Energy Dependence of π^-/π^+ Ratio in In+^{28}Si Reaction

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M. Sako[1], T. Murakami[1], Y. Ichikawa[1], S. Imajo[1], R. Sameshima[1], Y. Nakai[2], S. Nishimura[2], K. Ieki[3], M. Matsushita[3], J. Murata[3], and E.Takatda[4]

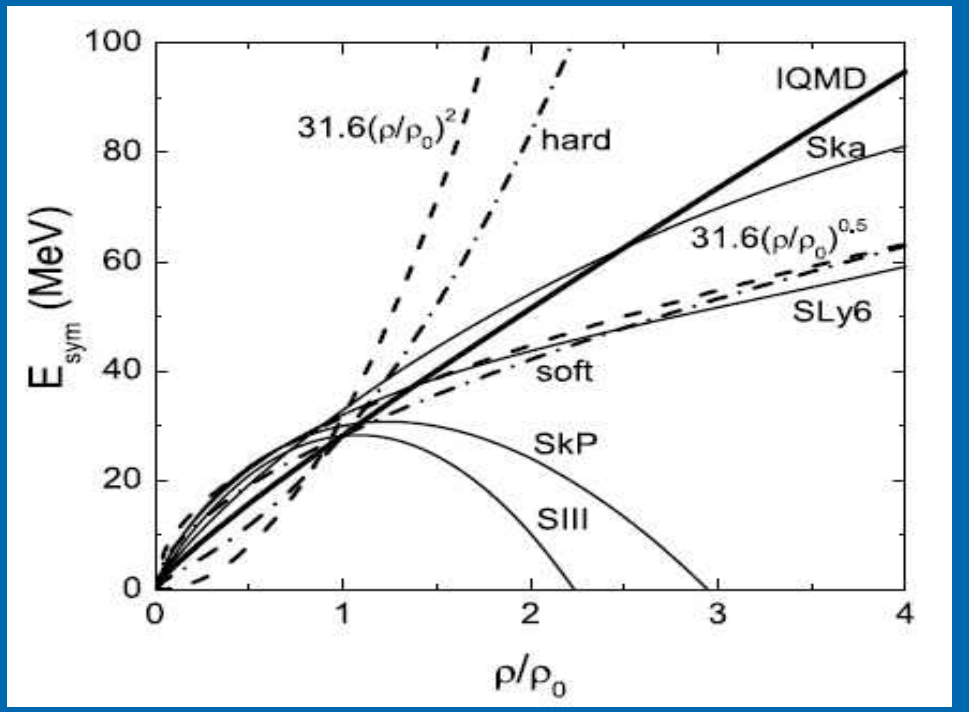
[1]Kyoto Univ., [2]RIKEN, [3]Rikkyo Univ., [4]NIRS

Introduction

Symmetry Energy at high density

- **sub-saturation density**
  - some constraints
- **supra-saturation density**

  ⇒ The trend is not fixed.



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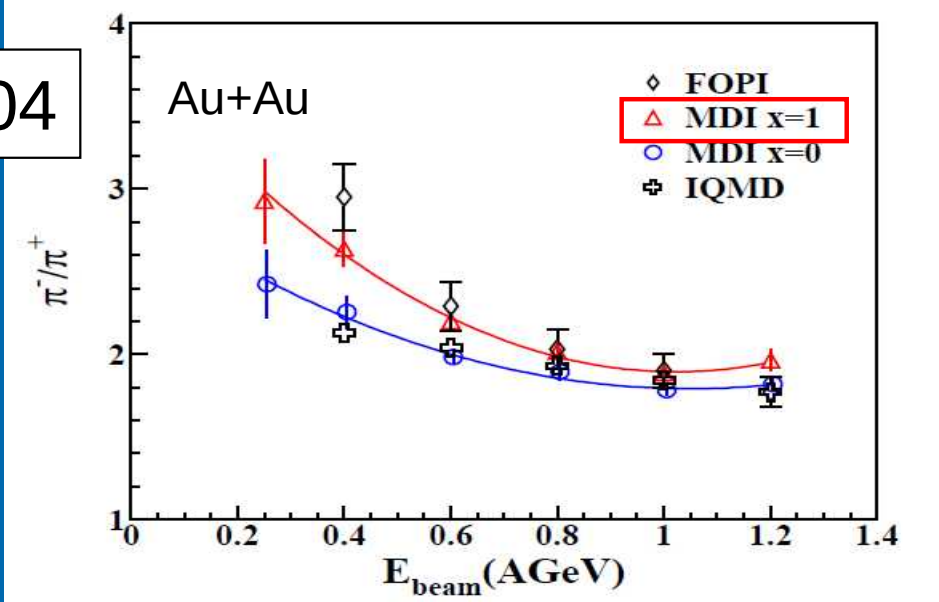
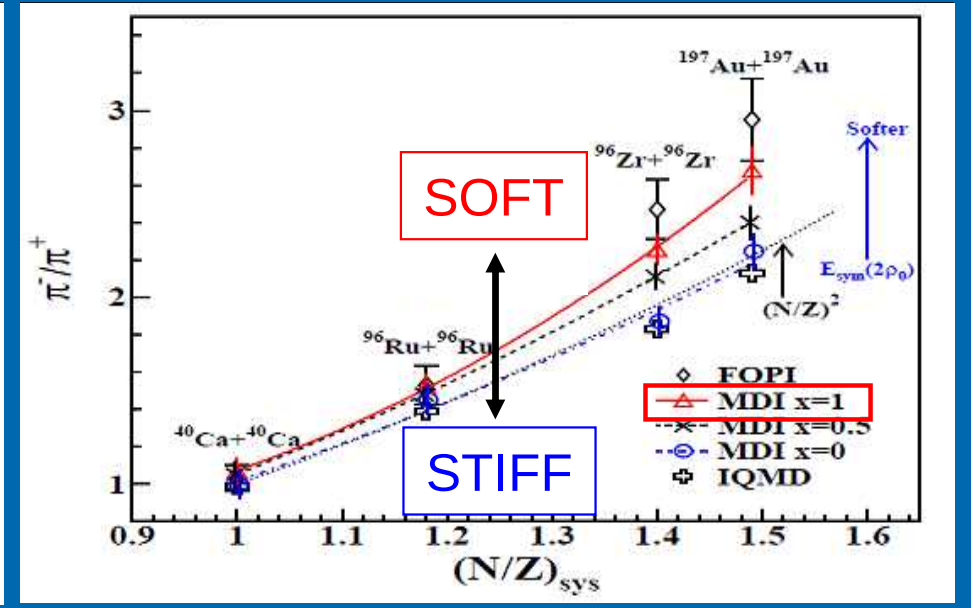
- **Experiment at supra-saturation density**
  - Heavy Ion Collision at a few hundred MeV/nucleon
  - probe : π^-/π^+ ratio
  - Pion : created by decay of $\Delta \rightarrow \pi^-/\pi^+ \propto (N/Z)^2$

Comparison between theory and experiment

IBUU04





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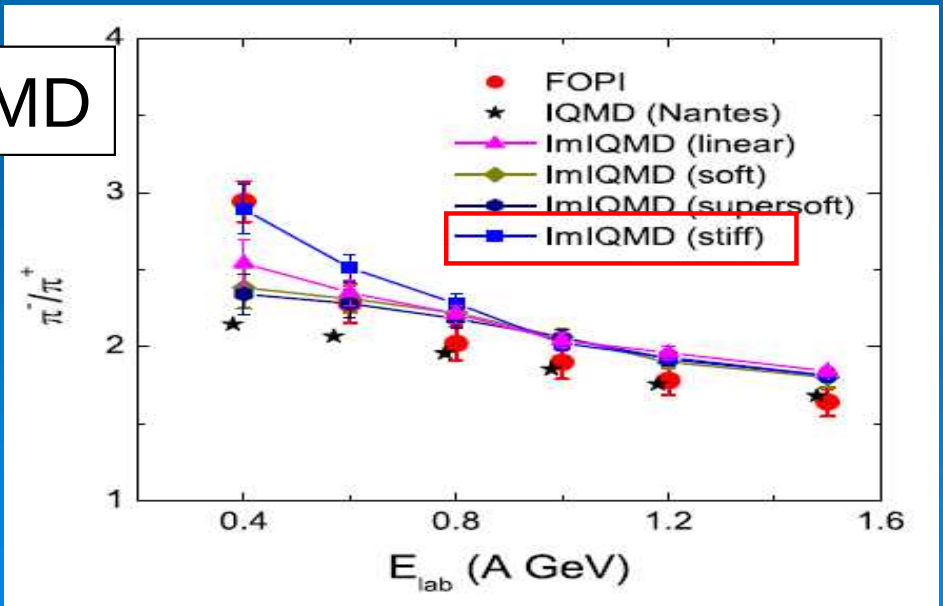
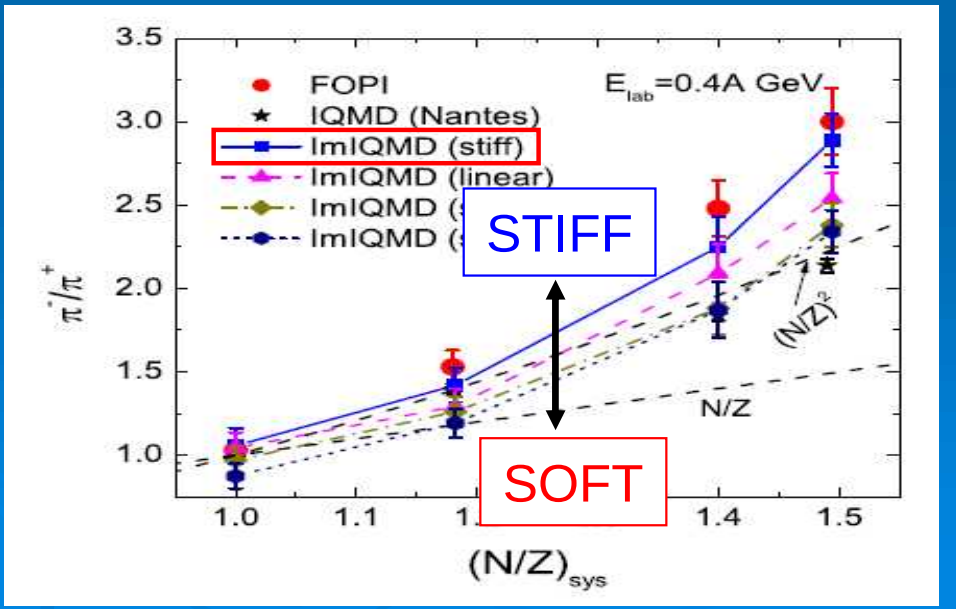
Im IQMD





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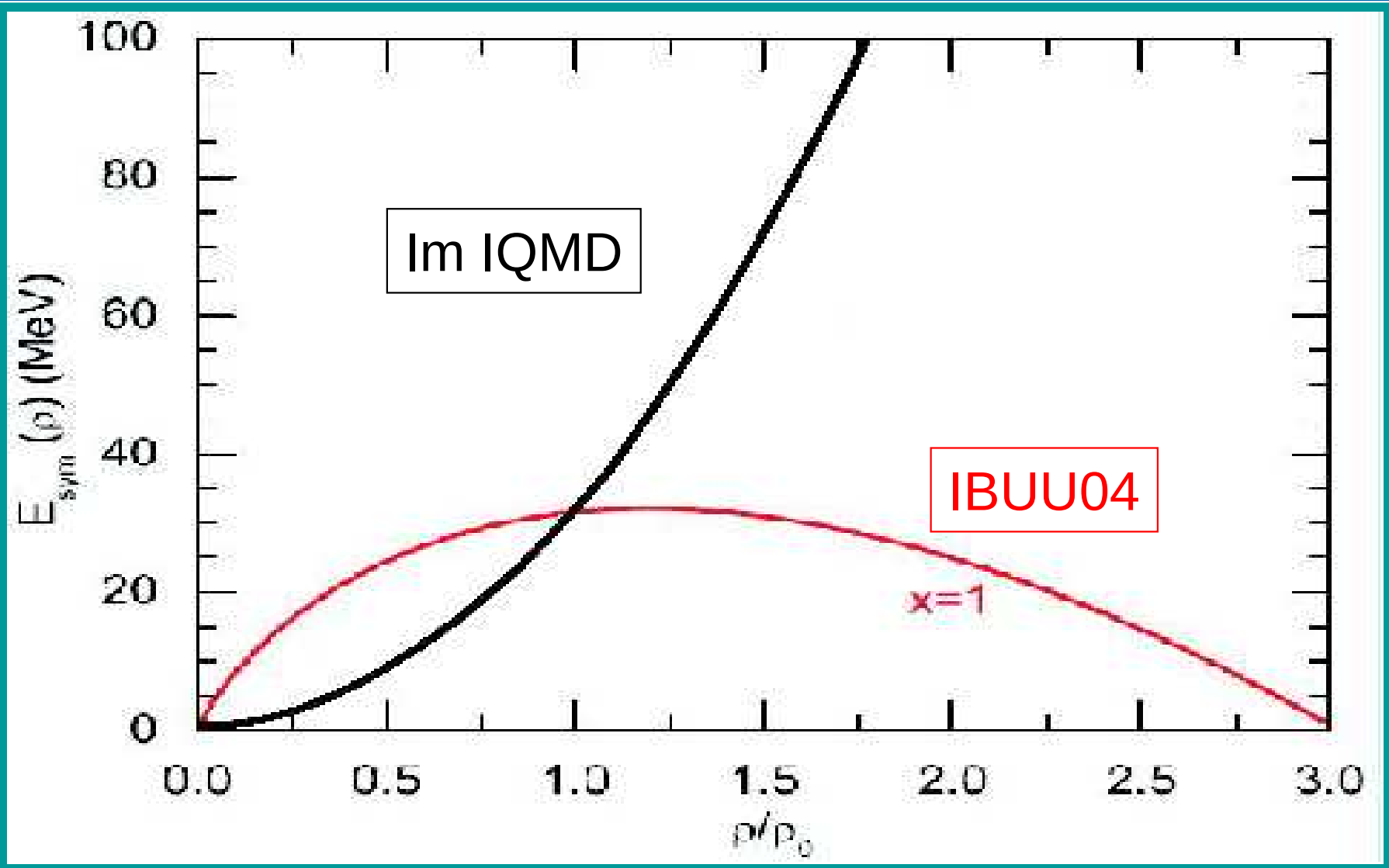
The results of two calculations



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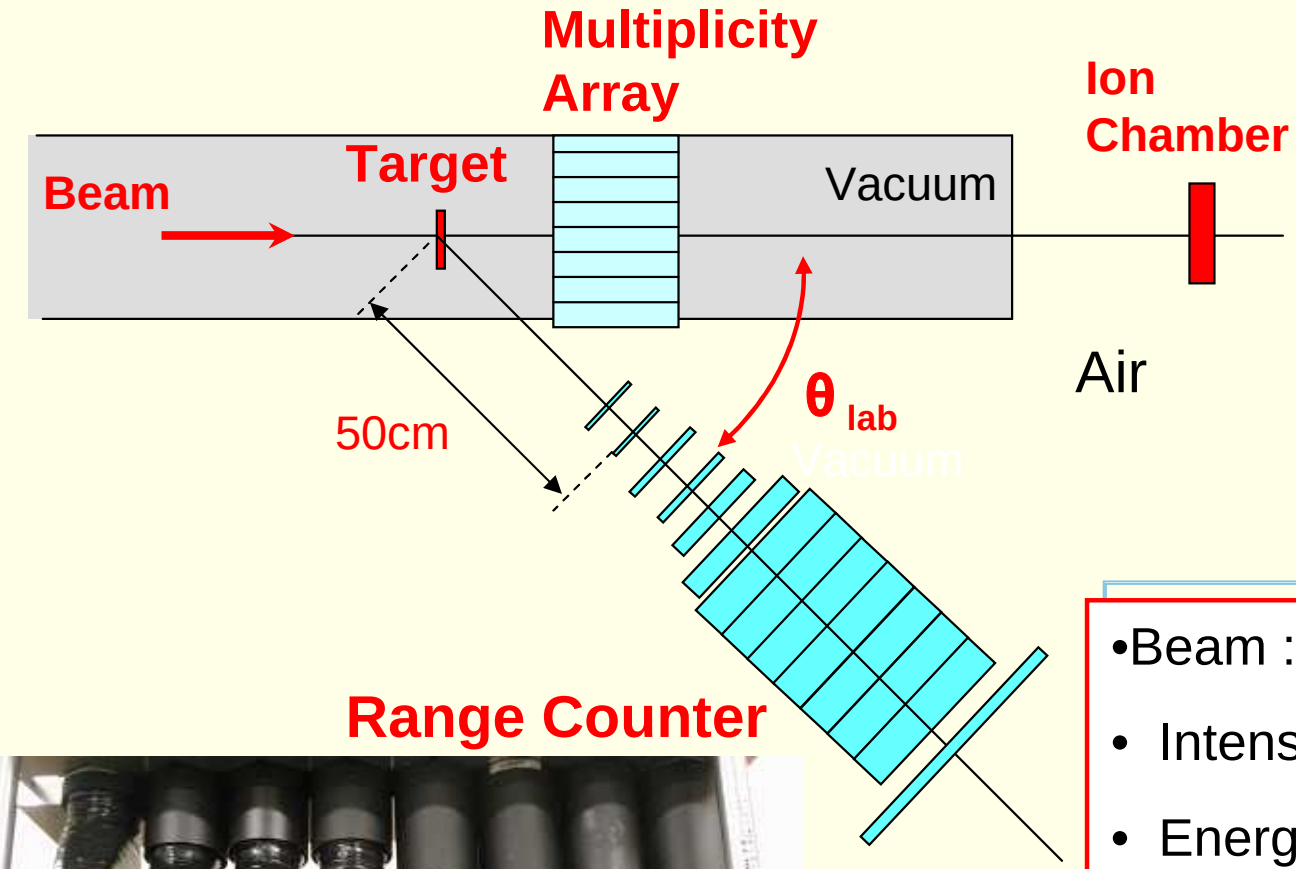
Motivation

- Long Term Plan
  - N/Z ratio using isotope (unstable nuclei)
  - Beam Energy : a few hundred MeV/nucleon
  - We plan Sn isotope experiments at RIBF using SAMURAI-TPC.
- Short Term Plan
  - Experiments using stable beam
  - Beam Energy & N/Z Ratio Dependence

    → Measurement with various conditions
  - Experiments @ Medical Accelerator HIMAC

Experiment and Analysis

Experimental Setup



Multiplicity Array

- Beam : ^{28}Si
- Intensity : ~ 10^7 ppp
- Energy : 400, 600, 800 AMeV
- Target : In ~ 390 mg/cm^2
- Range Counter : 14 layers (+2) of Sci.
- measured angle (θ lab) : 30, 45, 60, 75, 90, 120 degree
- solid angle : 10 msr

Identification principles of π^+ (and π^-)

<In flight> dE/dx is identical for both π^+ and π^-

<After STOP>

π^+

- π^+ decay to μ^+

  $\pi^+ \rightarrow \mu^+ + \nu_\mu$

- μ^+
  - Energy ~ 4 MeV
  - Range ~ 1 mm

π^+ : Double Hits in one counter

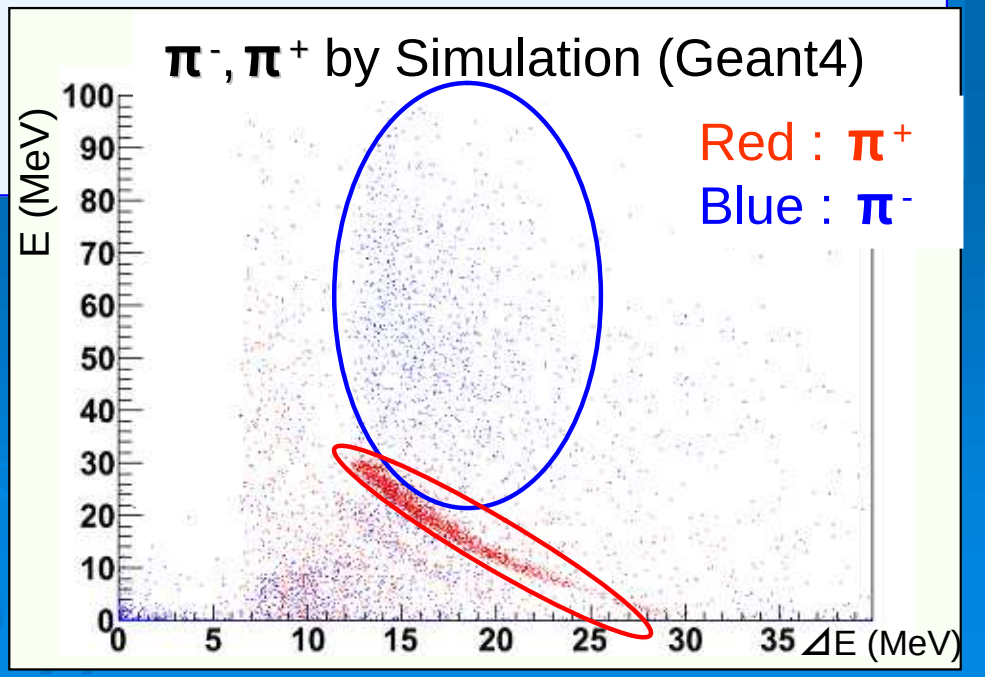
π^-

- create a pionic atom and captured by a nucleus
- decay to various particles

Unable to use the same identification method as π^+

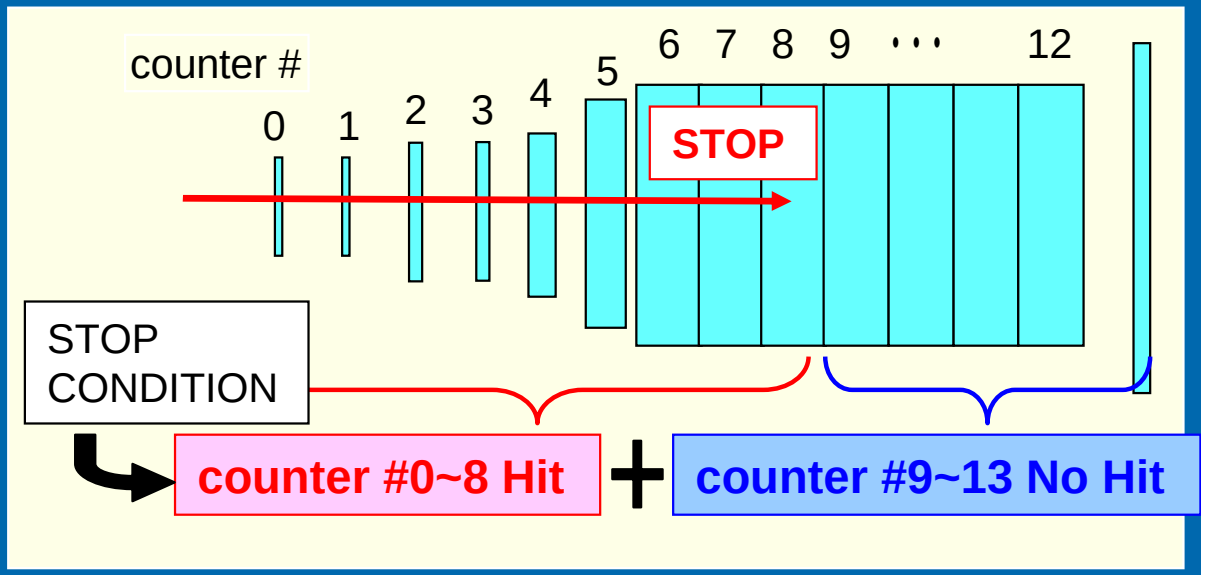
<π identification step>

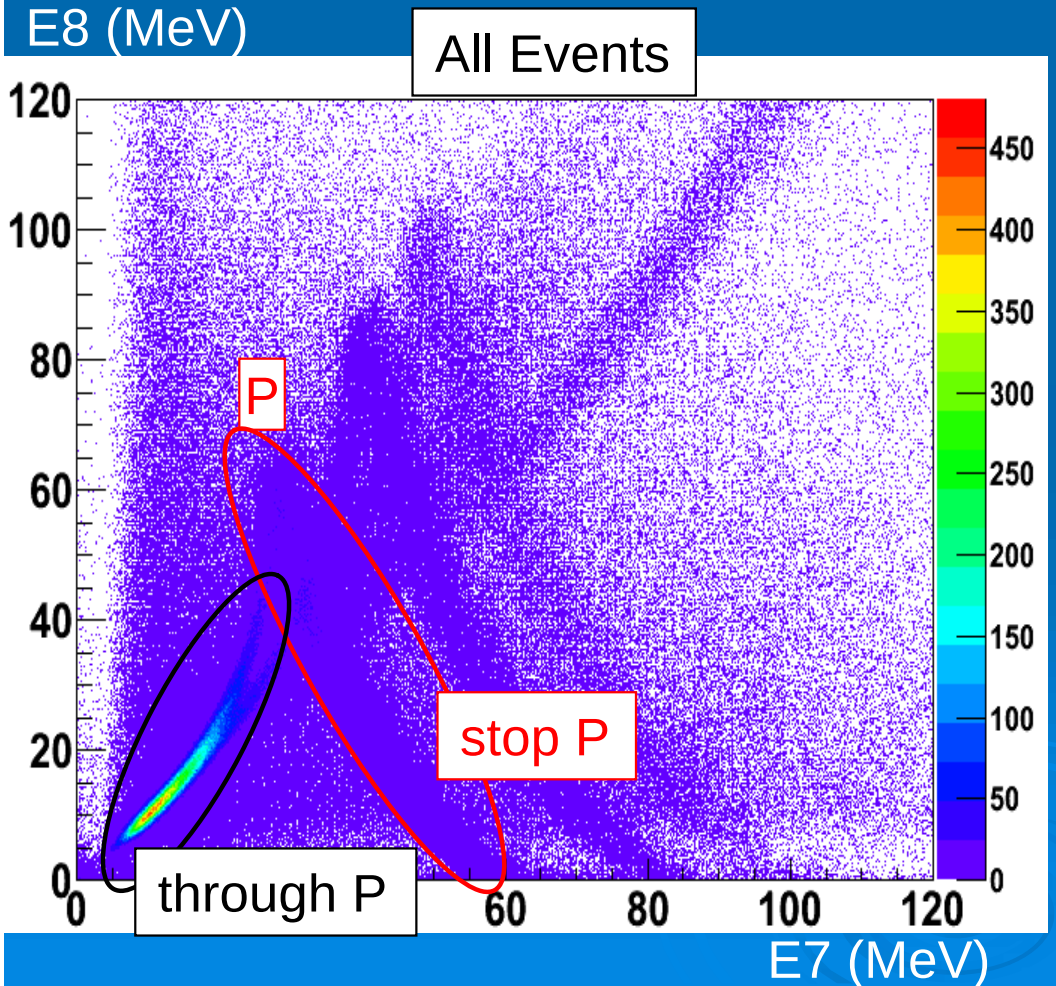
① π^+ ID using Double Hit Condition
② $\pi^\pm$ID using
ΔE conditions of well defined π^+
③ $\pi^- = \pi^\pm - \pi^+$

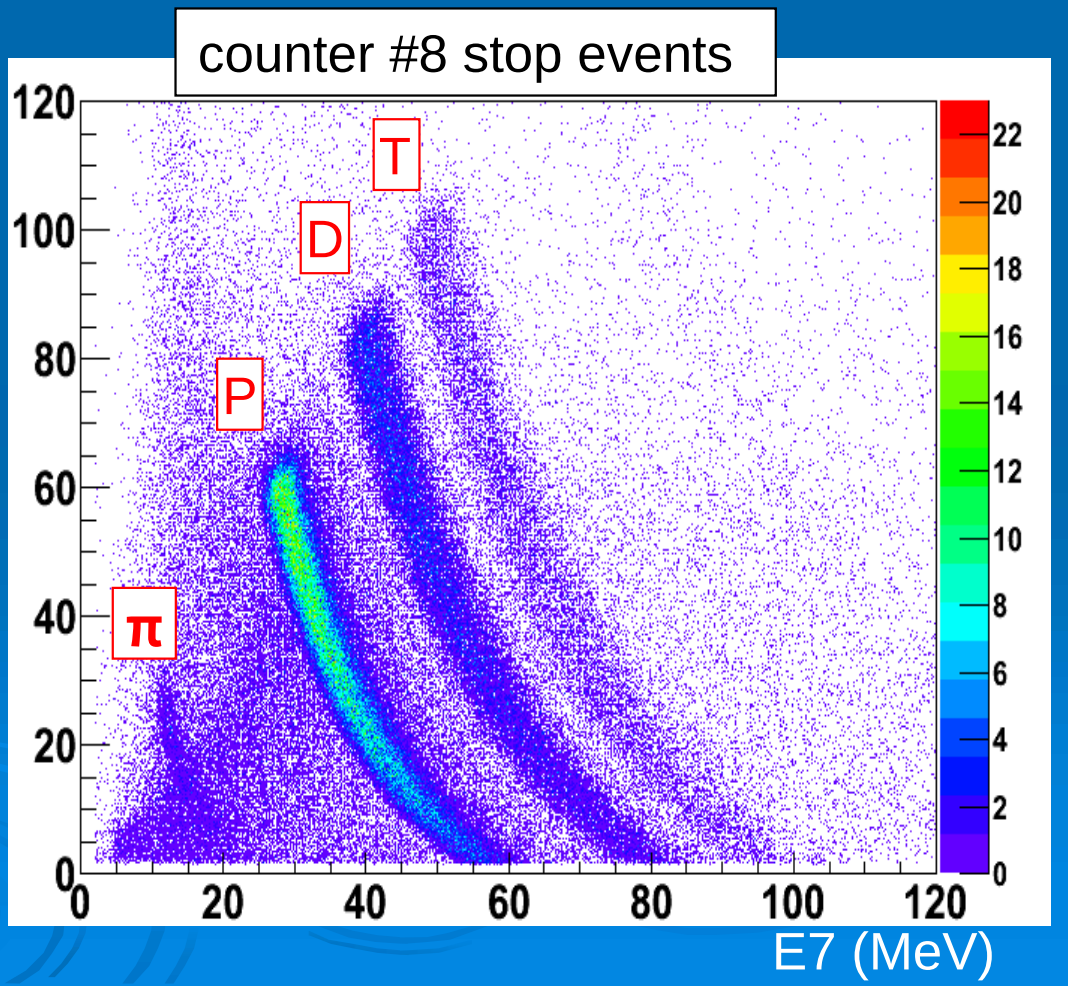


Histogram of Range Counter

Example counter : #8







π^+ Identification

＜π^+ events＞

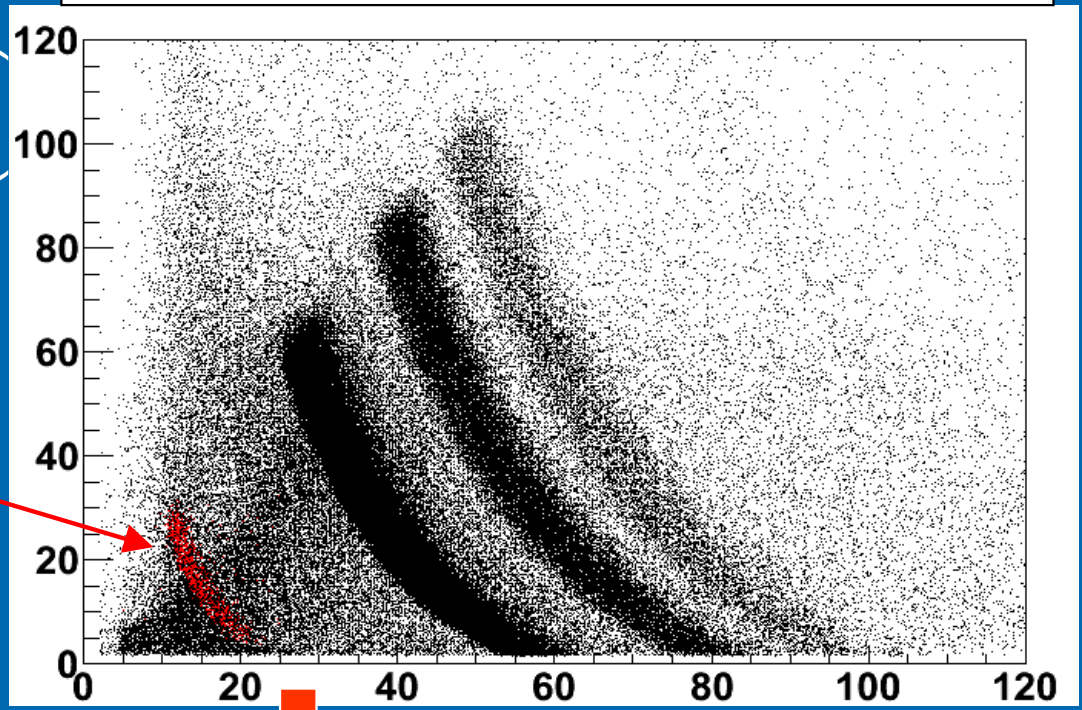
Counter #8 STOP Condition
+
#8 Double Hit Condition

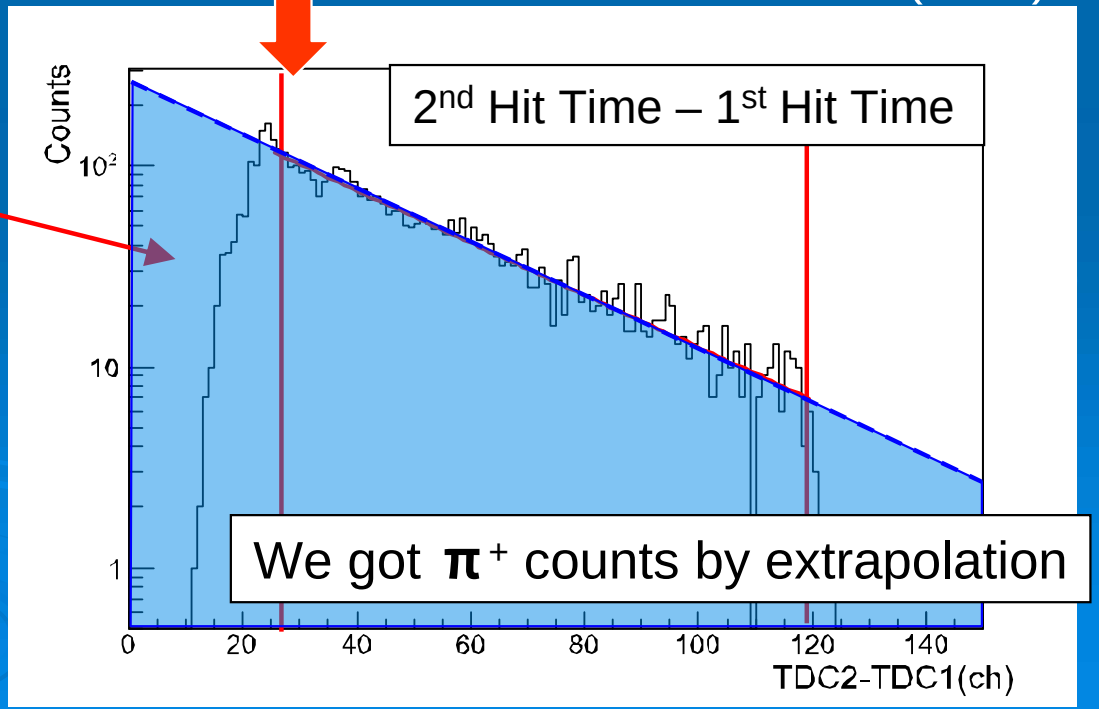
Fit the Histogram
"2nd Hit Time -1st Hit Time"
by C*exp*(- t / τ)

⇒ **τ = 26.0±0.6 nsec**

We could clearly select π^+

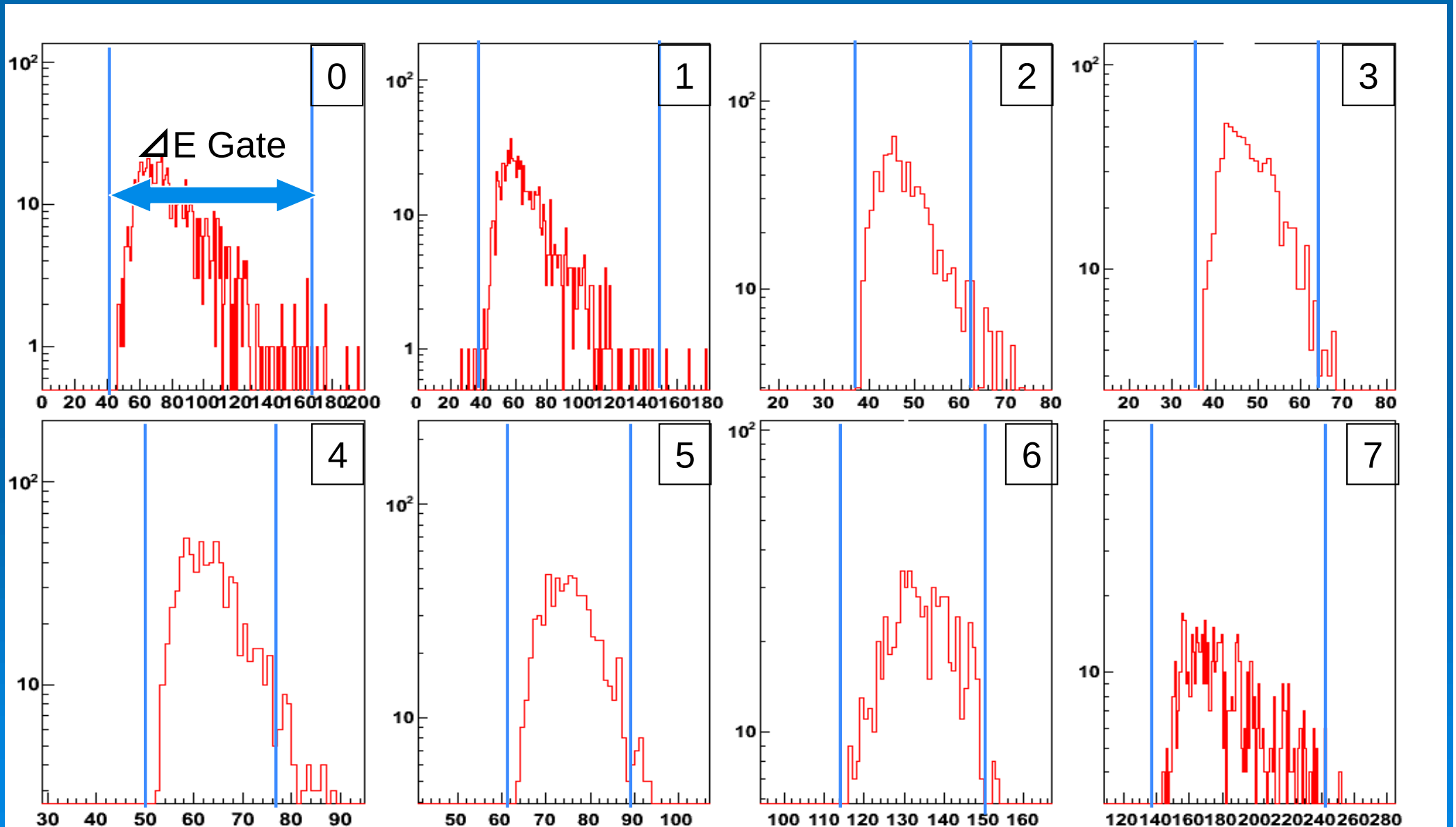
#8 stop events (black) & stop π^+ (red)





⊿E cut from #0 to 7 in 1 D

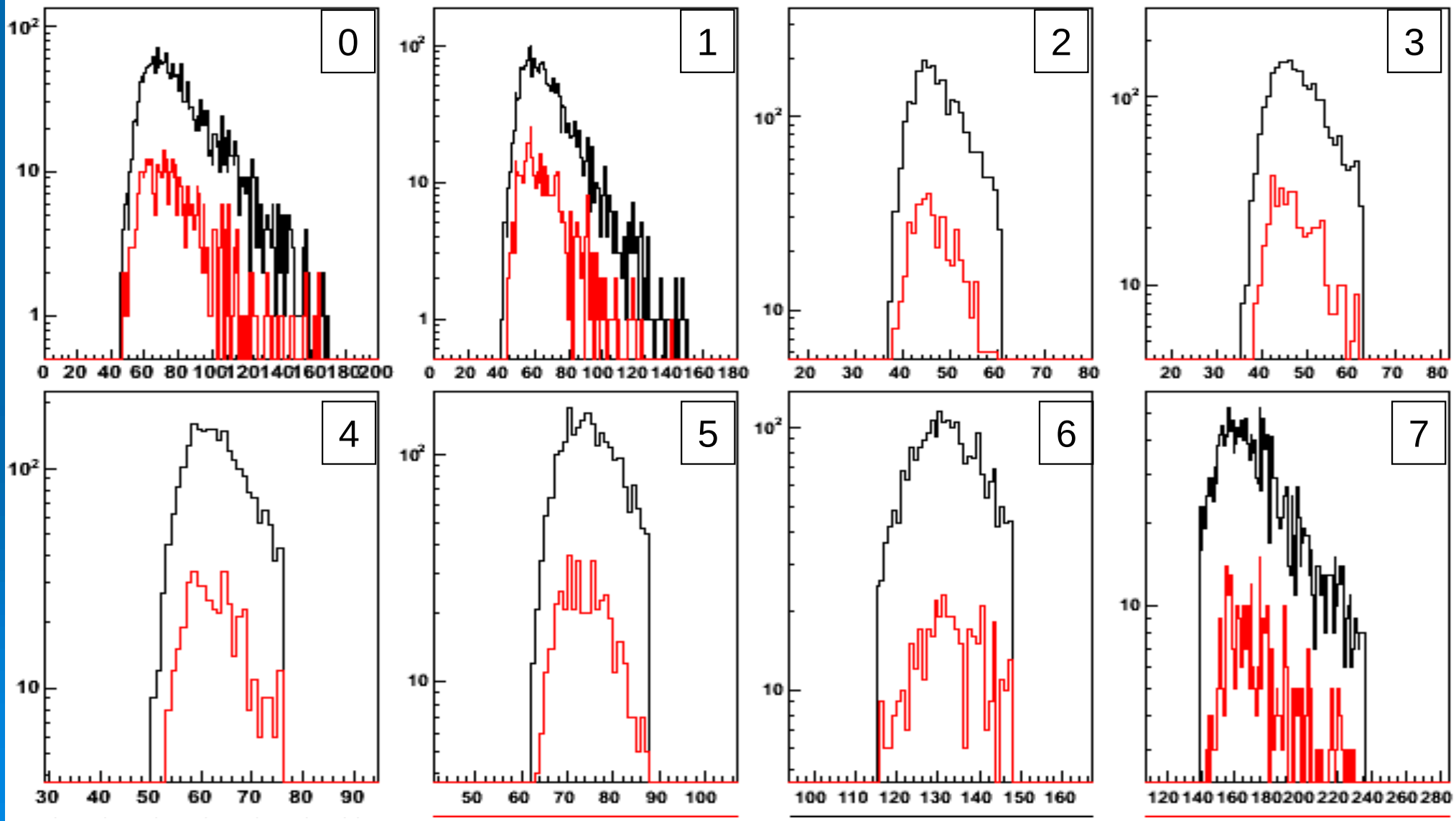
π^+ (red) : STOP + Double Hits Conditions



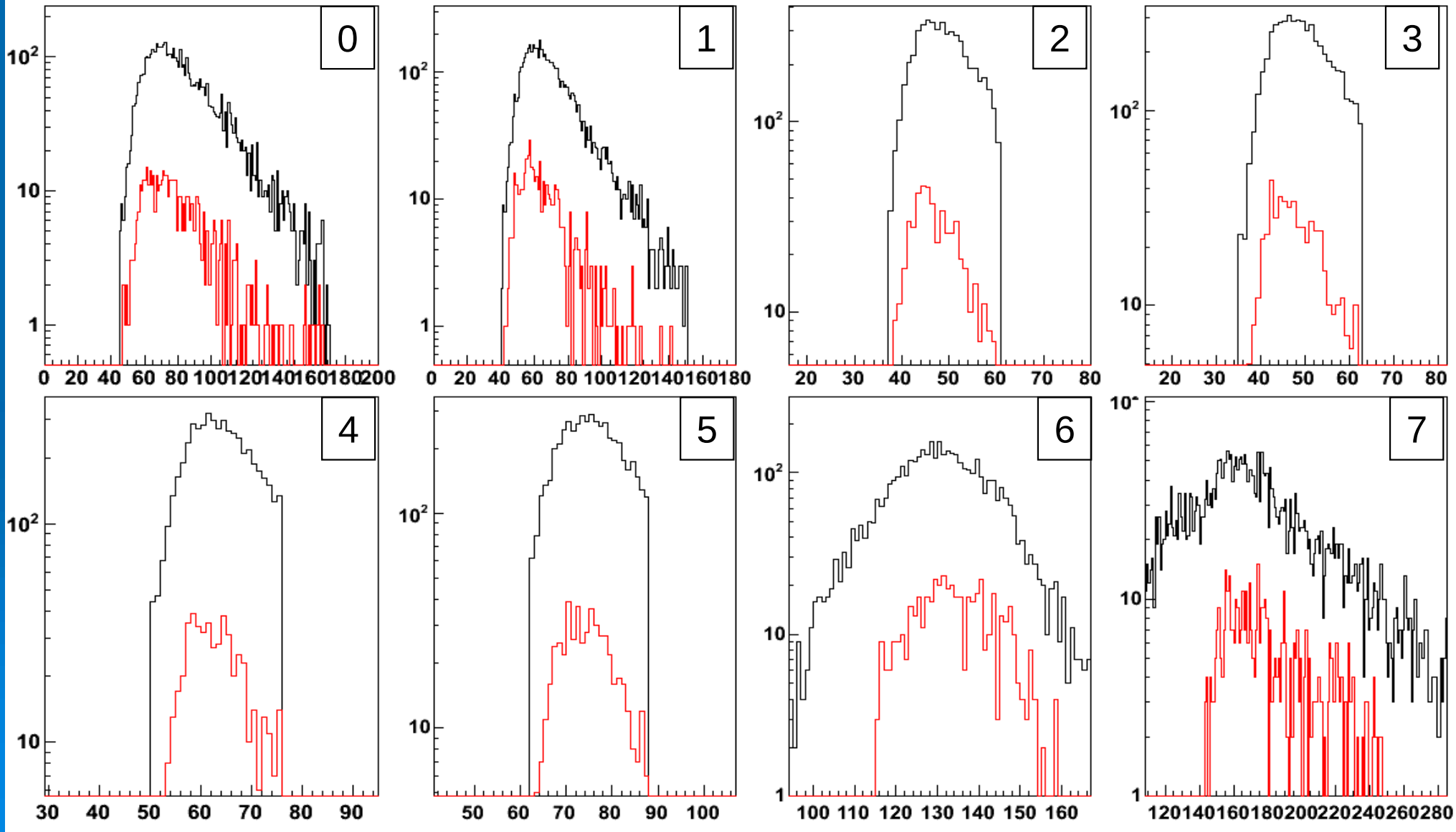
⊿E cut from #0 to 7 in 1 D

π^+ (red) : STOP + ⊿E CUT + Double Hit Conditions

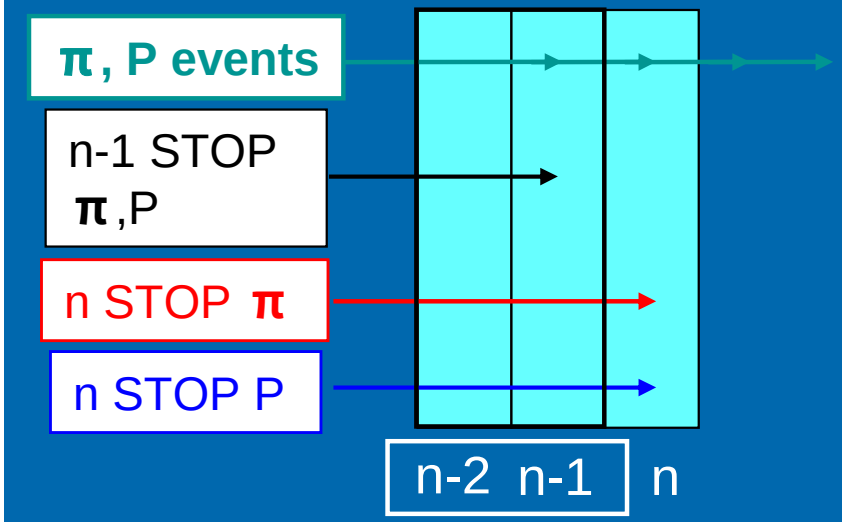
$\pi^\pm$ (black) : STOP + ⊿E CUT Conditions

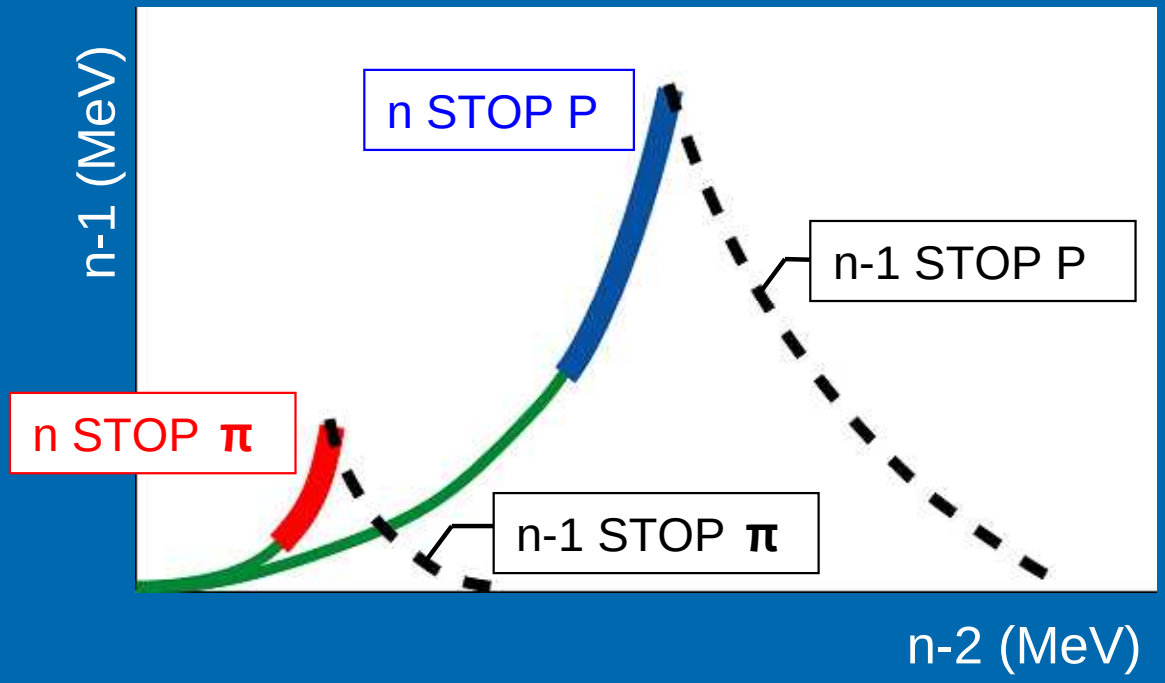


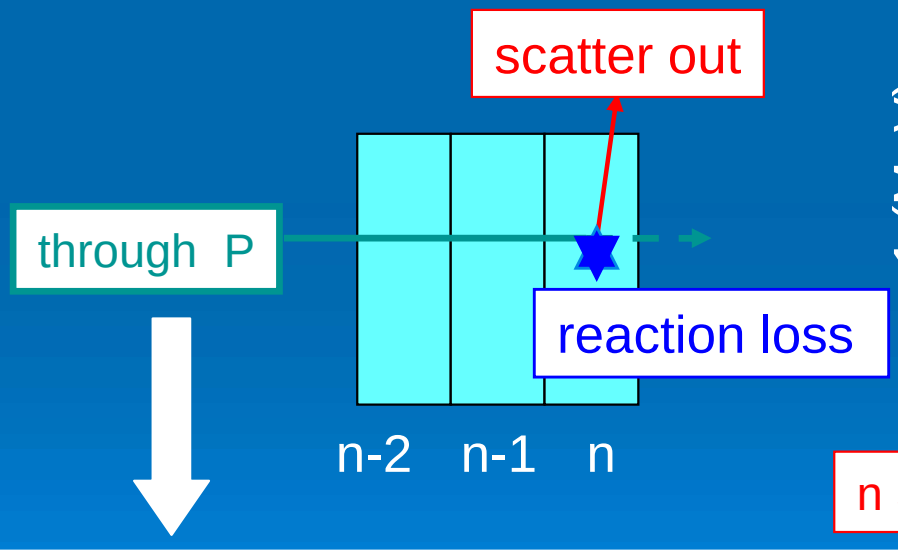
In order to check background,
we rejected counter 6 & 7 ⊿E conditions.
→ There are background in black histogram.

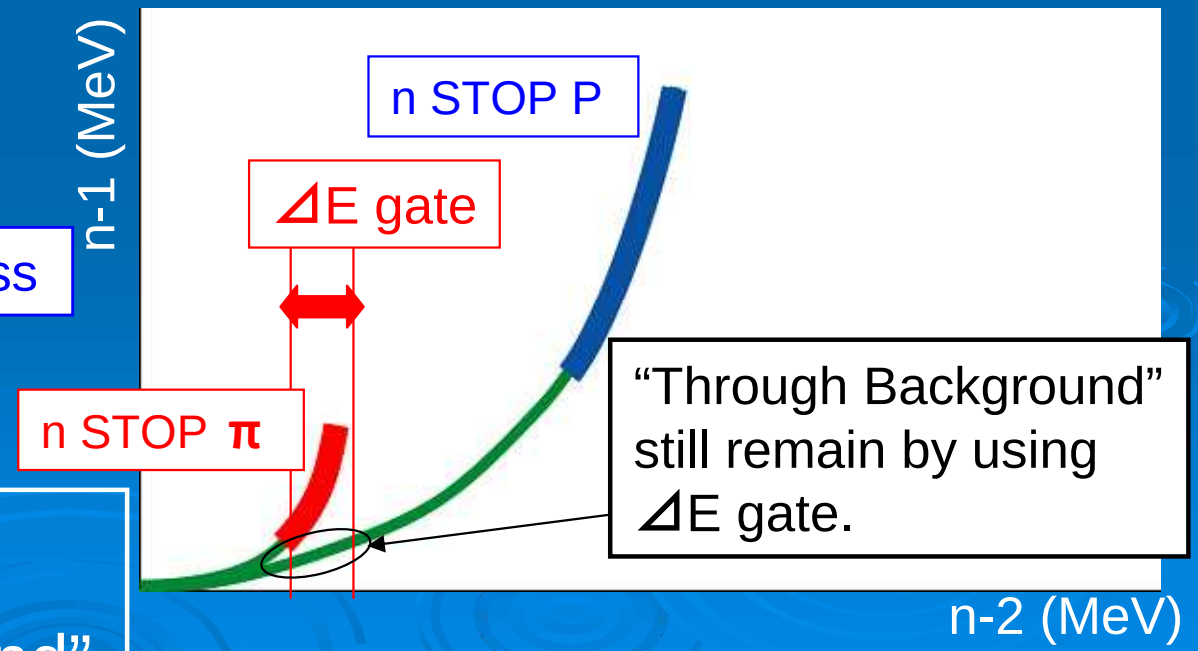


We look n stop events in “n-2 vs n-1” distribution









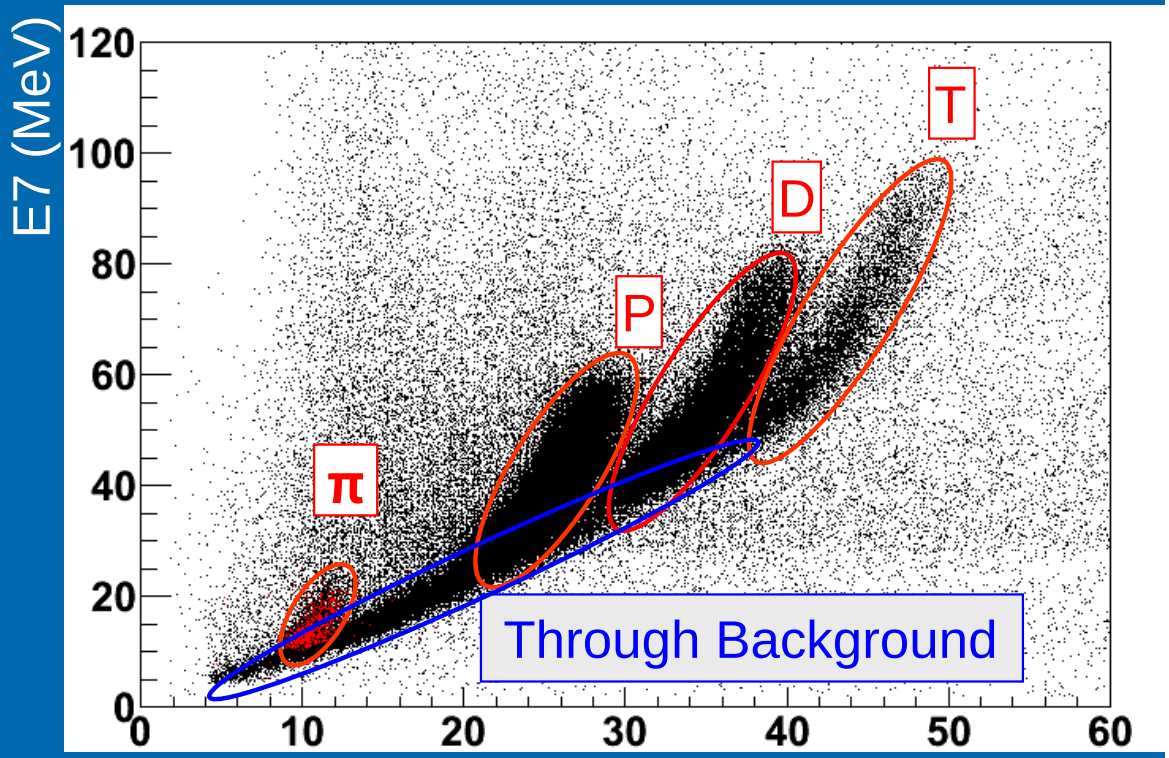
We call these background as

“Through Background”

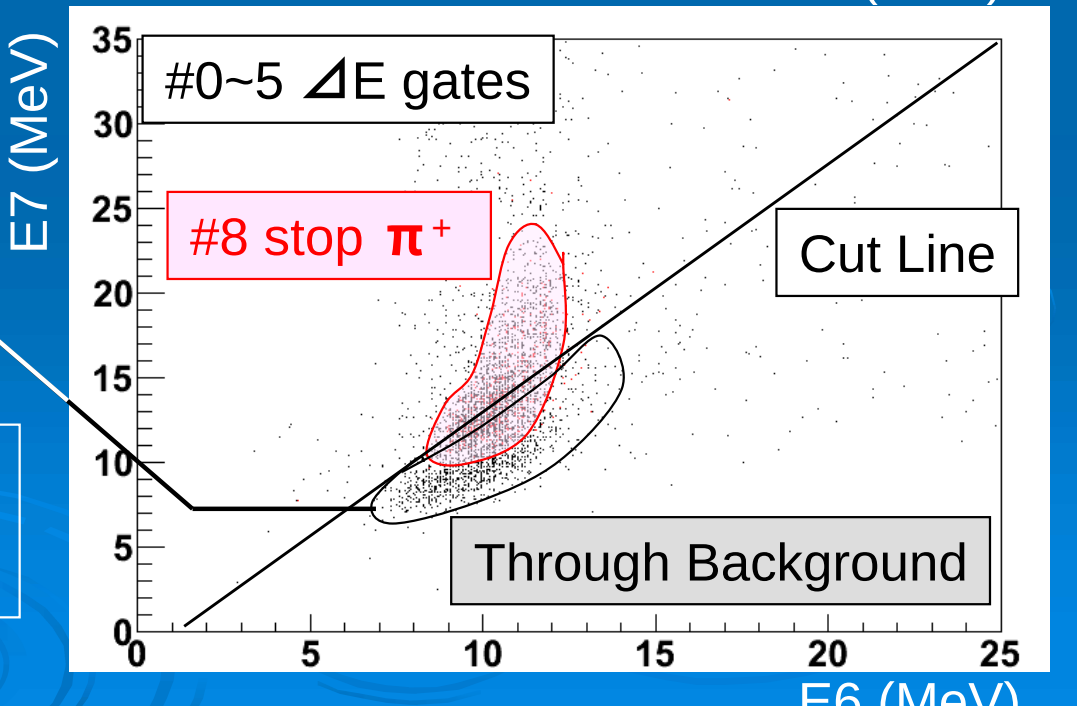
⊿E cut on 2D

CHECK 6 vs 7 Histogram of 8 stop events

- Red : π^+
- Black : Other Particles (Background etc)



<Background Check>
⊿E gates from #0 to 5
→ "Through Background" still exits.



Cut the "Through Background" using the straight line

Definition of π^-/π^+ ratio

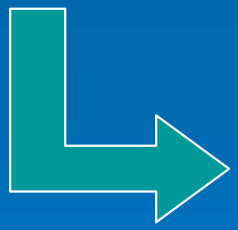
- $\pi^{\pm}$: STOP + ΔE cut + cut line
- π^+ : STOP + ΔE cut + cut line
  + Double Hit (extrapolation)

$$\pi^- / \pi^+ ratio = \frac{\pi^{\pm} - \pi^+}{\pi^+}$$

Discussion

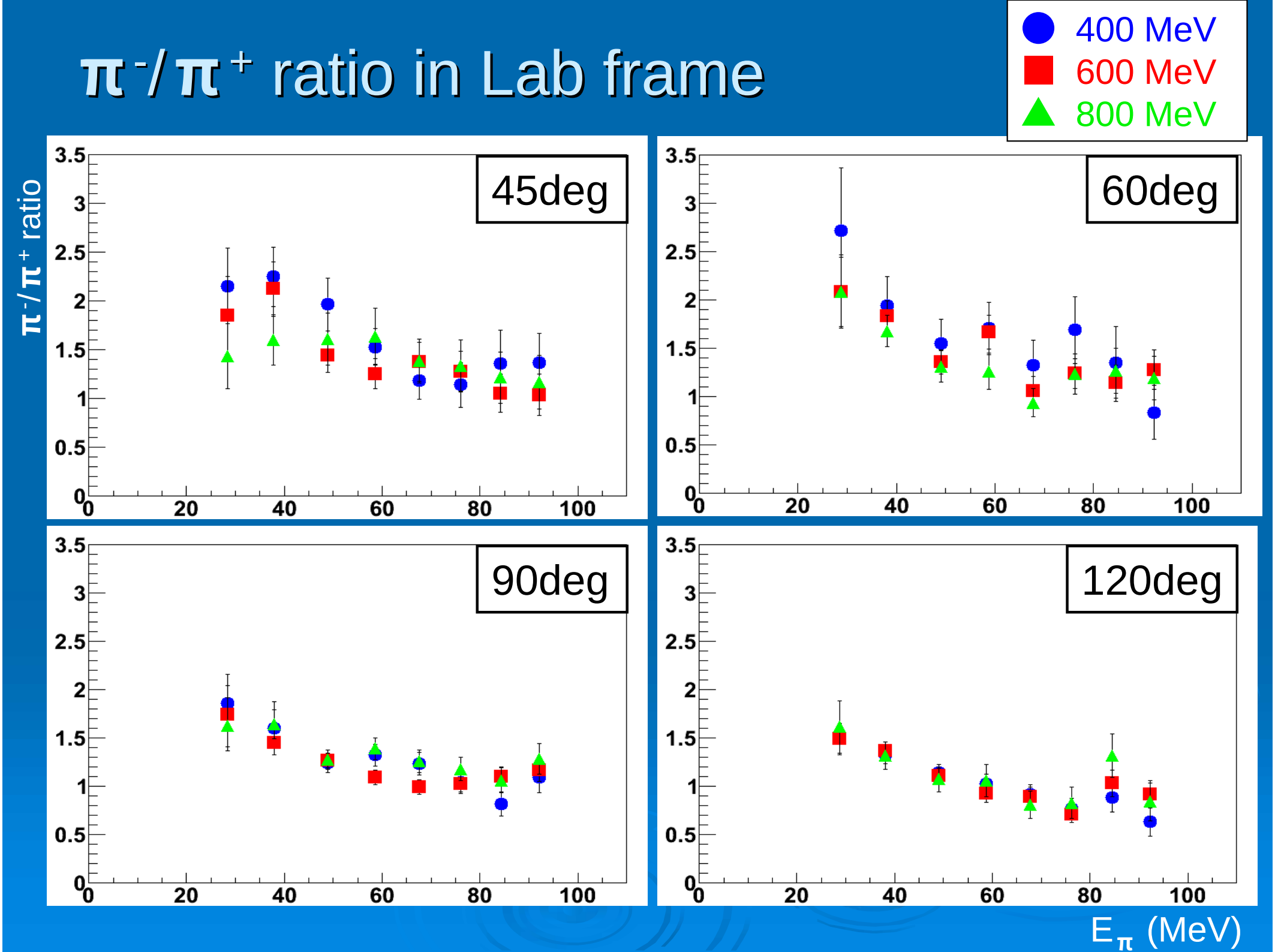
Analysis Frame

- Target frame (lab frame)
- Projectile frame
- CM frame (c.m.s. of projectile and target)
- mid Rapidity frame (N-N frame)

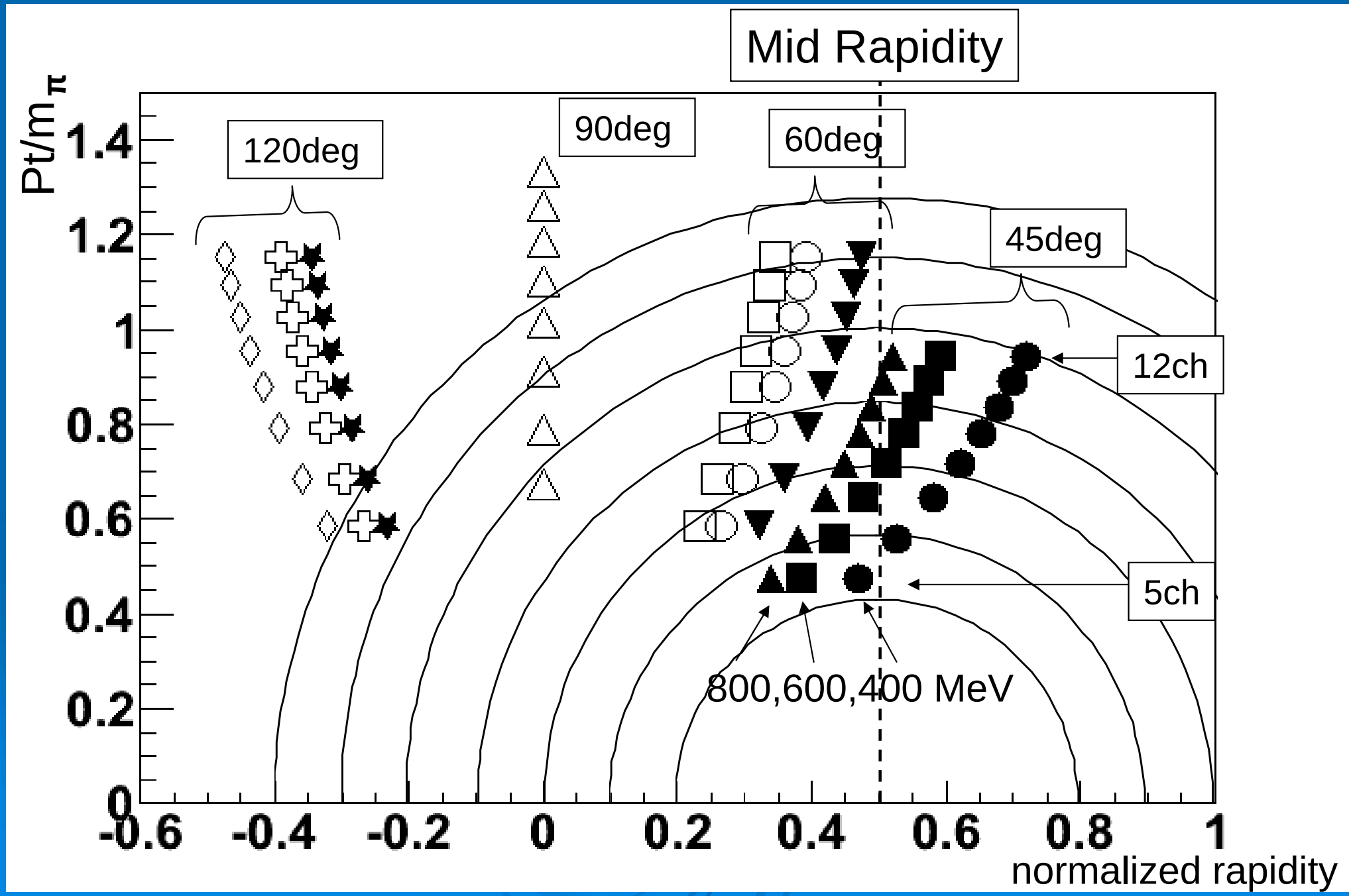


We discuss the data
in Target and Mid Rapidity frames.

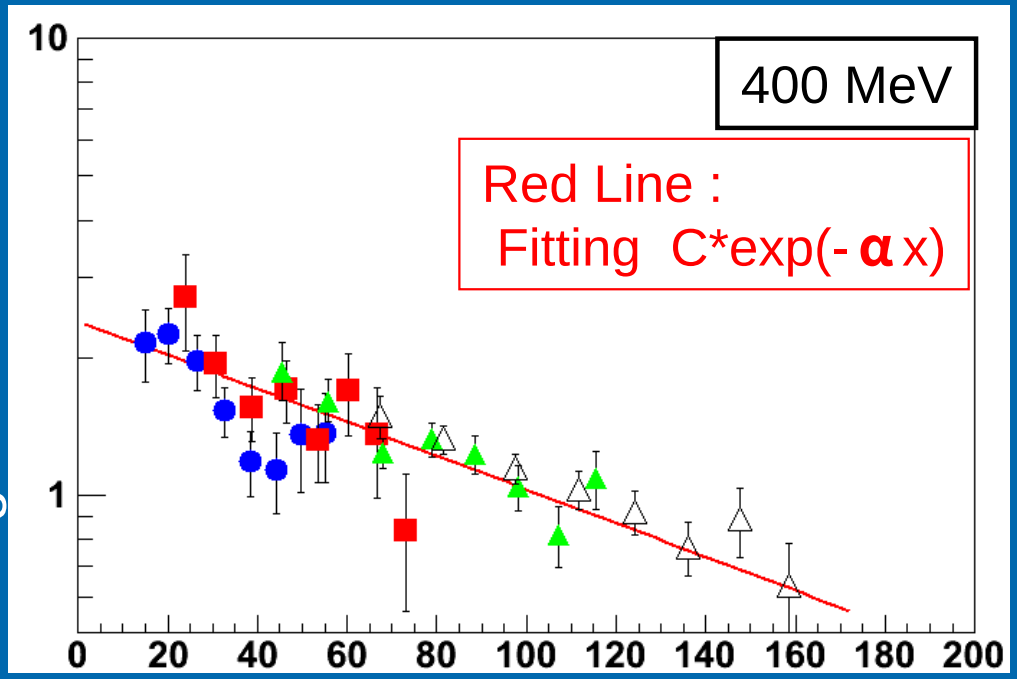
π^-/π^+ ratio in Lab frame

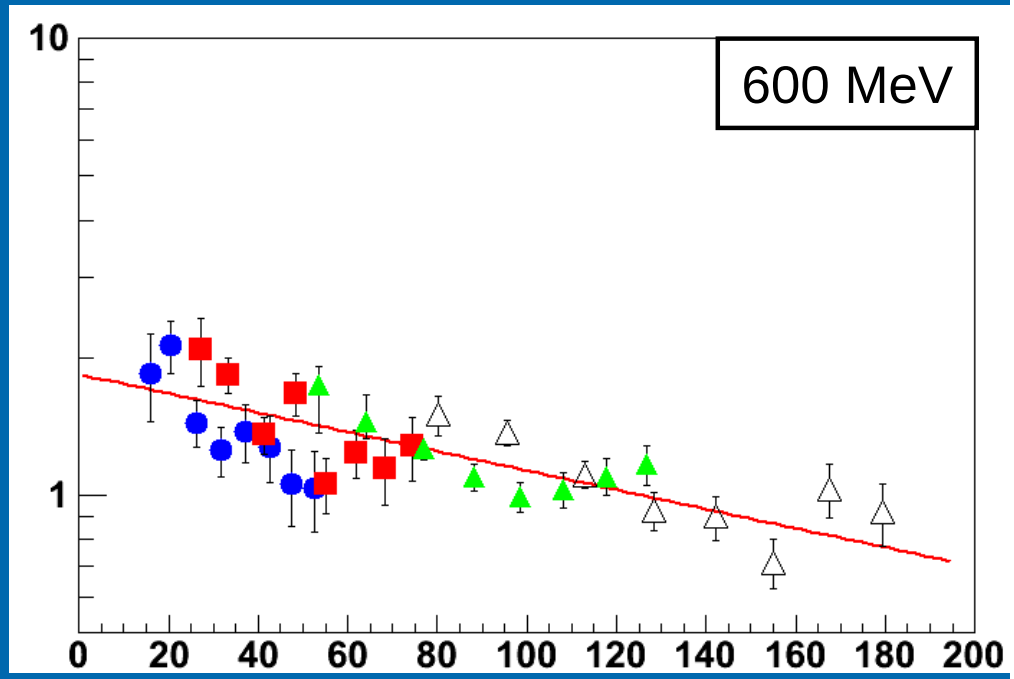


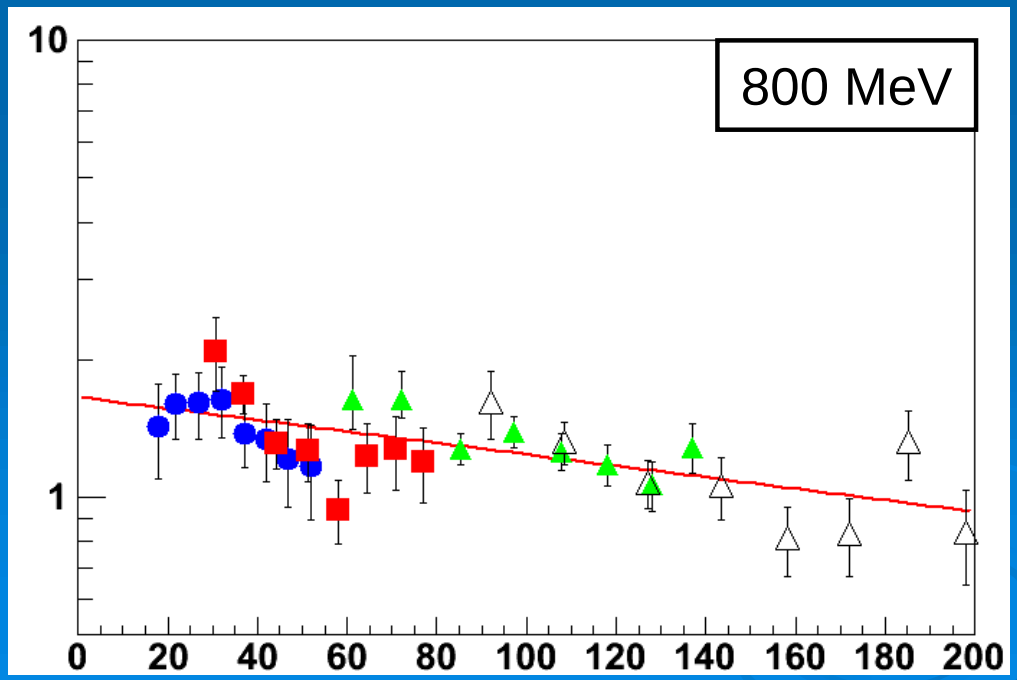
Energy Distribution in Mid Rapidity Frame



mid rapidity frame (log scale)







slope α :
- 400 : (8.5±1.1)×10^{-3}
- 600 : (4.8±0.9)×10^{-3}
- 800 : (2.9±0.7)×10^{-3}

45deg
60deg
90deg
120deg

Slopes depend on Beam Energy

$E_{rap\,\pi}$ (MeV)

Summary and Next Step

<Summary>

- There are energy dependence in pion ratio.
  - Especially for low energy pion in the mid rapidity frame.

<Next Step>

- We are planning next experiments
  - Good sensitivity to low energy pion
  - N/Z dependence using Xe isotope beam