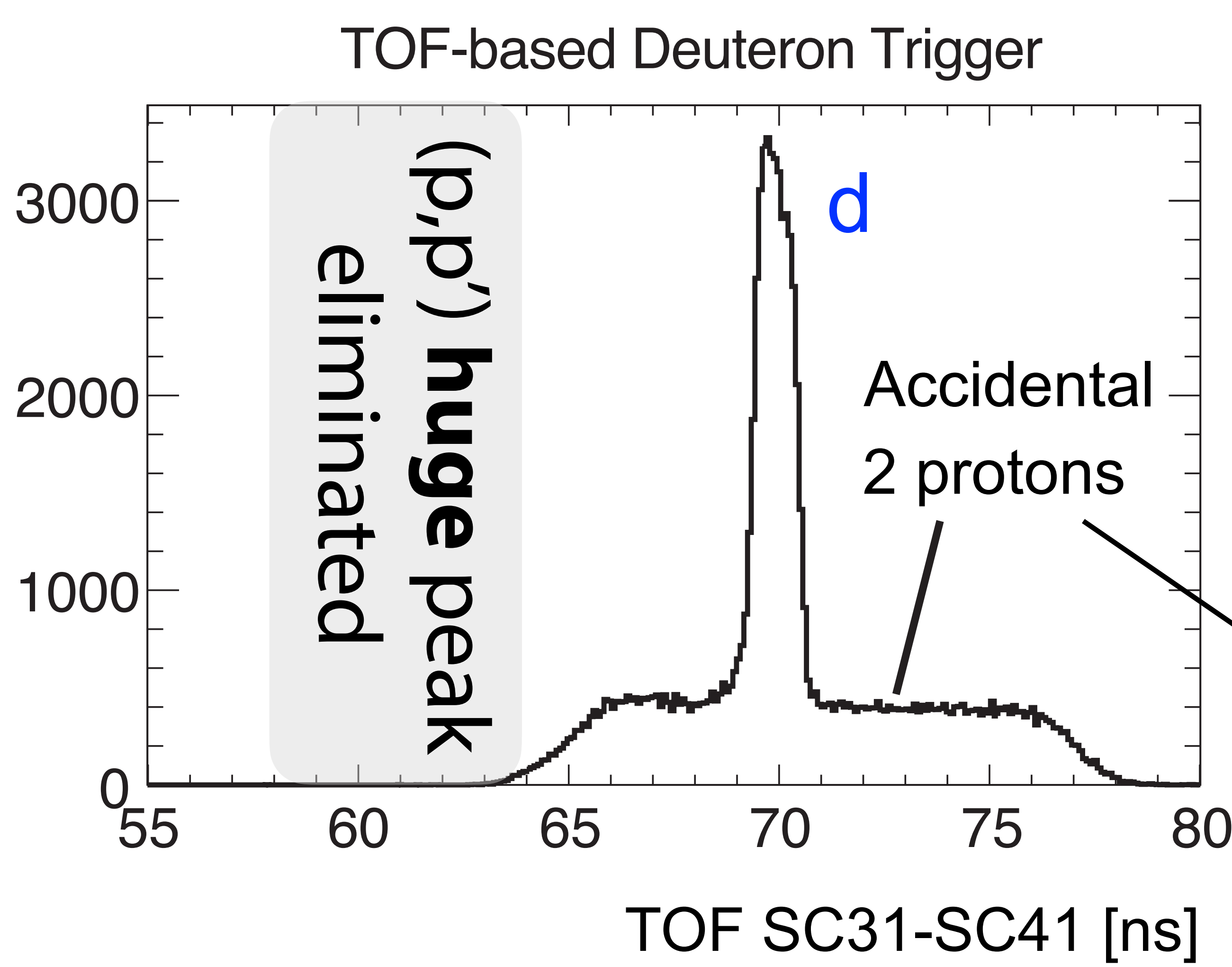
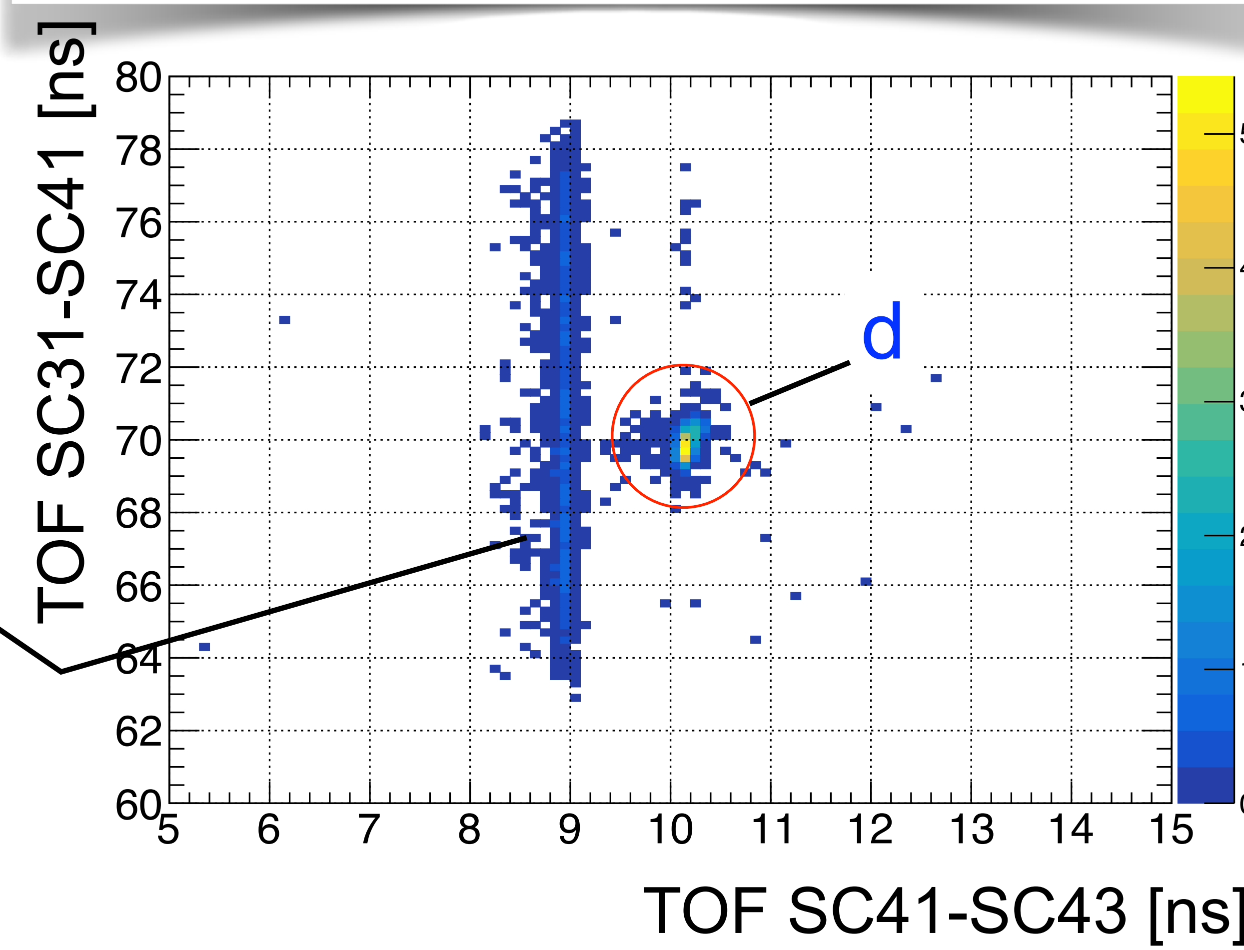
SC31-SC41 TOF trigger
→ ***p/d*** **ratio ~10**



SC31-SC41-SC43 TOF made perfect offline PID





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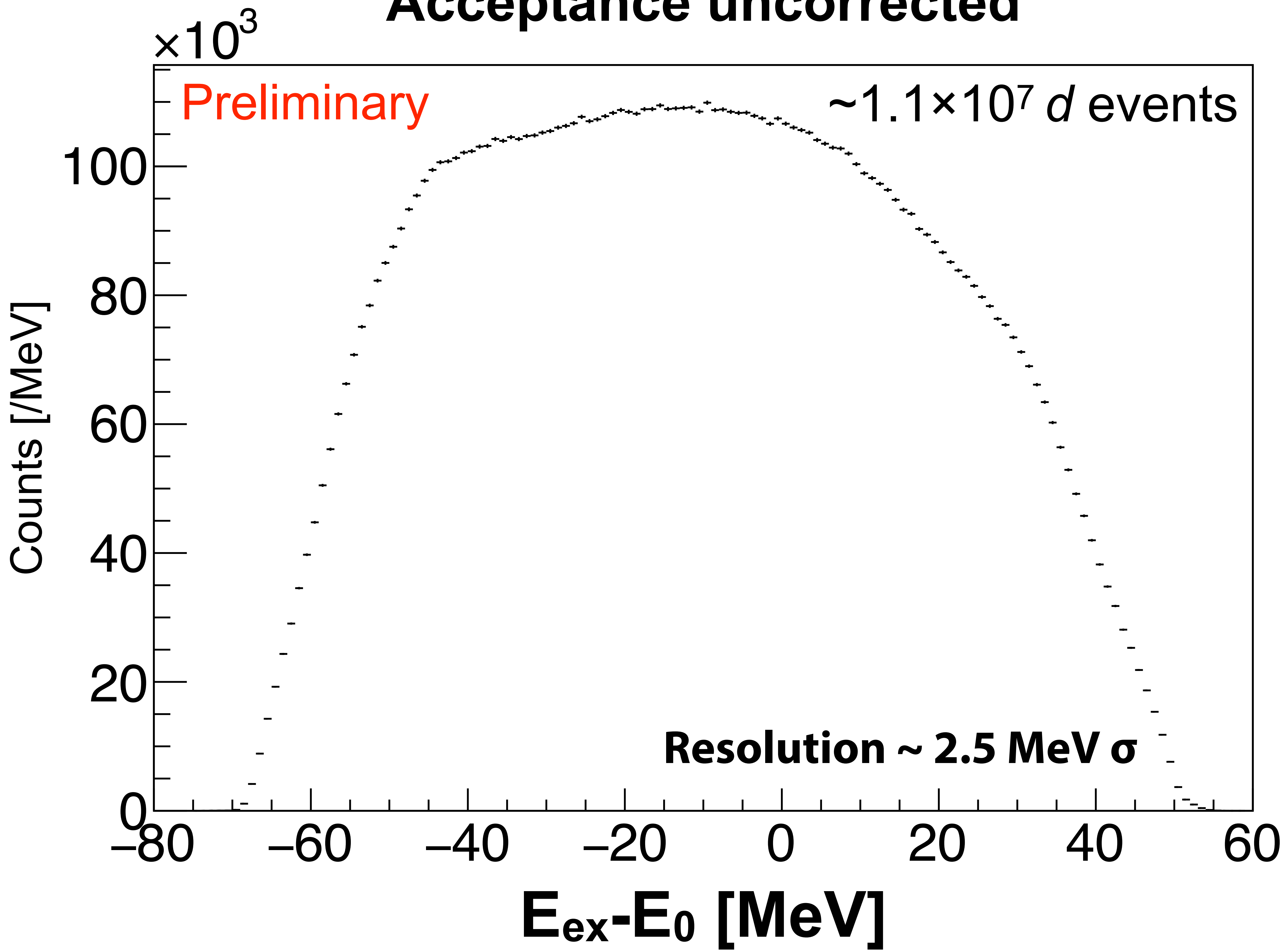
Inclusive Spectrum at S4

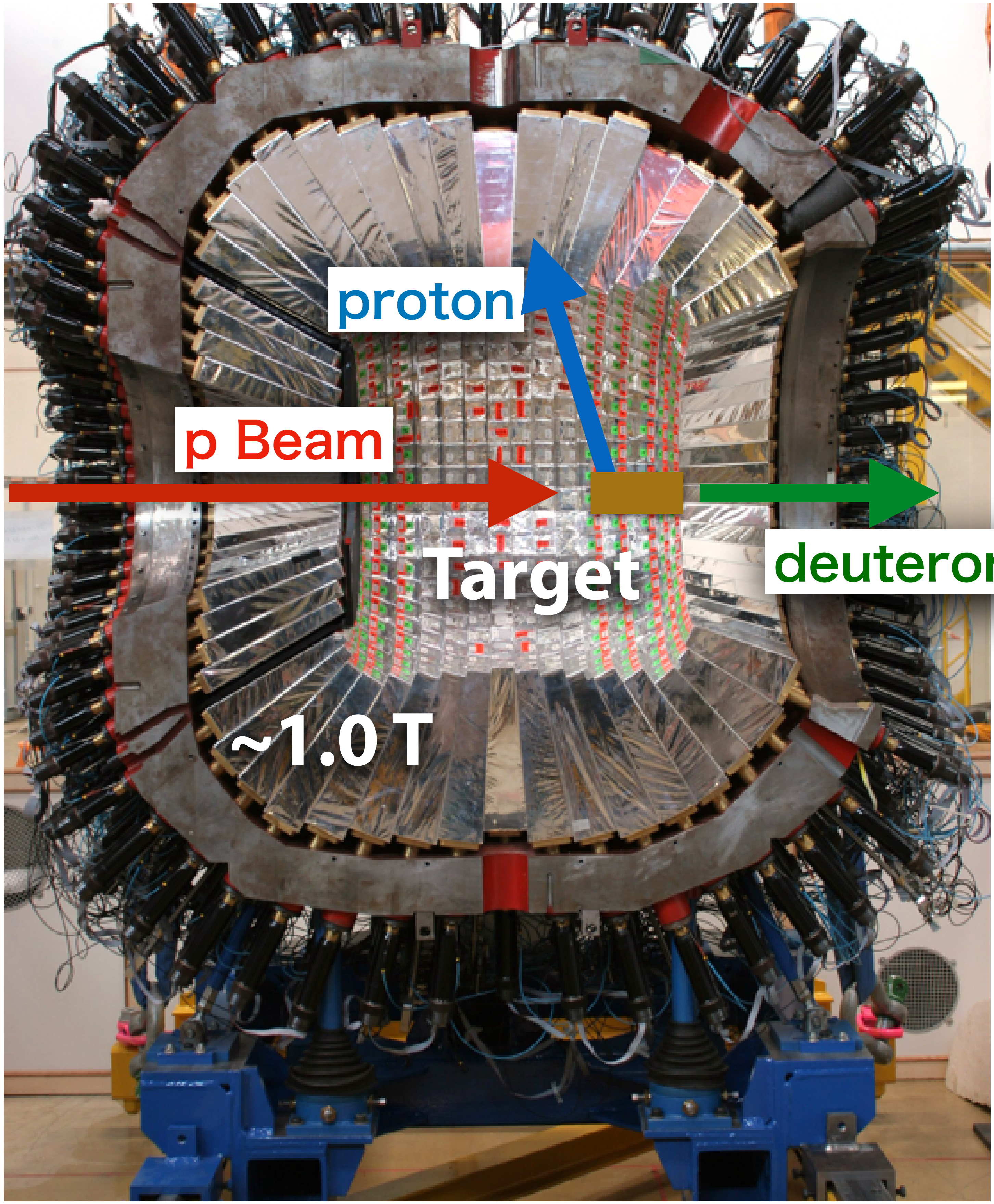
comparable to S437

Acceptance uncorrected

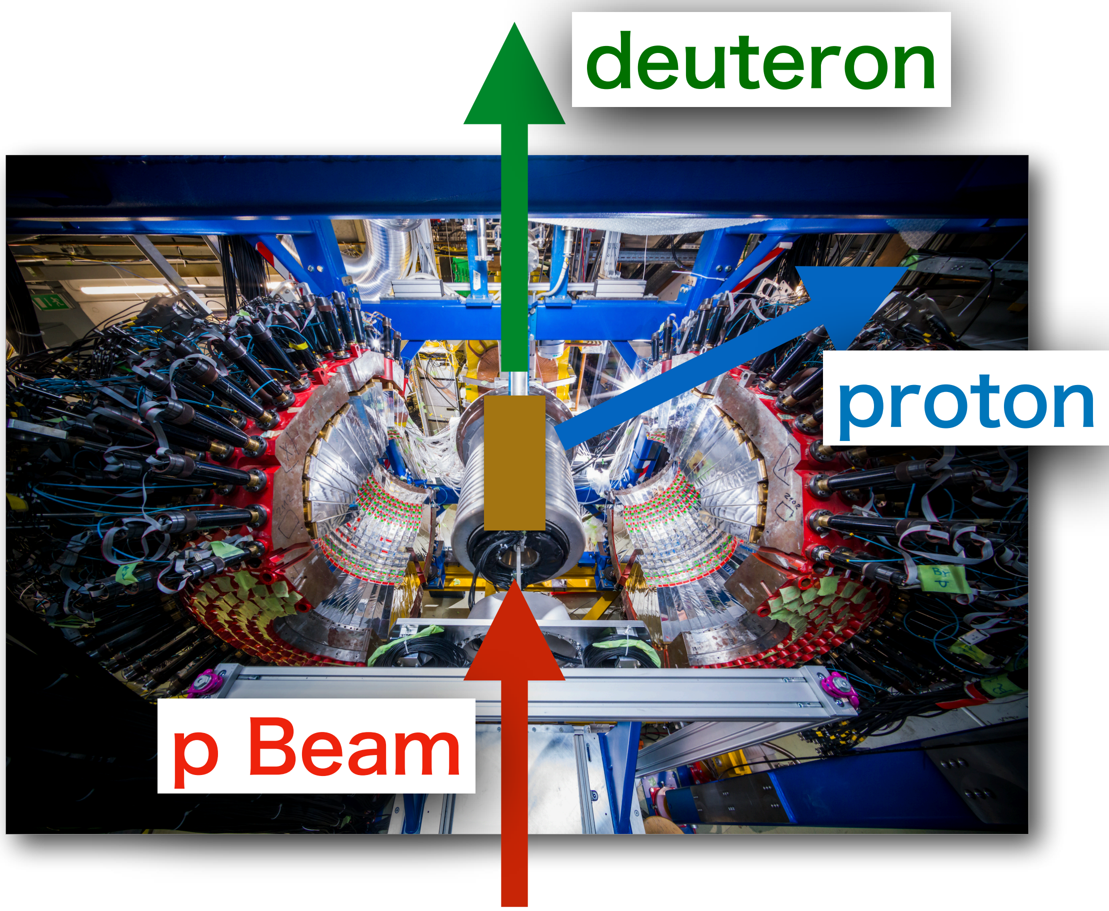


Y.K. Tanaka

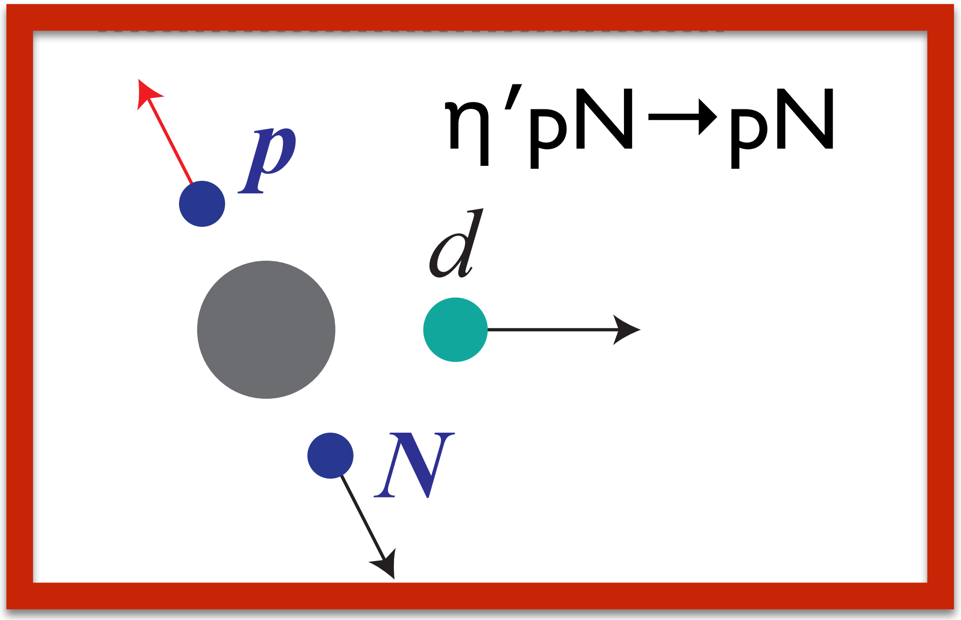
Detectors in WASA



Cooperation with COSY-WASA collaboration



High energy proton tagging in coincidence with forward *d*



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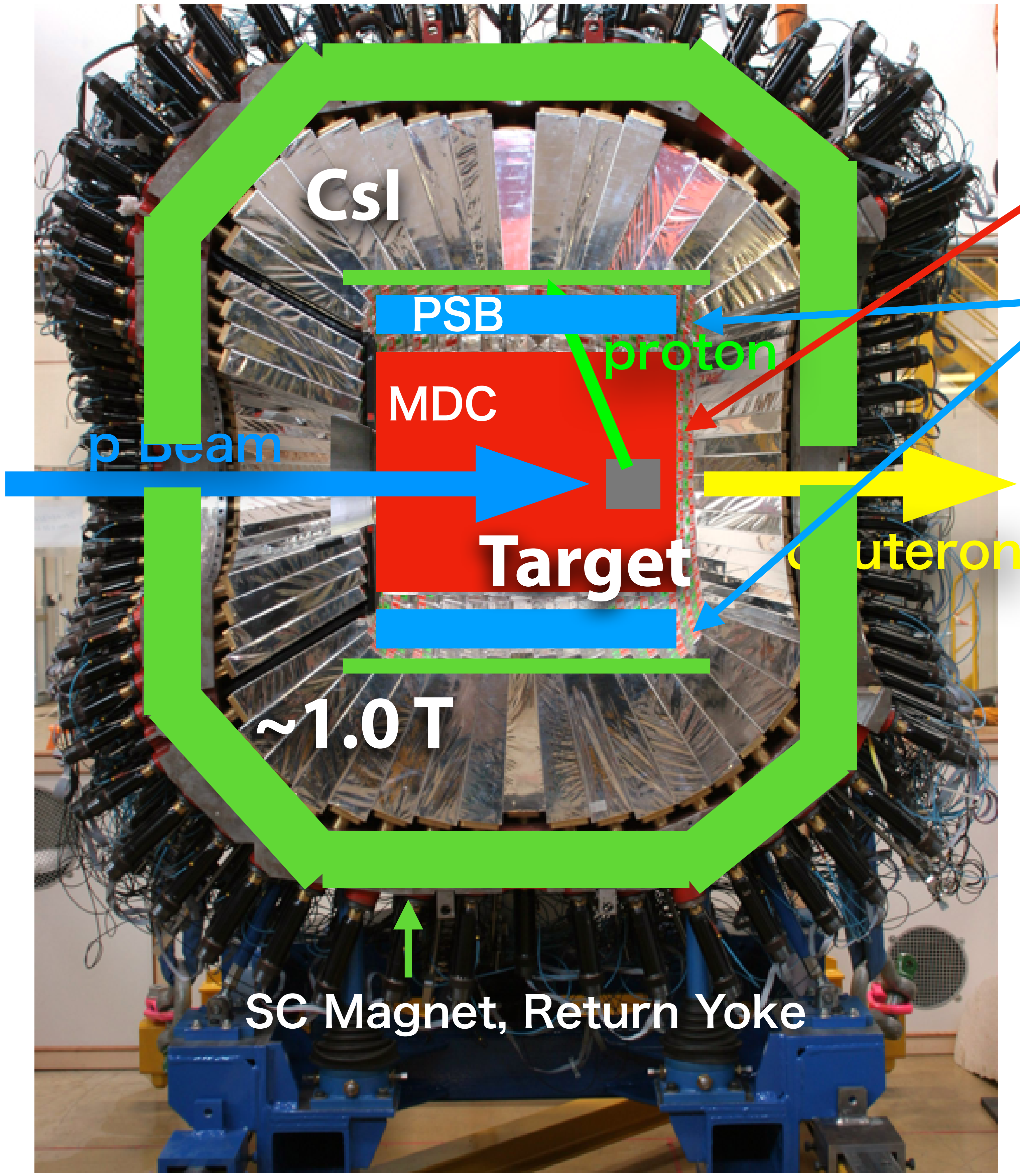
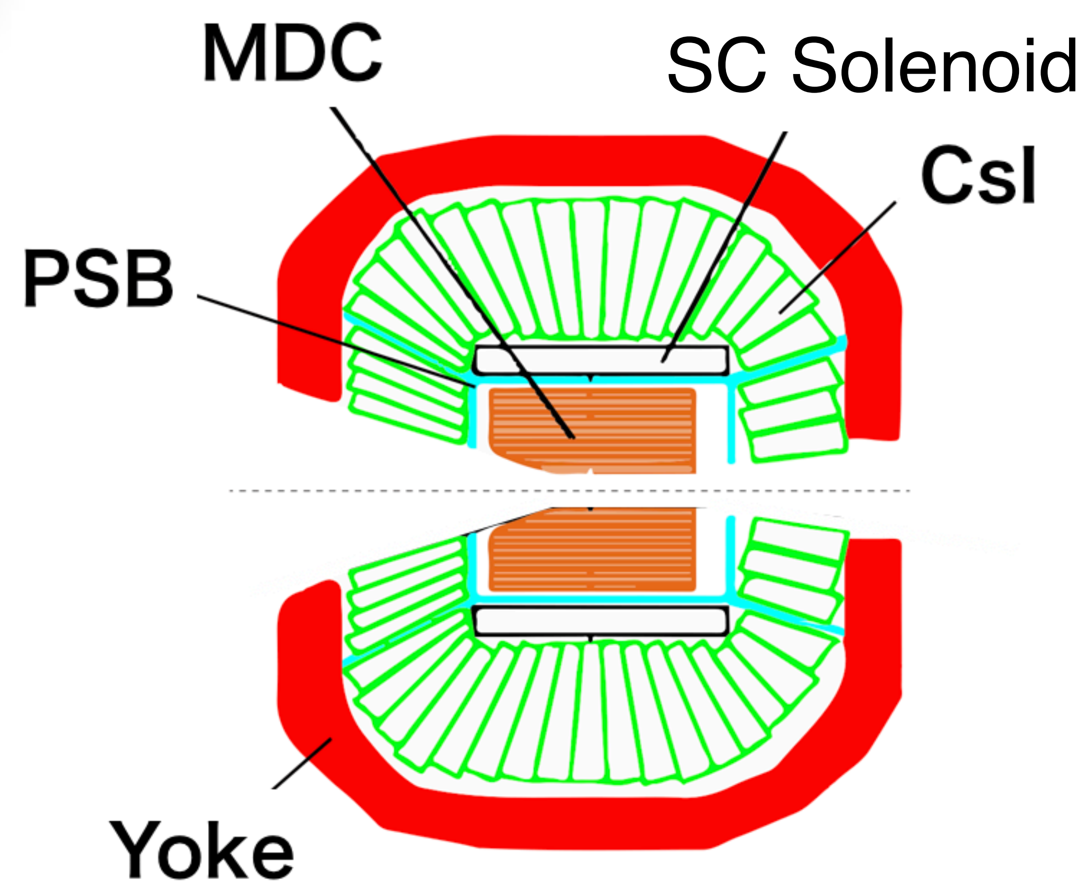


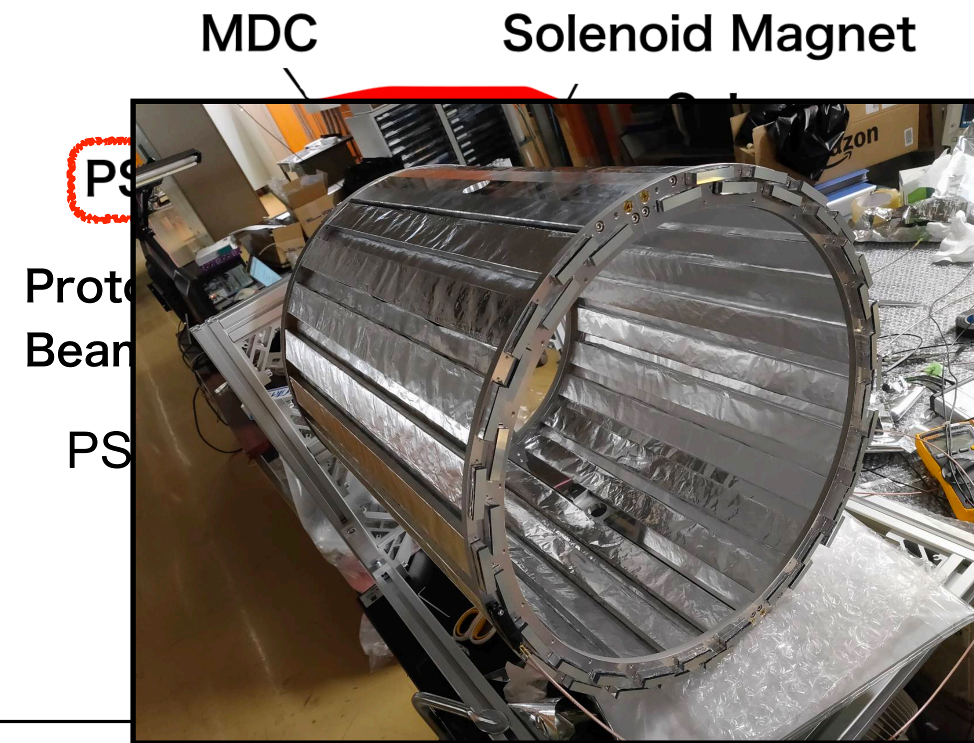
- **MDC (Mini Drift Chamber)**
  Charged particle tracking
- **PSB (Plastic Scintillator Barrel)**
  ΔE + Timing measurement
- **CsI**
  γ detection for calibration

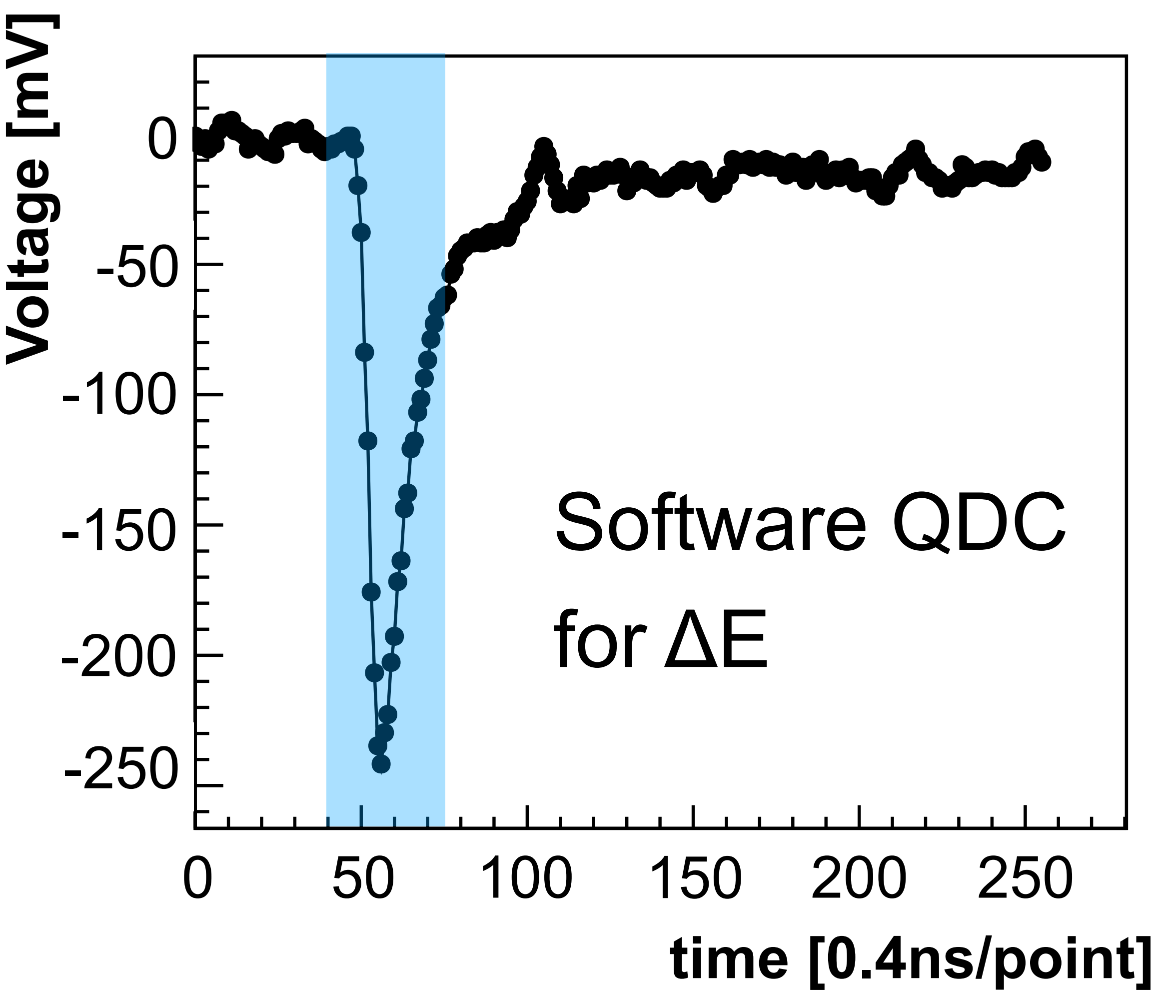


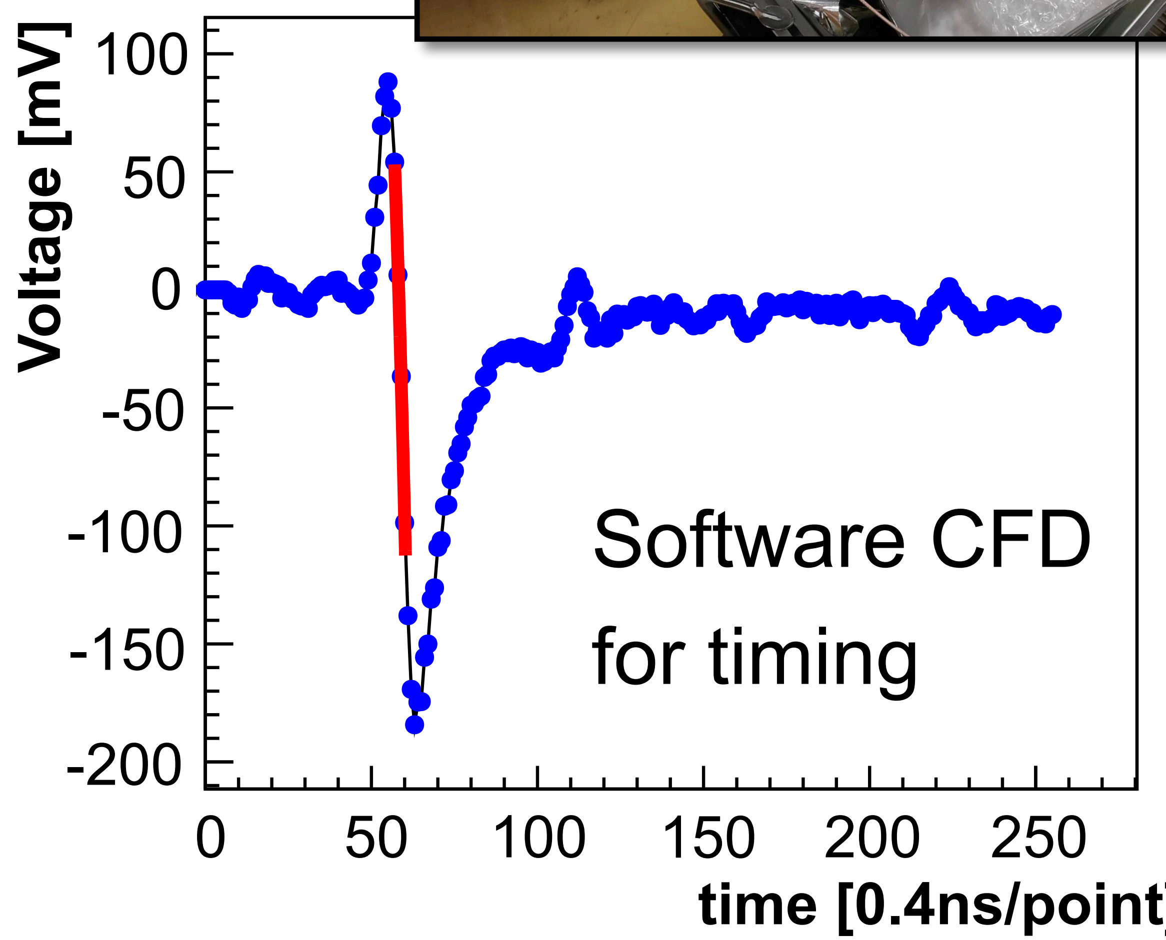
Cooperation with COSY-WASA collaboration

WASA detectors analysis (PSB waveform)

- PSB analysis for ΔE and hit timing.
  - Analyzed 2.5 GHz waveform data.







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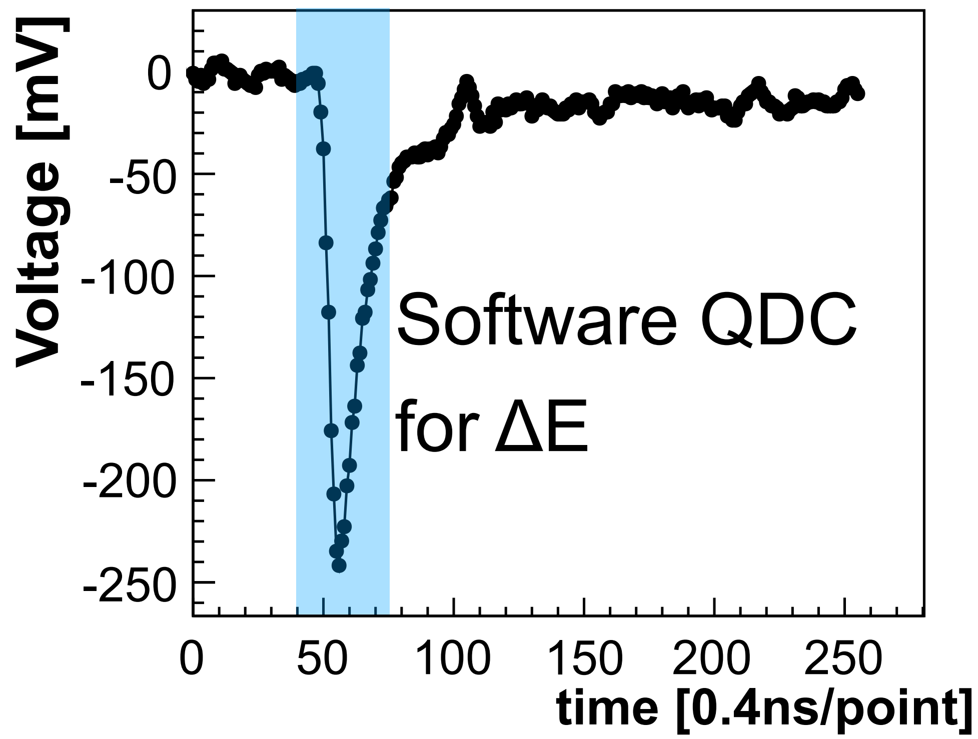
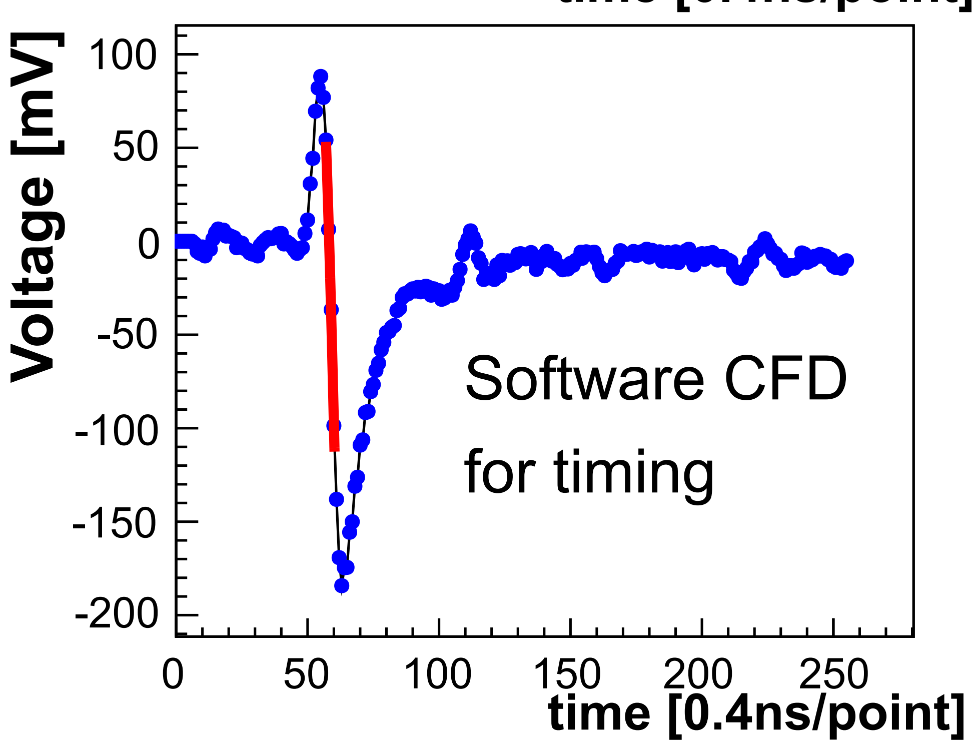
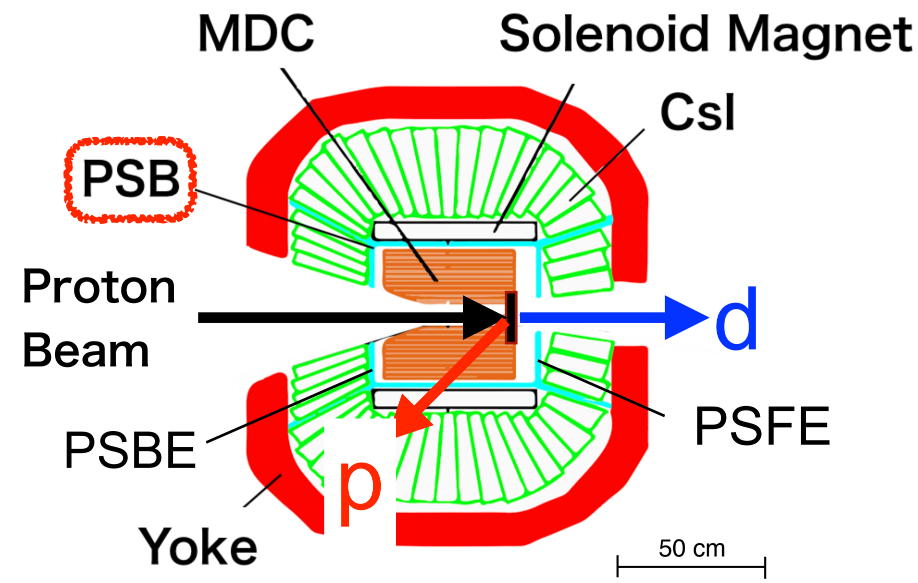
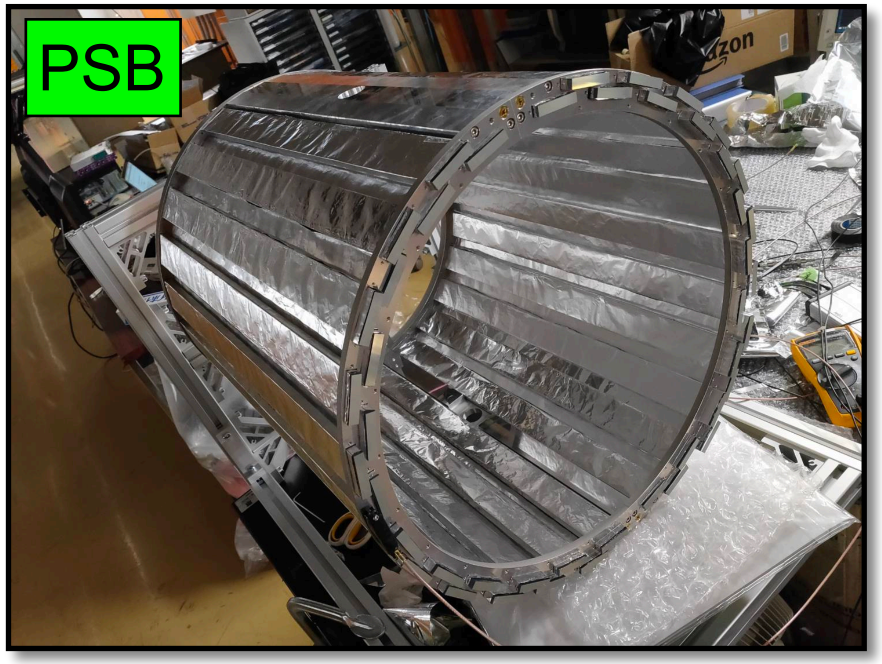


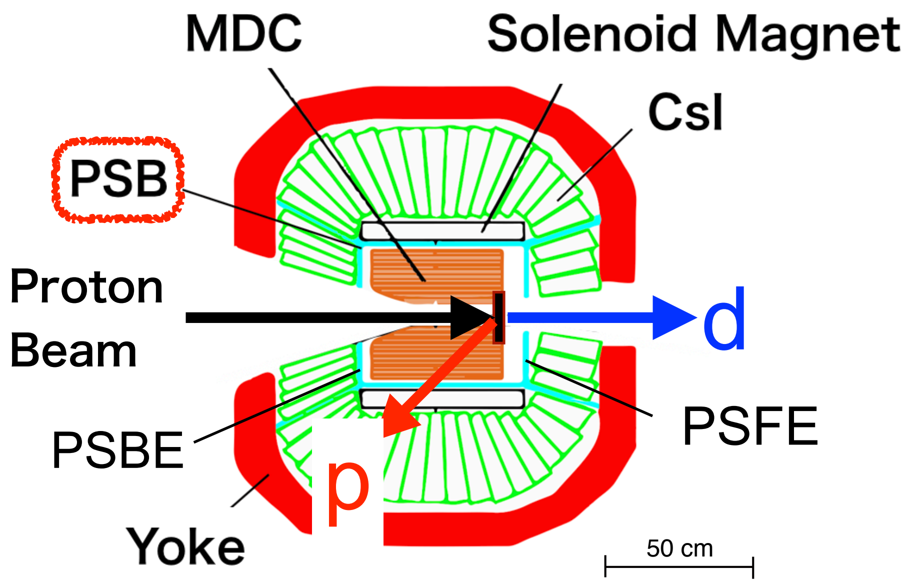


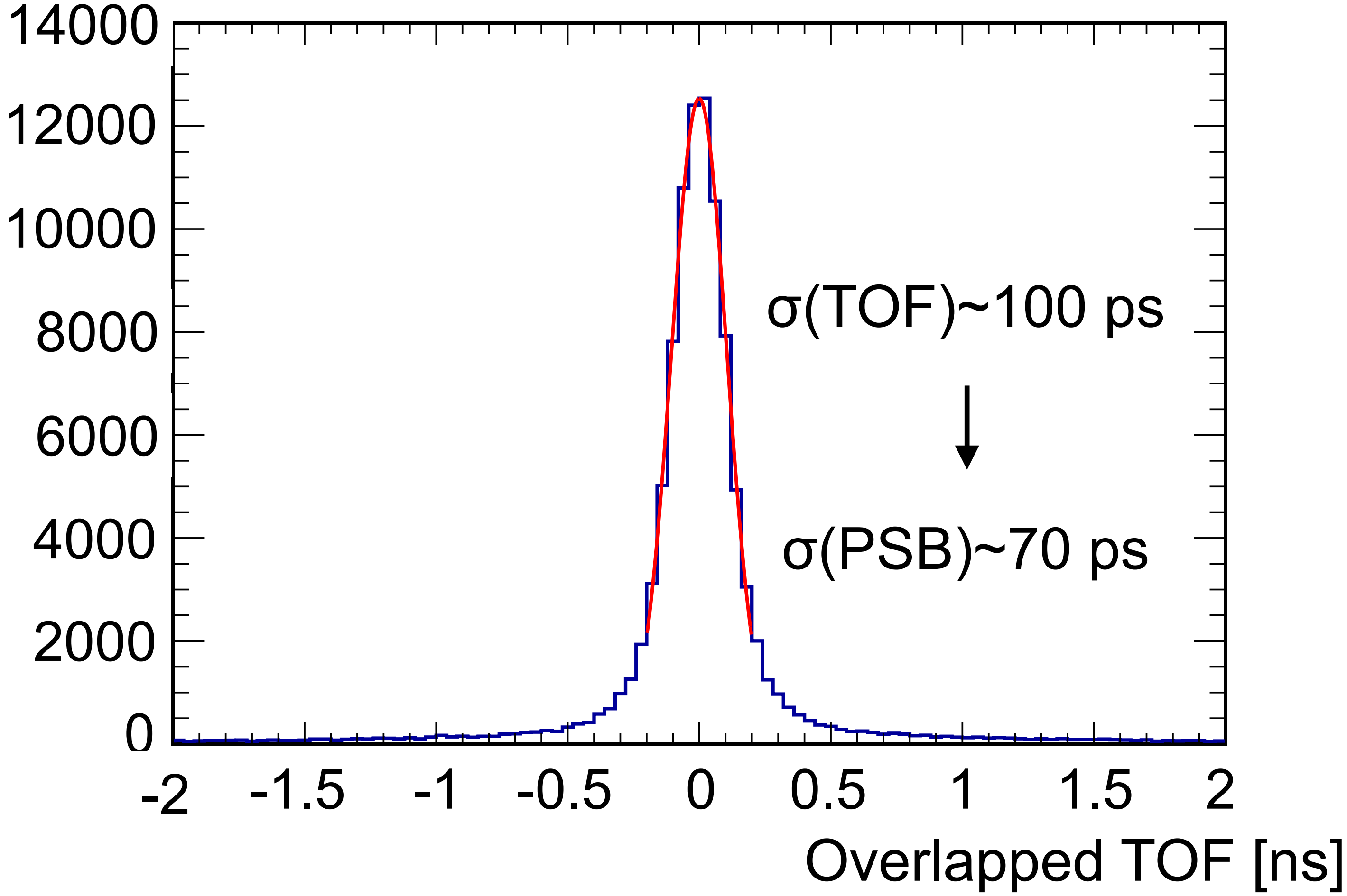


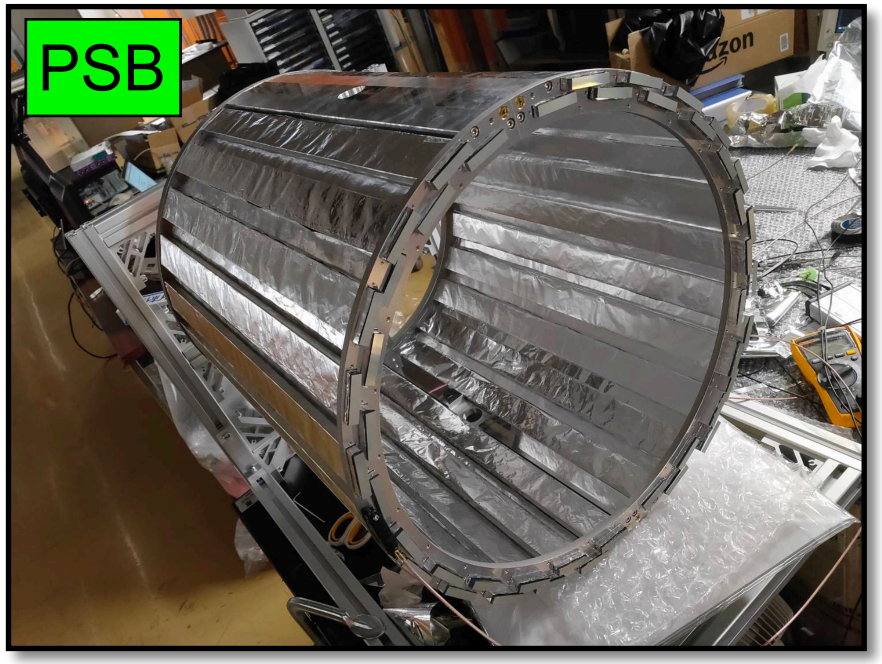


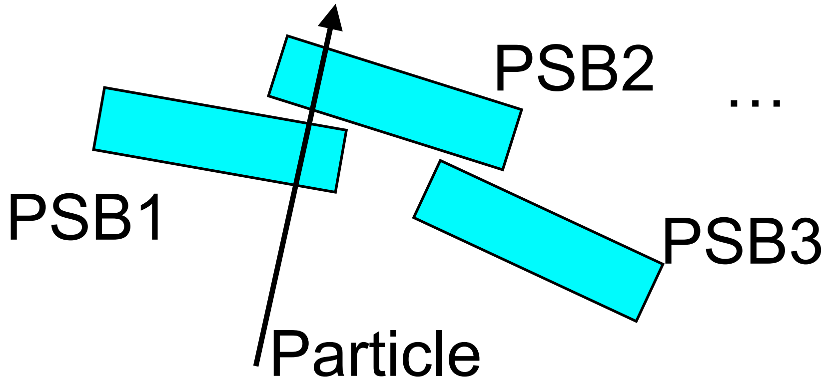
WASA detectors analysis (PSB time resolution)

- PSB analysis for ΔE and hit timing.
  - Analyzed 2.5 GHz waveform data.



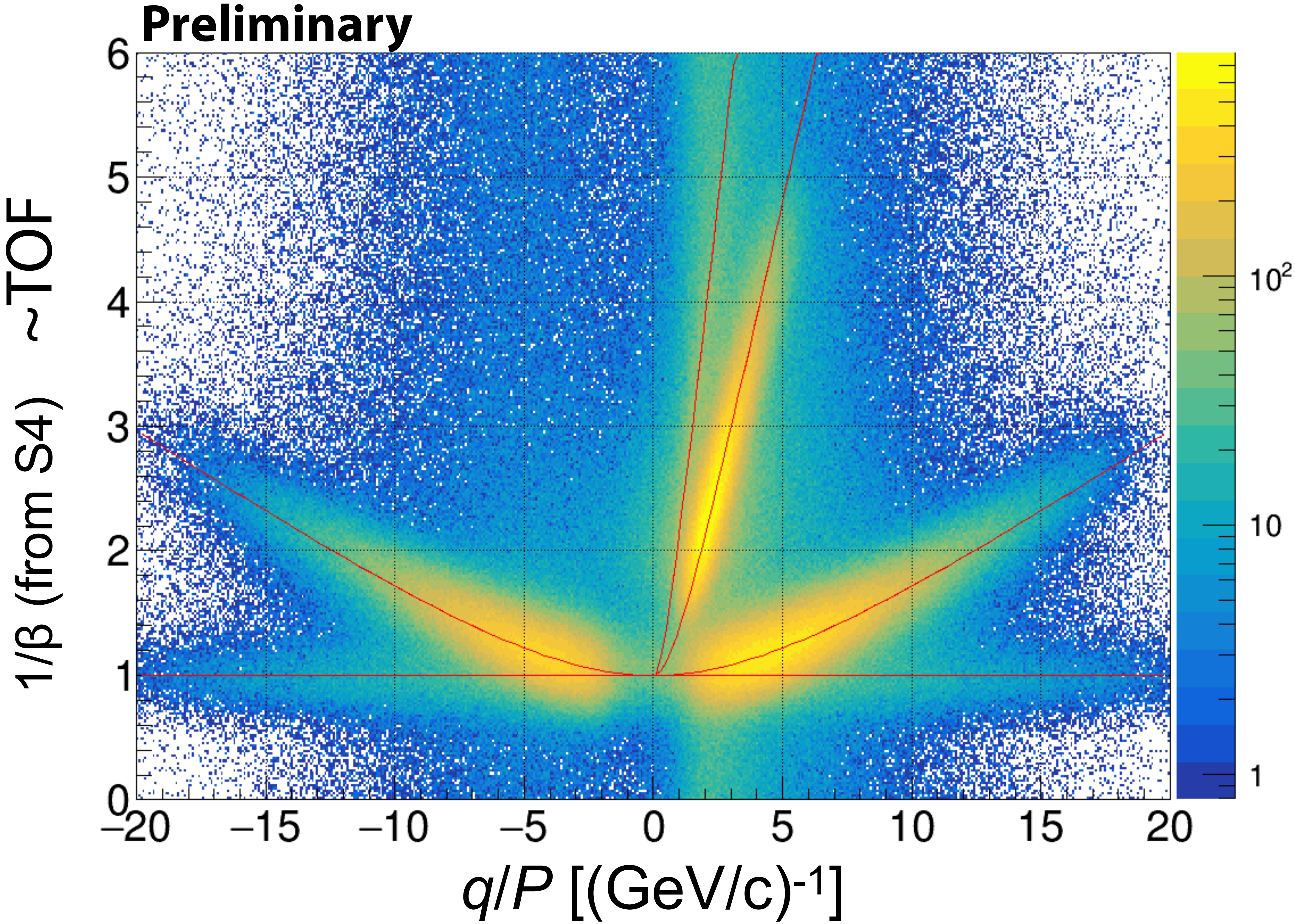






WASA PID with TOF and *q/p*

TOF start ~ 200 ps computed based on S4 + track information in FRS



R.Sekiya

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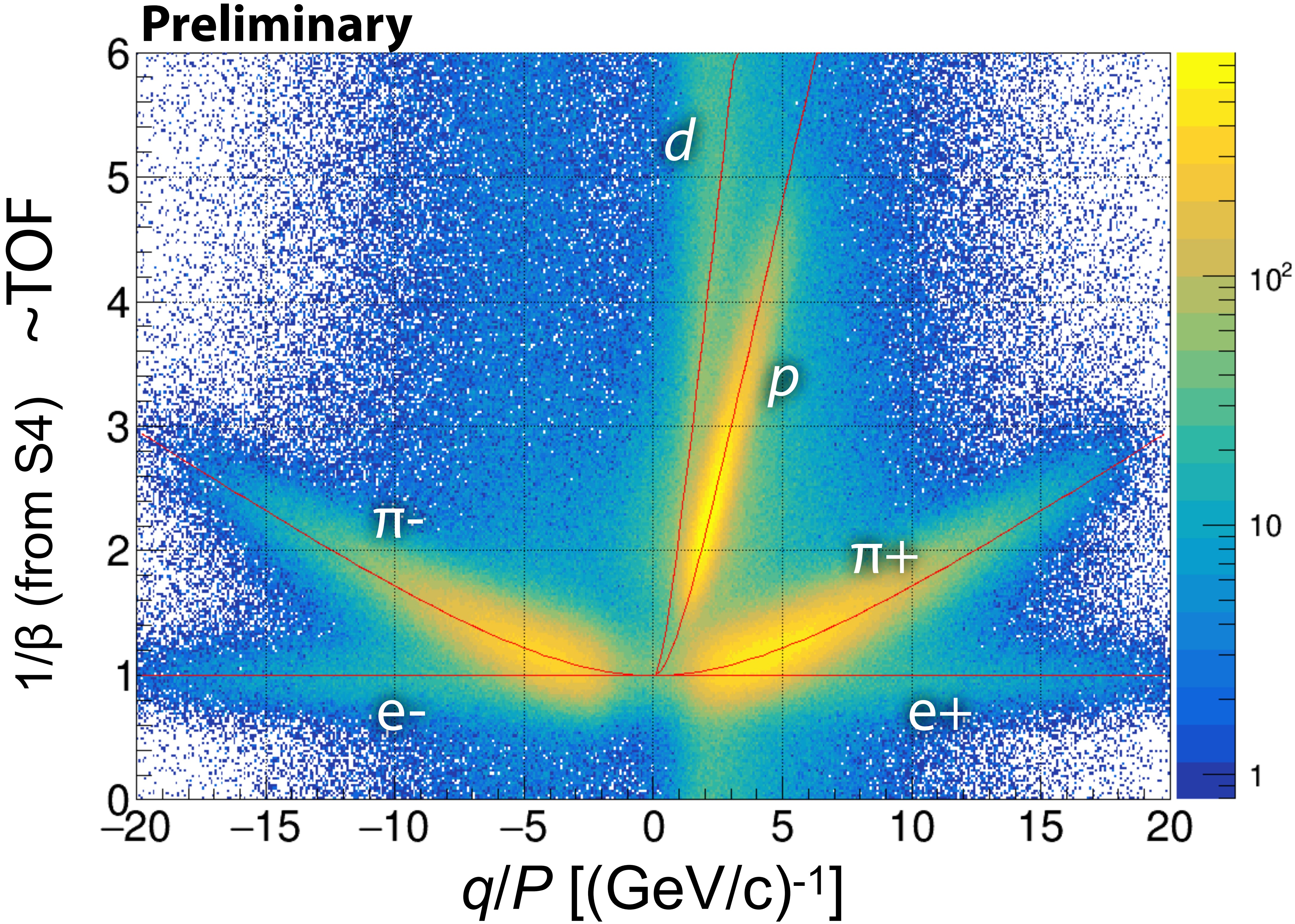
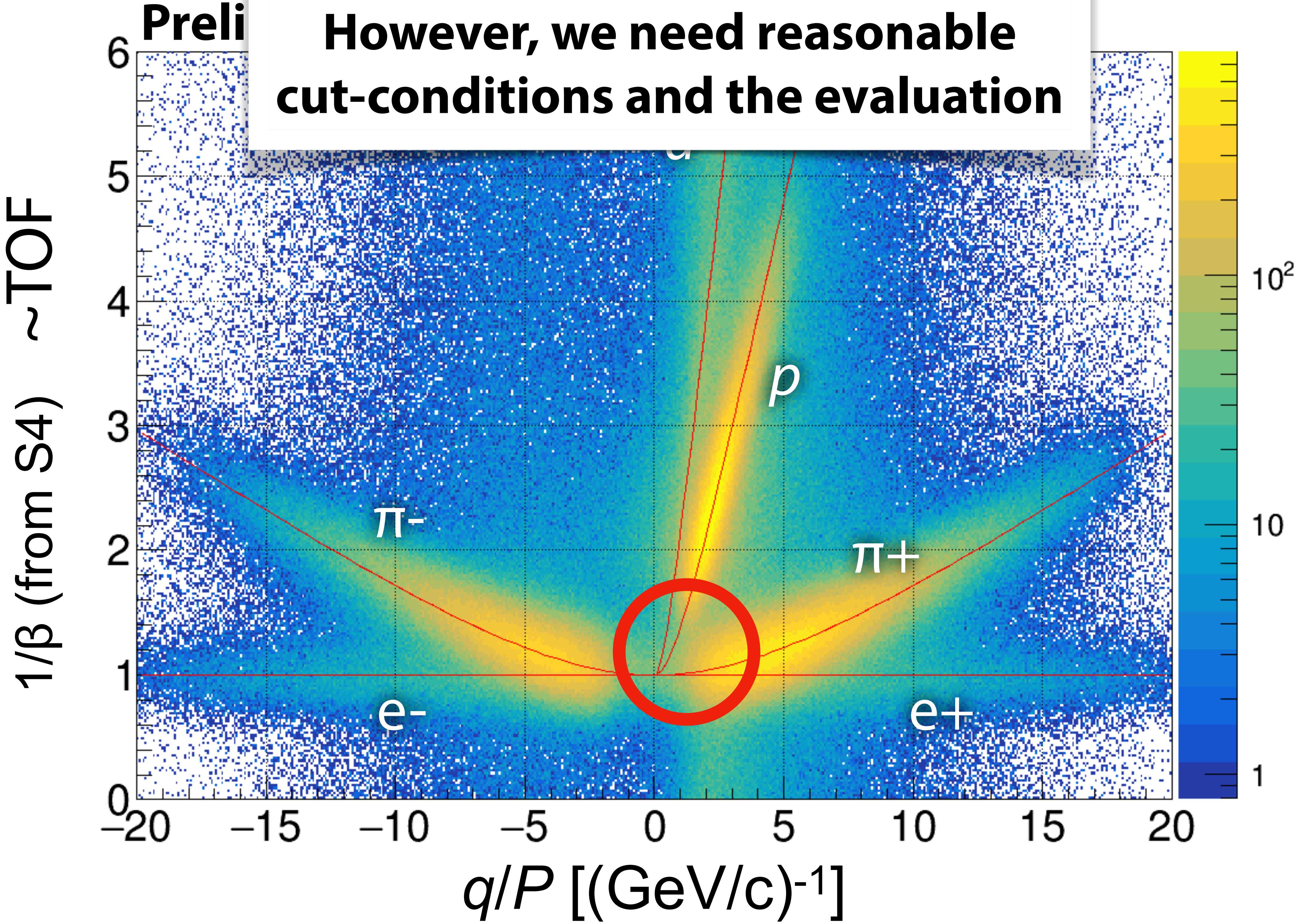


R.Sekiya

WASA PID with TOF and q/p

TOF start ~ 200 ps ... mation in FRS

PID seems to work fine
Reduction of 1/200
However, we need reasonable cut-conditions and the evaluation



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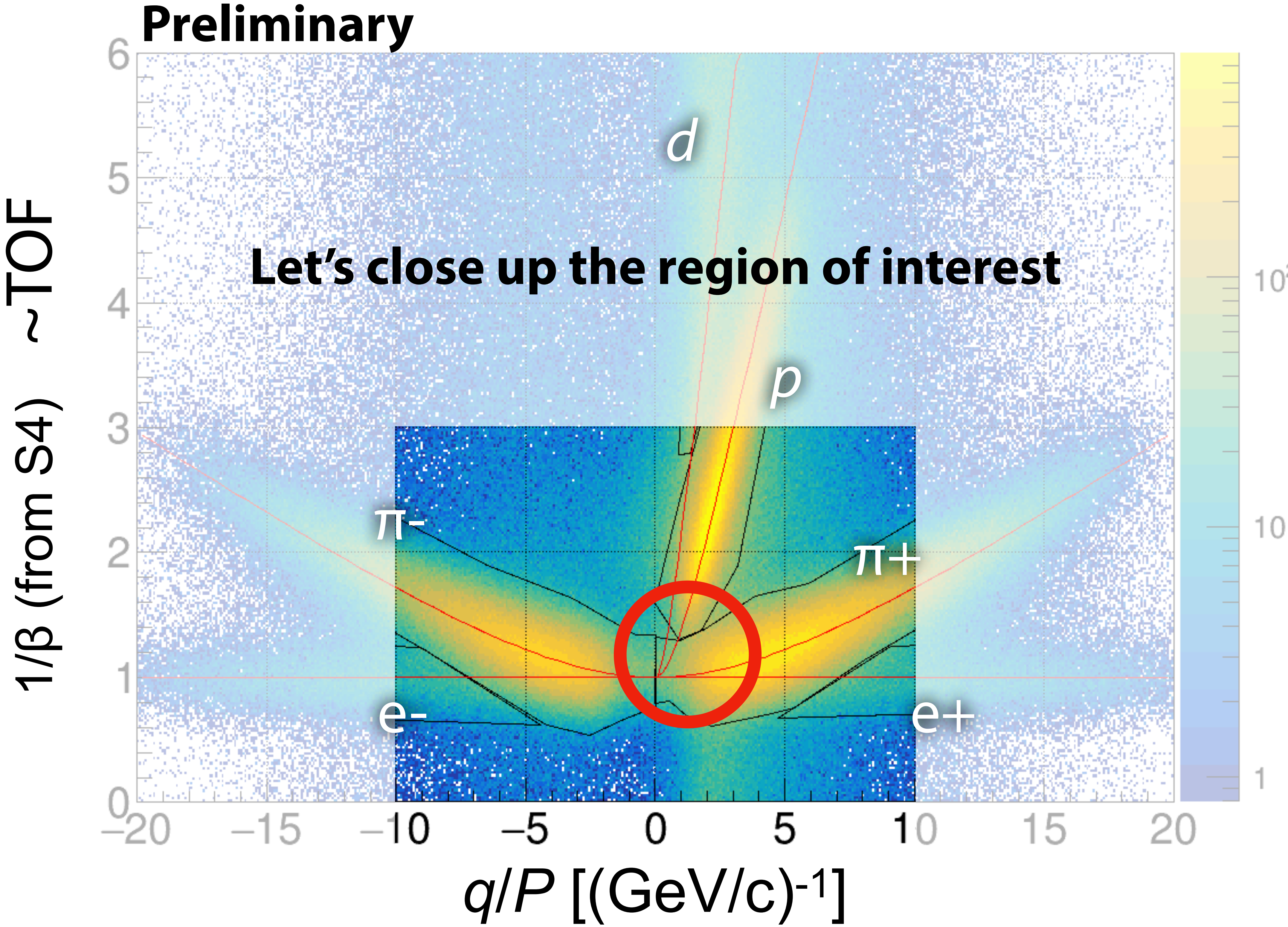

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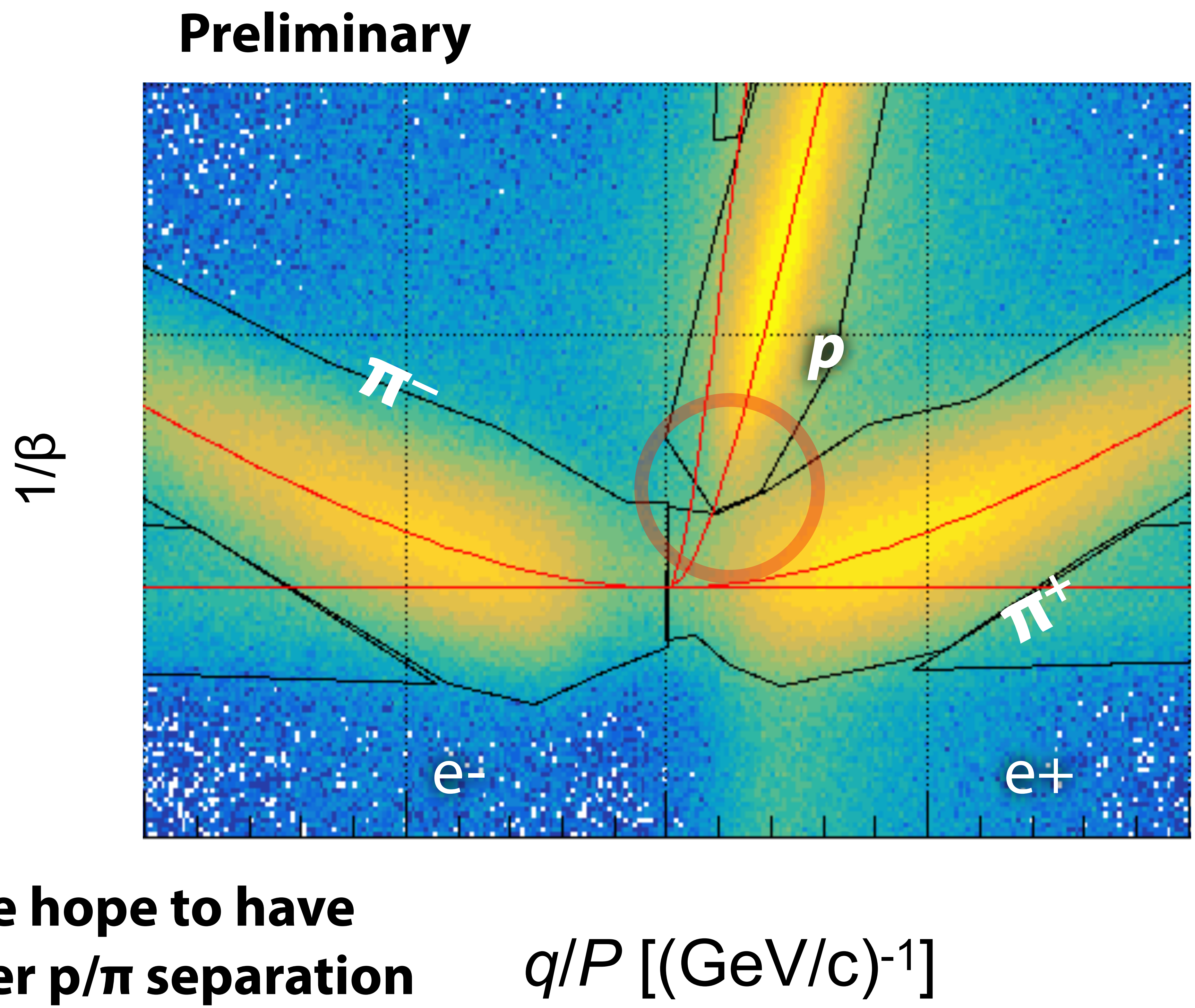


We hope to have better p/π separation

R.Sekiya

R. Sekiya's work

For better momentum resolution

3 measureables in PSB and MDC are combined

- **TOF → $1/\beta$**
- **ΔE → $1/\beta^2$**
- **p → $m_0\beta\gamma = m_0\beta/\sqrt{1-\beta^2}$**

Given physical mass m_0, all 3 give information of β

- **TOF / ΔE need calibration + "brushup"**
- **We need resolution depending on θ and β for statistically correct estimation.**

"Brushup"
Jitter correction
TOF resolution in WASA
Start: ScS4
Stop: PSB
120 ps (σ) achieved!

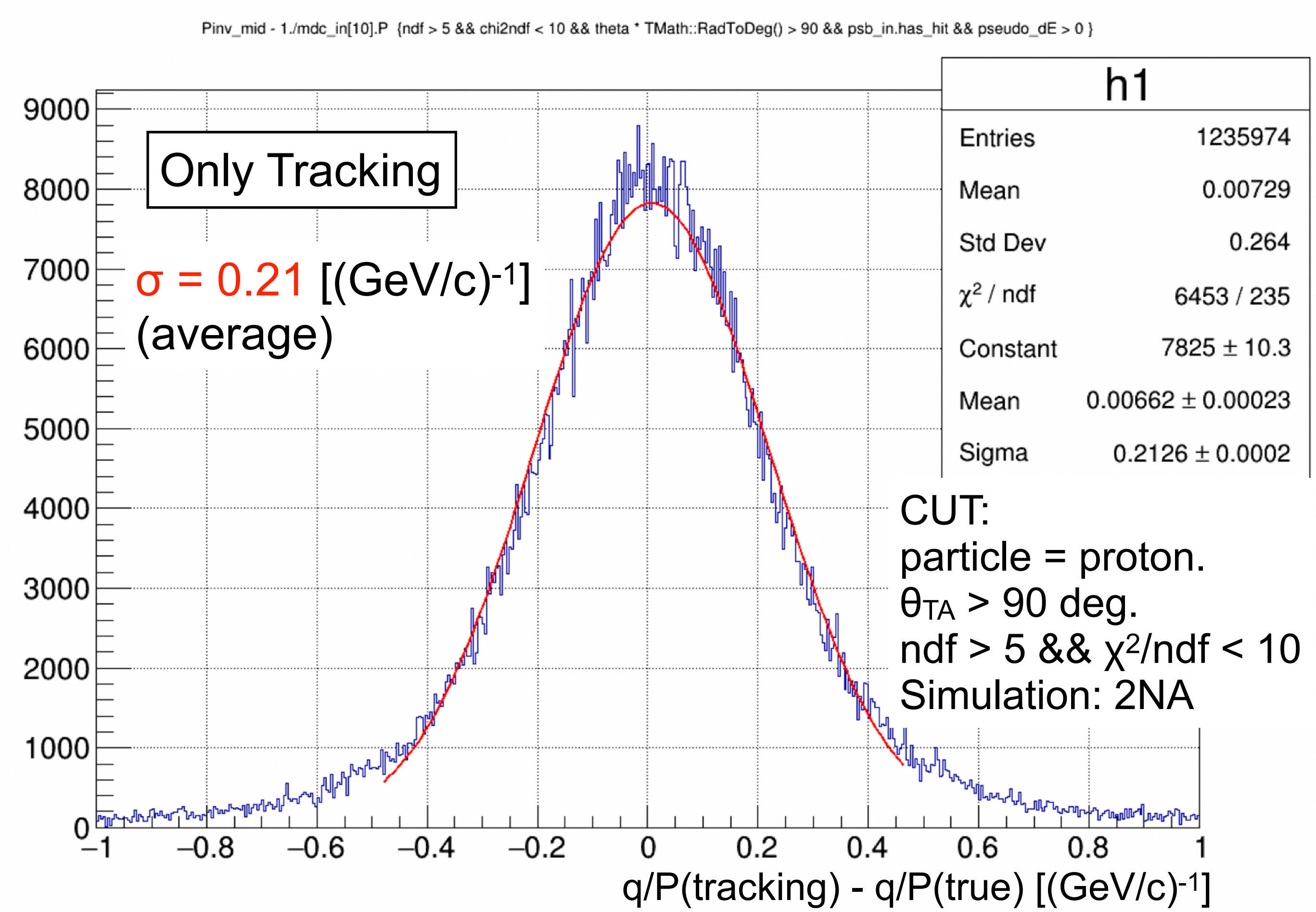
ΔE in WASA-PSB
Resolution evaluated in
ΔE-TOF plane

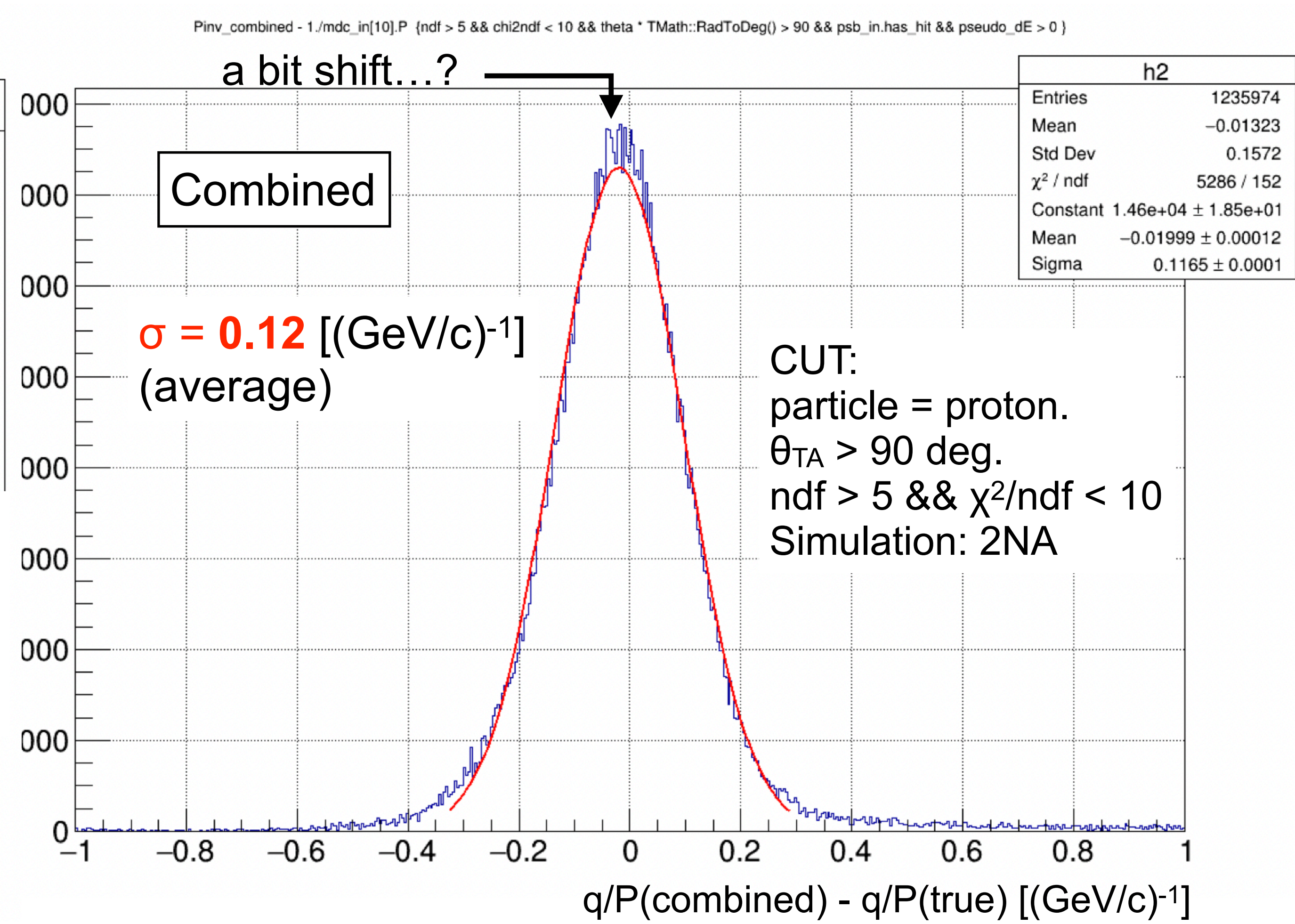
R. Sekiya's work

For better momentum resolution

<u>Improvement of momentum resolution evaluated by GEANT4 (in mixed event method)</u>

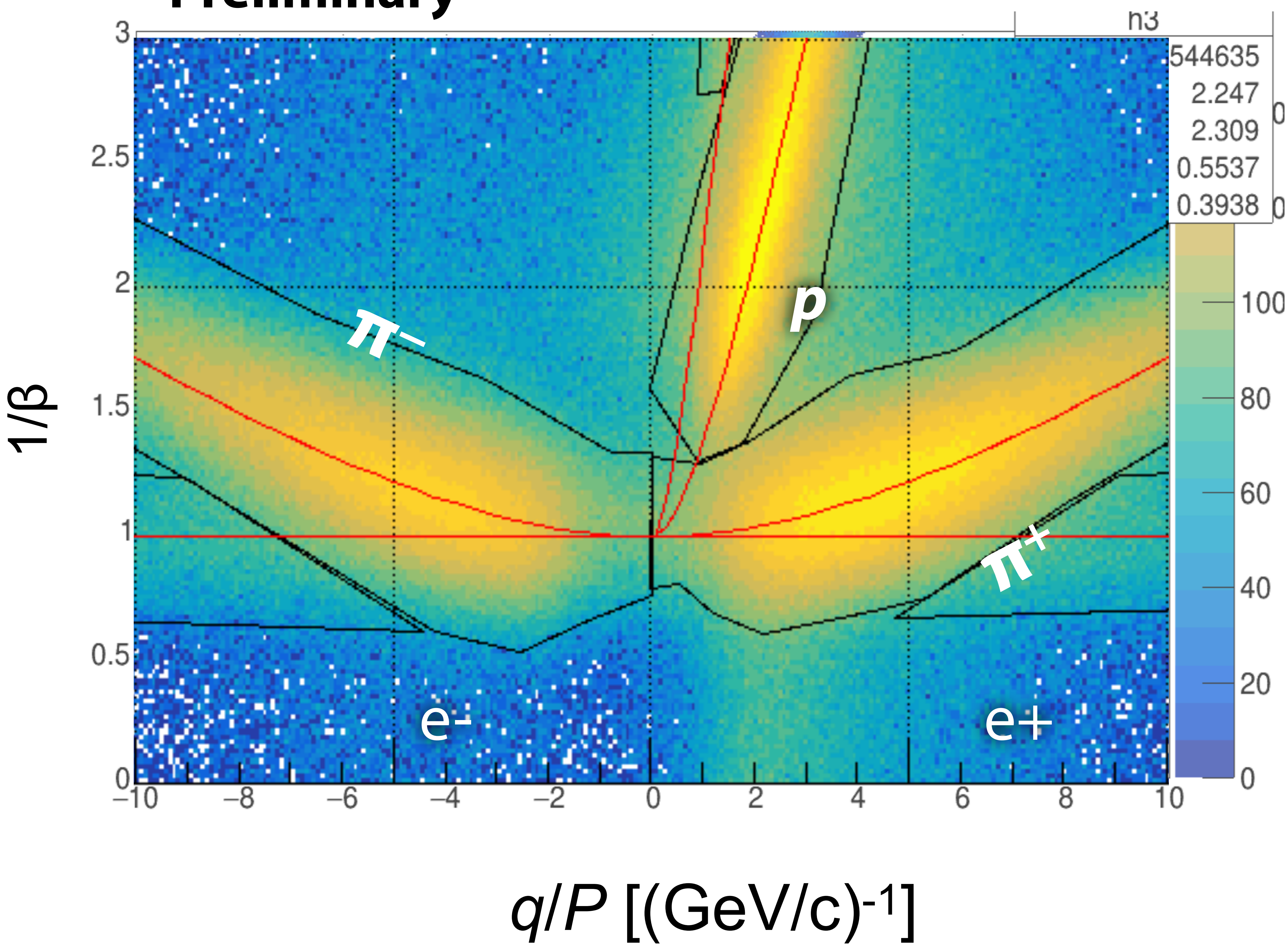
- The performance of the combined momentum in case of proton is tested with 2NA simulation.
- Left: q/P(tracking) - q/P(true)
- Right: q/P(combined) - q/P(true).
- The combined q/P resolution becomes roughly **twice better** than only with tracking!





WASA PID with TOF and *q/p*

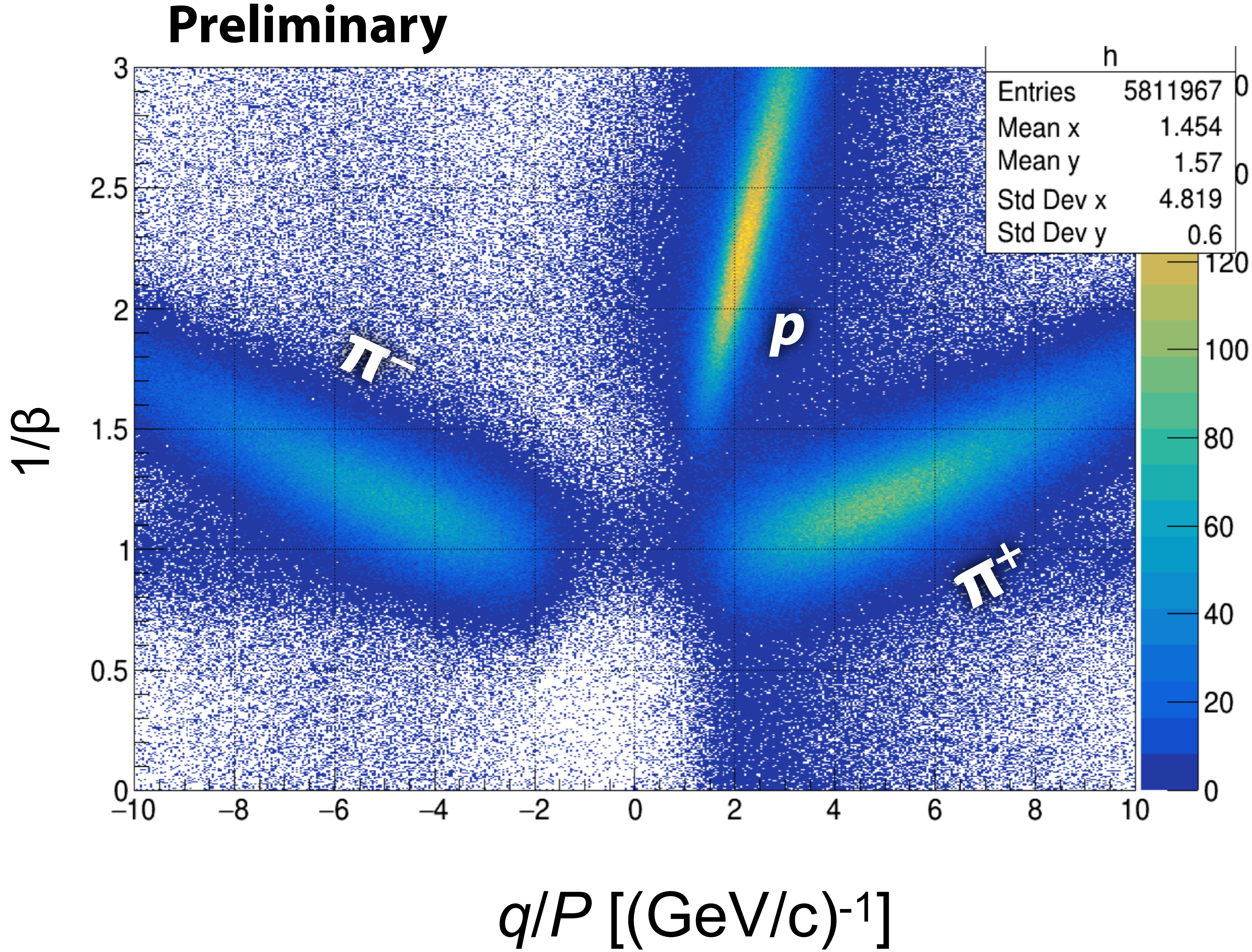
Preliminary



R.Sekiya

WASA Combined PID with TOF, ΔE and *q/p*

TOF start ~ 200 ps computed based on S4 + track information in FRS



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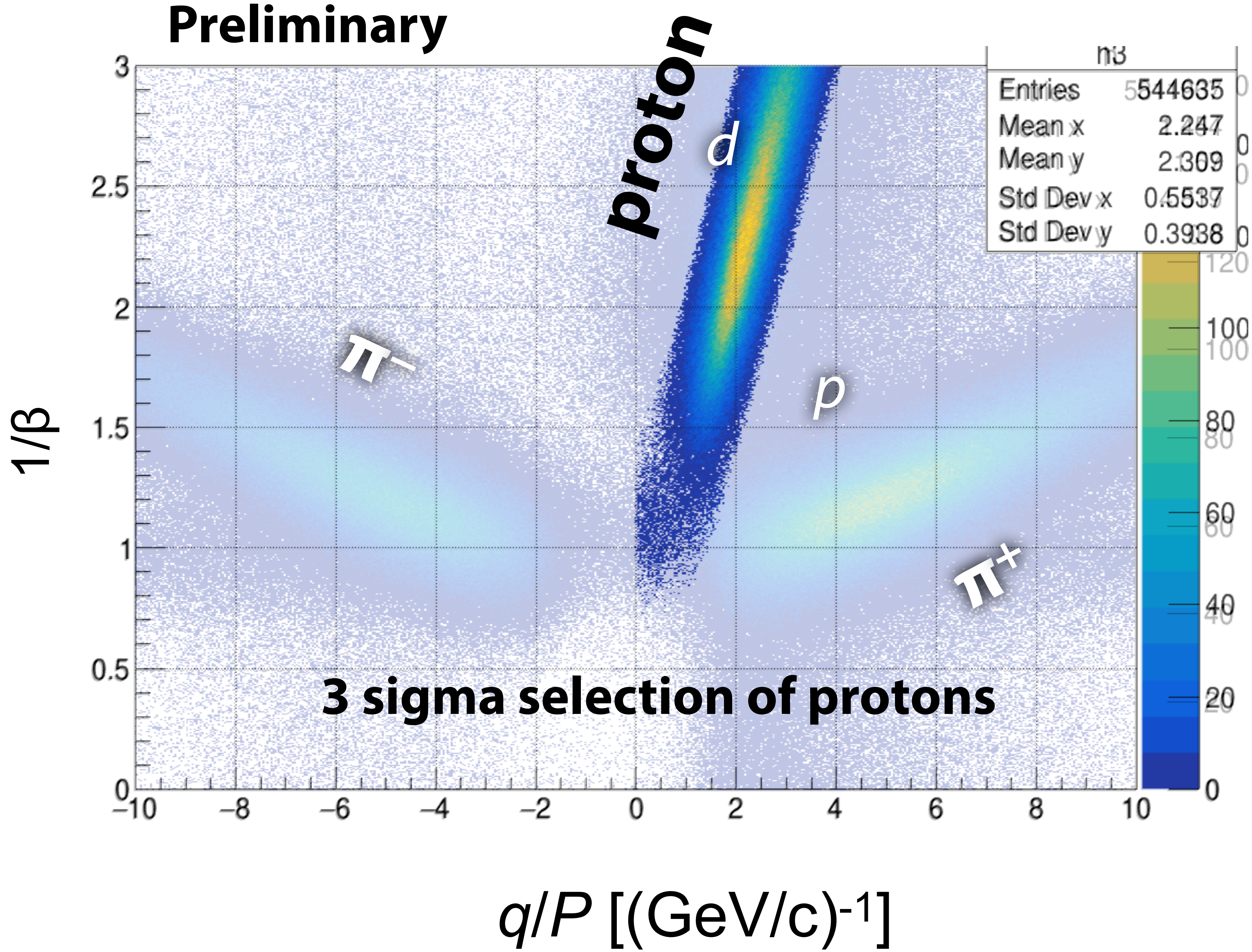

R.Sekiya

Summary

- **We have conducted missing-mass spectroscopy of ^{12}C(*p,d*) reaction with tagging ~1 GeV/*c* proton emitted nearly isotropically in two nucleon absorption of η′ η′NN→NN. WASA worked nicely for tagging the protons**
- **We accumulated 1.1x10^{7} forward *d* in the inclusive spectrum of (*p,d*) by FRS, which corresponds to 110% of the proposed value. Detected proton number with WASA in coincidence with forward *d* roughly agrees with simulations**
  → BG suppression of ~1/200 !!
- **WASA PID works fine with TOF, tracking, and ΔE information**
- **WASA momentum resolution was by a factor of 1.4-1.5 worse compared with simulation. However, we combined ΔE, TOF, and tracking information to make "kinematical fitting" for better momentum resolution, which improved the resolution by a factor of ~2.**
- **We have started considerations about next experiment.**