Exclusive measurement of $\gamma d \to d\pi^+\pi^-$ with NKS2 at ELPH (Search for NΔ dibaryon)

Yuichi Toyama

for the NKS2 collaboration

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  - What's Dibaryon?
  - $\gamma d \to d\pi^0\pi^0$ from Forest
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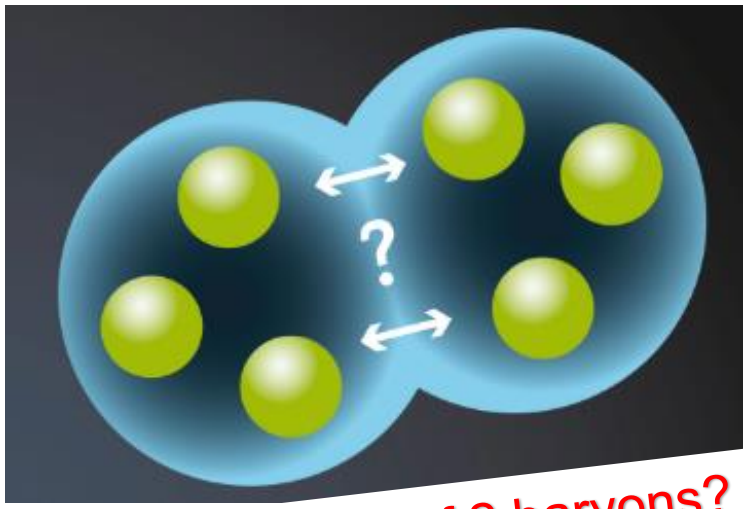
- Search for NΔ dibaryon
  - Event selection
  - Invariant mass
  - Possible scenario
- Future prospects
- Summary

What is “dibaryon” ?



Molecule state of 2 baryons?
Compact 6 quarks state?

Classification of 2-baryon state without strangeness

$\mathcal{D}_{IS}$	$\mathcal{D}_{01}$	$\mathcal{D}_{10}$	$\mathcal{D}_{12}$	$\mathcal{D}_{21}$	$\mathcal{D}_{03}$	$\mathcal{D}_{30}$
BB	NN	NN	NΔ	NΔ	ΔΔ	ΔΔ
Mass formula	A	A	A+6B	A+6B	A+10B	A+10B
Approx. mass	1878	1878	2160	2160	2348	2348

Deuteron
$^3S_1$

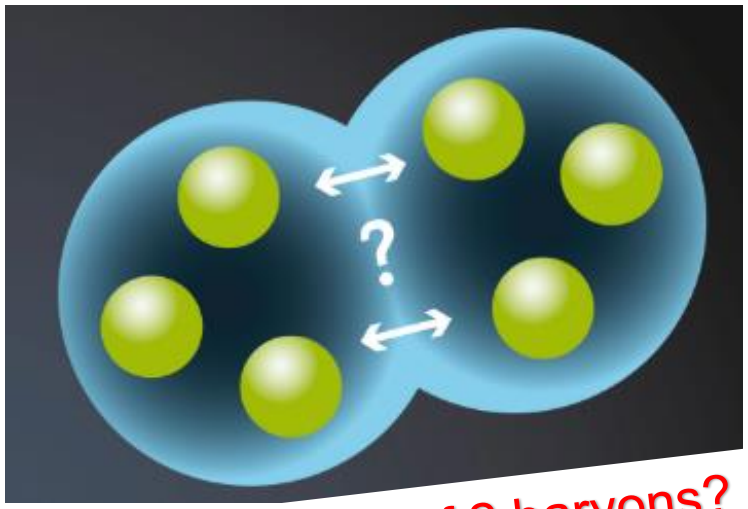
Virtual state
(pp, nn, np)
$^1S_0$

WASA at COSY
$d^*(2380)$

$$M = A + B\,(I(I+1) + S(S+1) - 2)$$

A = 1878 MeV
B = 47 MeV
Dyson-Xuong, PRL 13 (1964) 815

What is “dibaryon” ?



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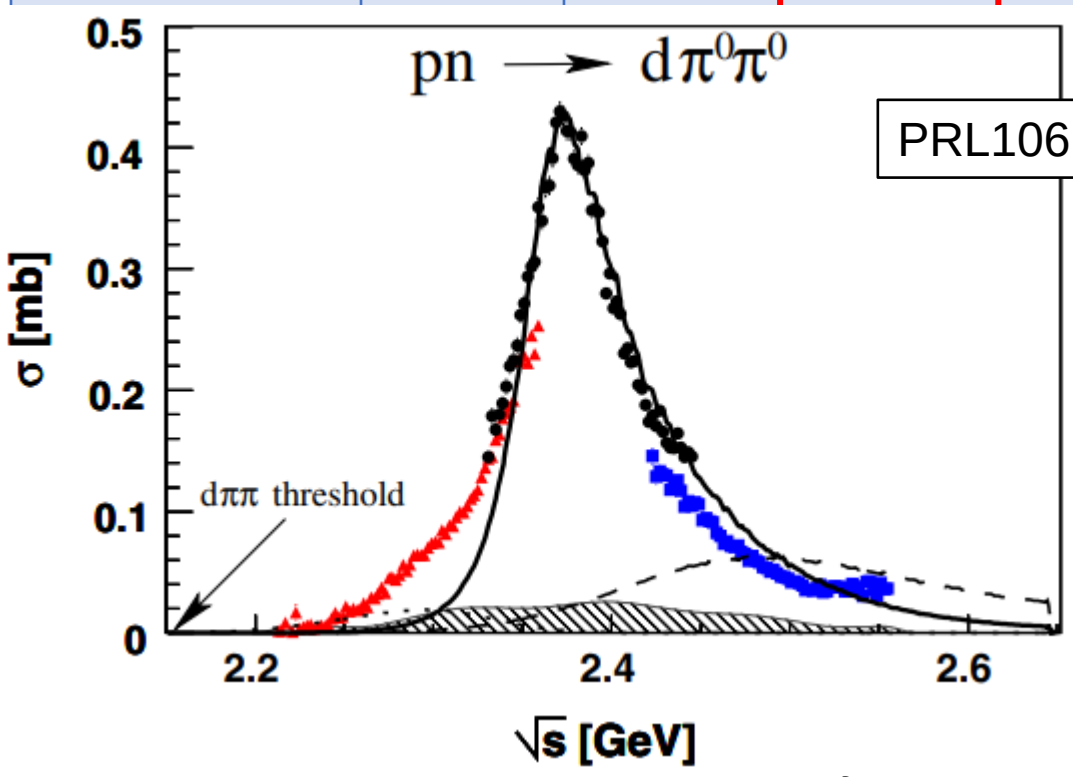
BB	NN	NN	NΔ	NΔ	ΔΔ	ΔΔ
				3B	A+10B	A+10B
						2348



PRL106, 242602 (2011)

WASA at COSY
d*(2380)

$(I(I+1)+S(S+1)-2)$
/leV
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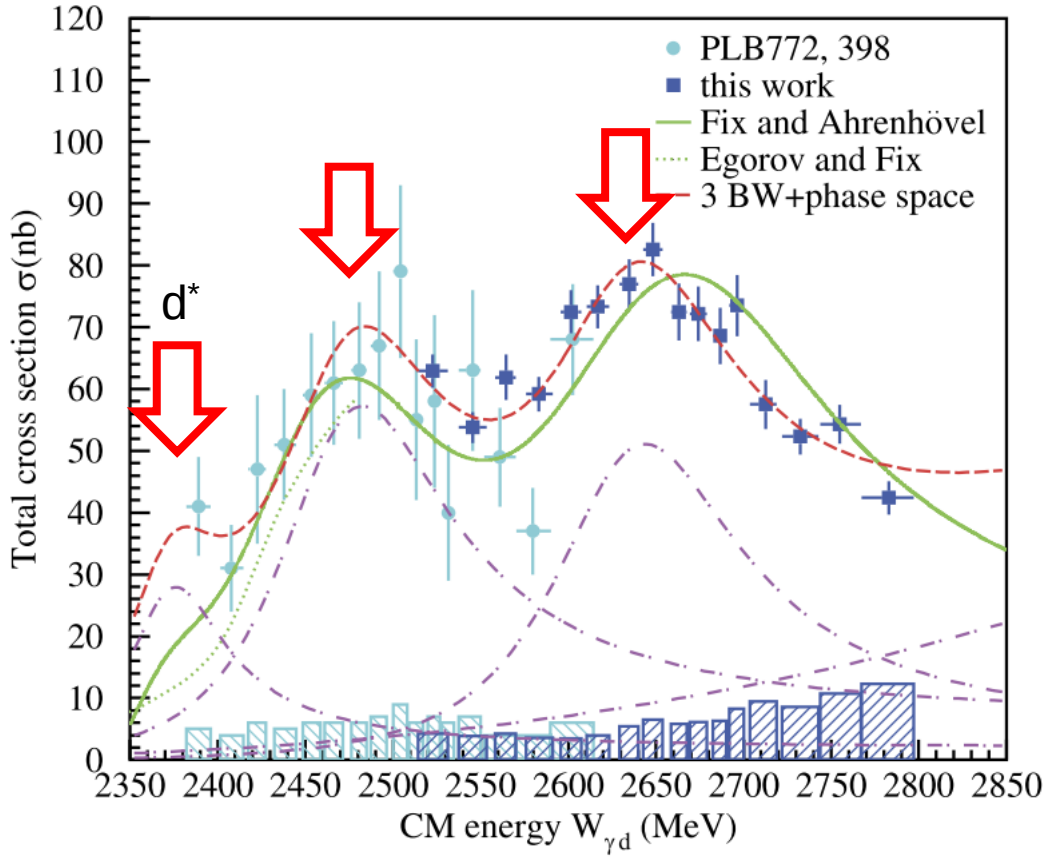
g, PRL 13 (1964) 815

T. Ishikawa et al., PLB789, 413 (2019)

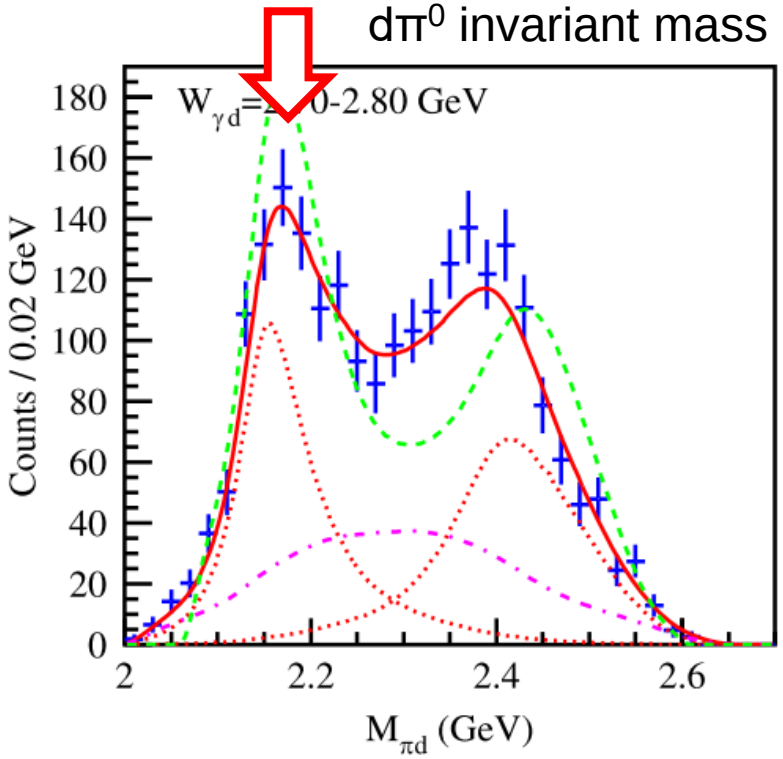
$\gamma d \to d\pi^0\pi^0$

Forest, ELPH

Total cross section



dπ⁰ invariant mass



- 3 iso scaler dibaryon, 1 iso vector dibaryon

T. Ishikawa et al., PLB789, 413 (2019)

$\gamma d \to d\pi^0\pi^0$

Forest, ELPH

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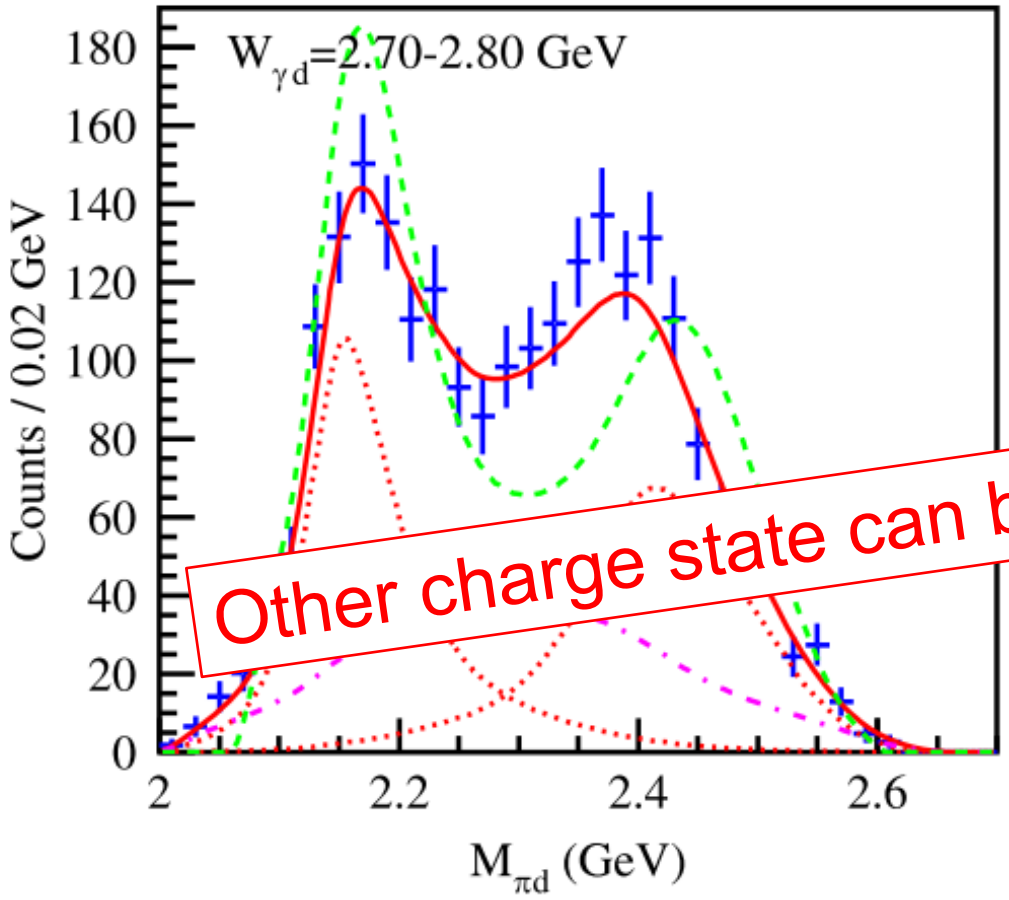
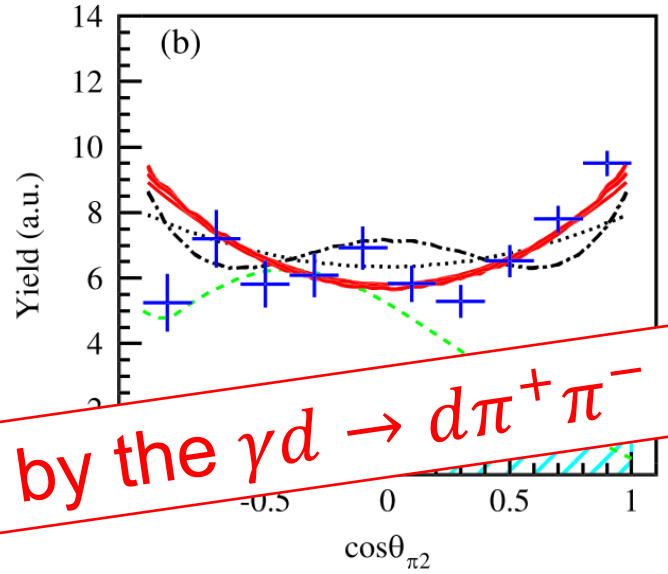




Other charge state can be measured by the $\gamma d \to d\pi^+\pi^-$

M = 2.14± 0.01 GeV
Γ = 0.09±0.01 GeV
$J^P = 1^+, 2^+$, or 3^-

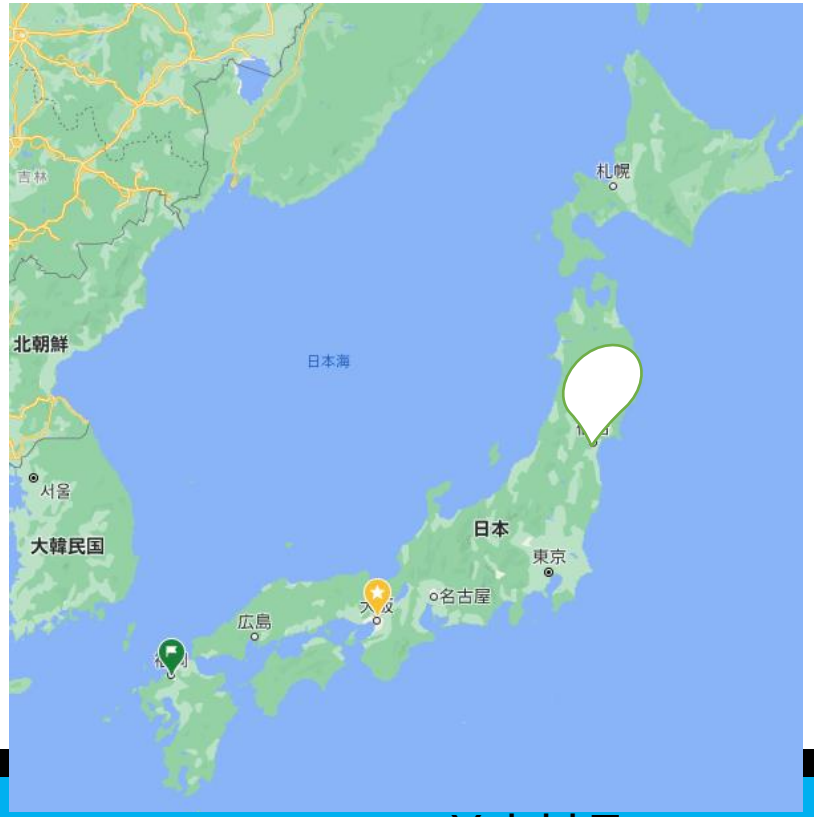
- 3 iso scaler dibaryon, 1 iso vector dibaryon

Experiment

Research Center for ELectron PHoton Science (ELPH)

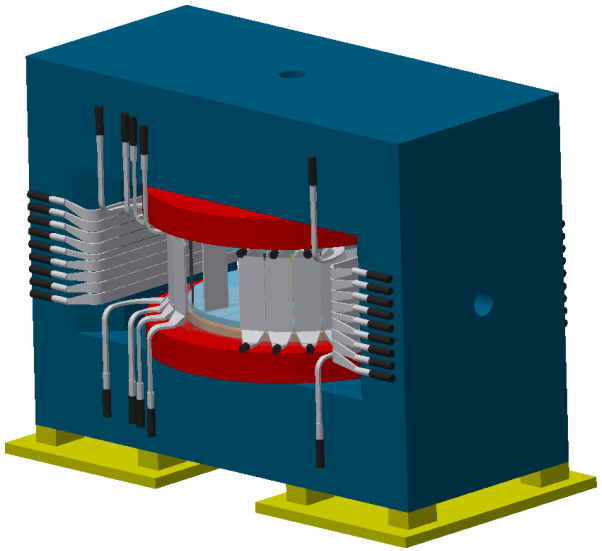
- Location: Sendai, Japan
- Electron Synchrotron
  - Internal target system for γ beam

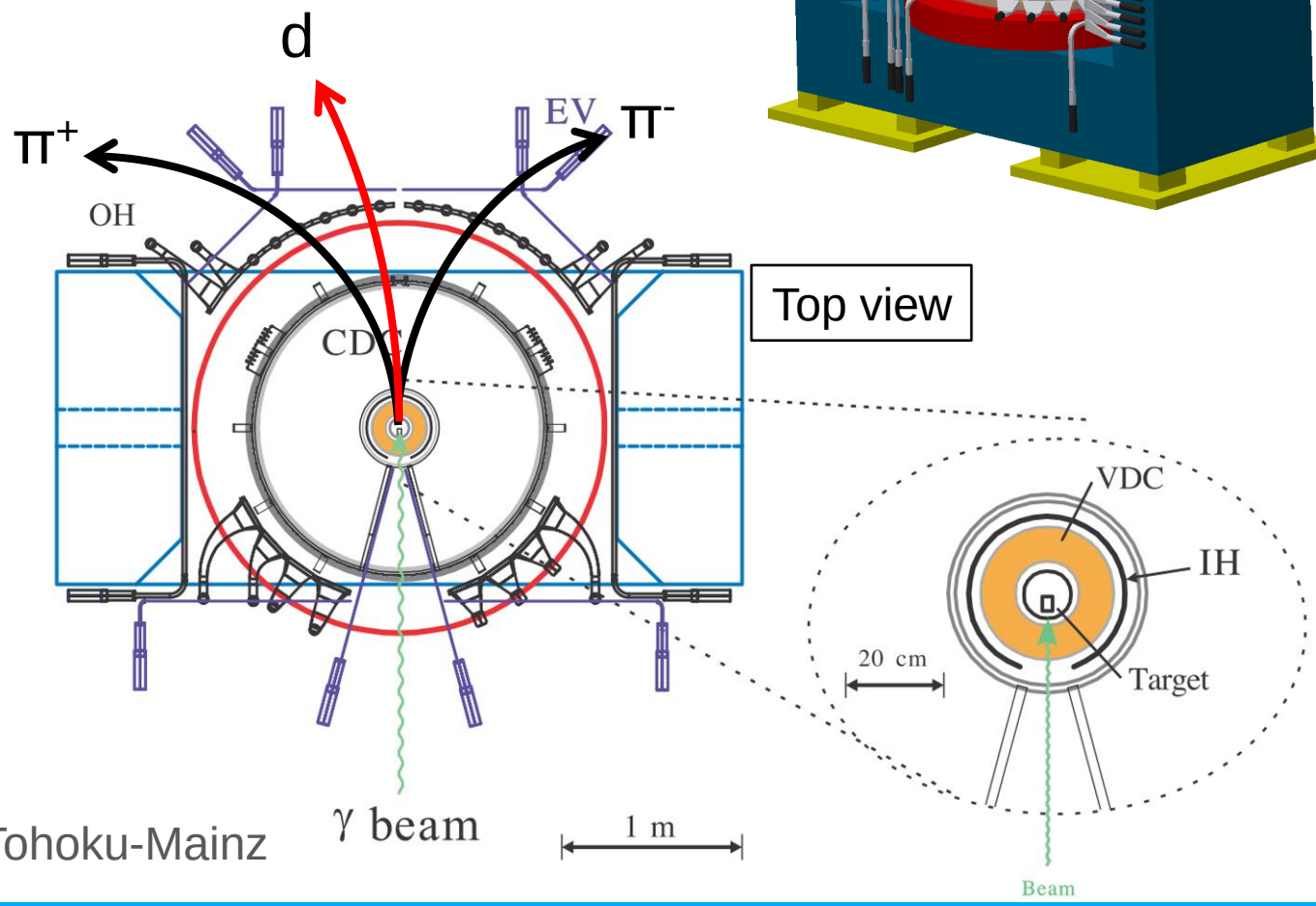
Max Beam current	30 mA
Ring top energy	0.8—1.3 GeV
Duty factor	~0.7
Injection Beam energy	90 MeV



Neutral Kaon Spectrometer 2 (NKS2)

- $\gamma + d \rightarrow \pi^{\pm} + X \rightarrow \pi^{+} + \pi^{-} + d$
- Data taken in Oct. 2010
- E_γ = 0.8–1.1 GeV (before 2011)
- liq. D target (516 mg/cm^2)
- N_γ = 3 x 10^{12}





- Dipole magnet : B ~ 0.42 T, R = 0.8 m
- Hodoscopes (IH and OH): TOF measurement
- MWDC's (CDC and VDC) : Tracking for momentum and vertex finding
- EV: Reduction of e^+e^- background
- Geometrical acceptance: ~ 1 π sr

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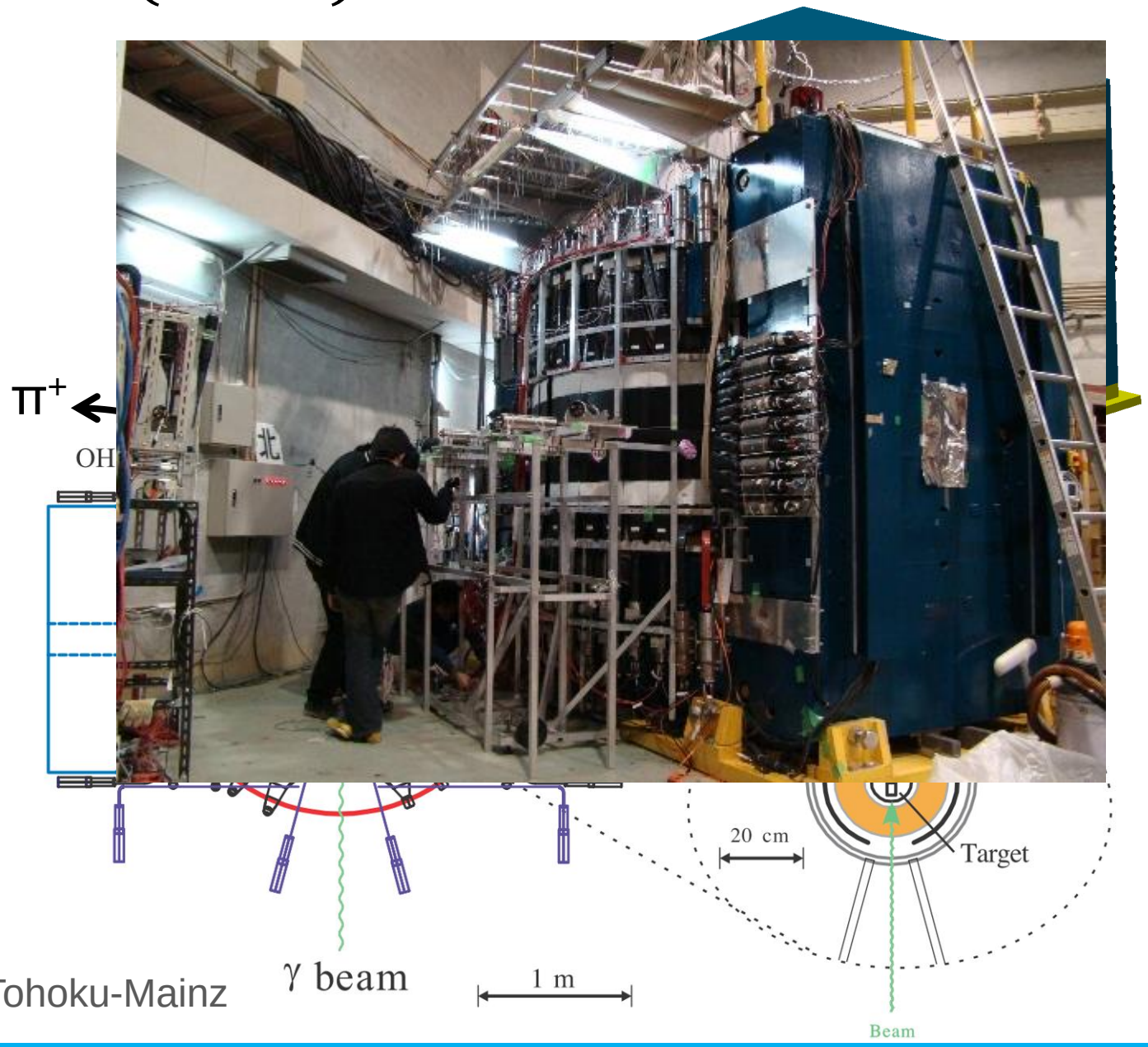
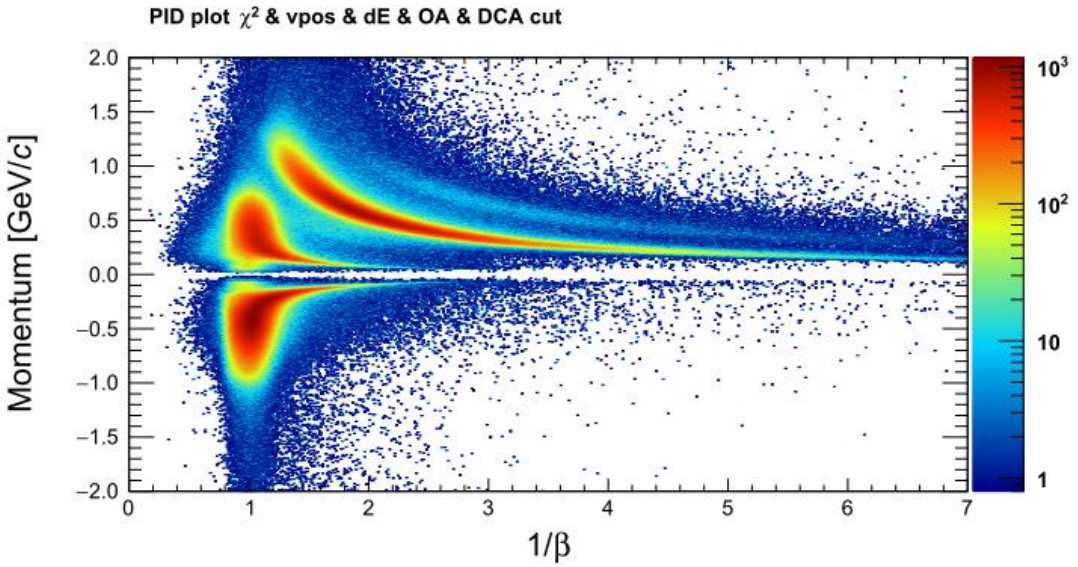
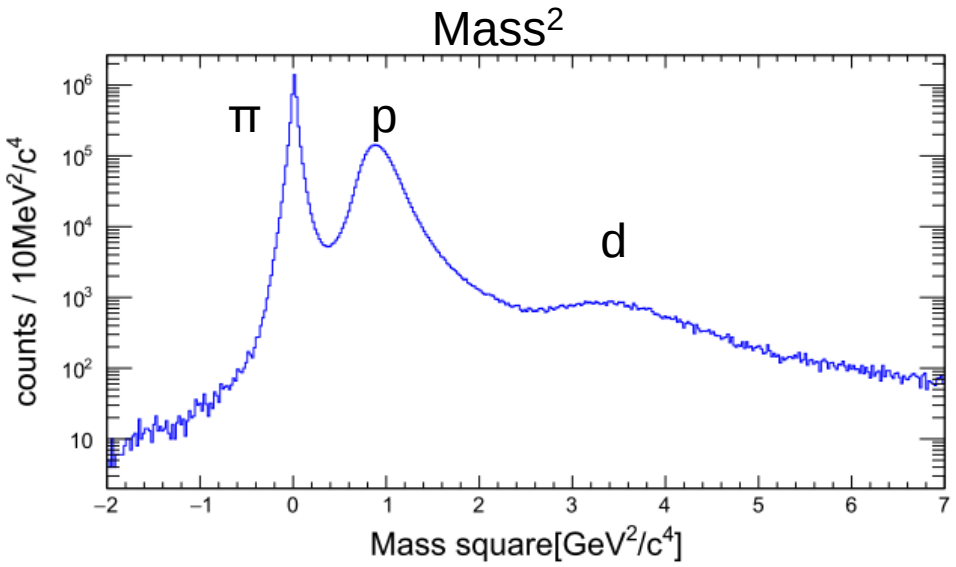


Particle ID

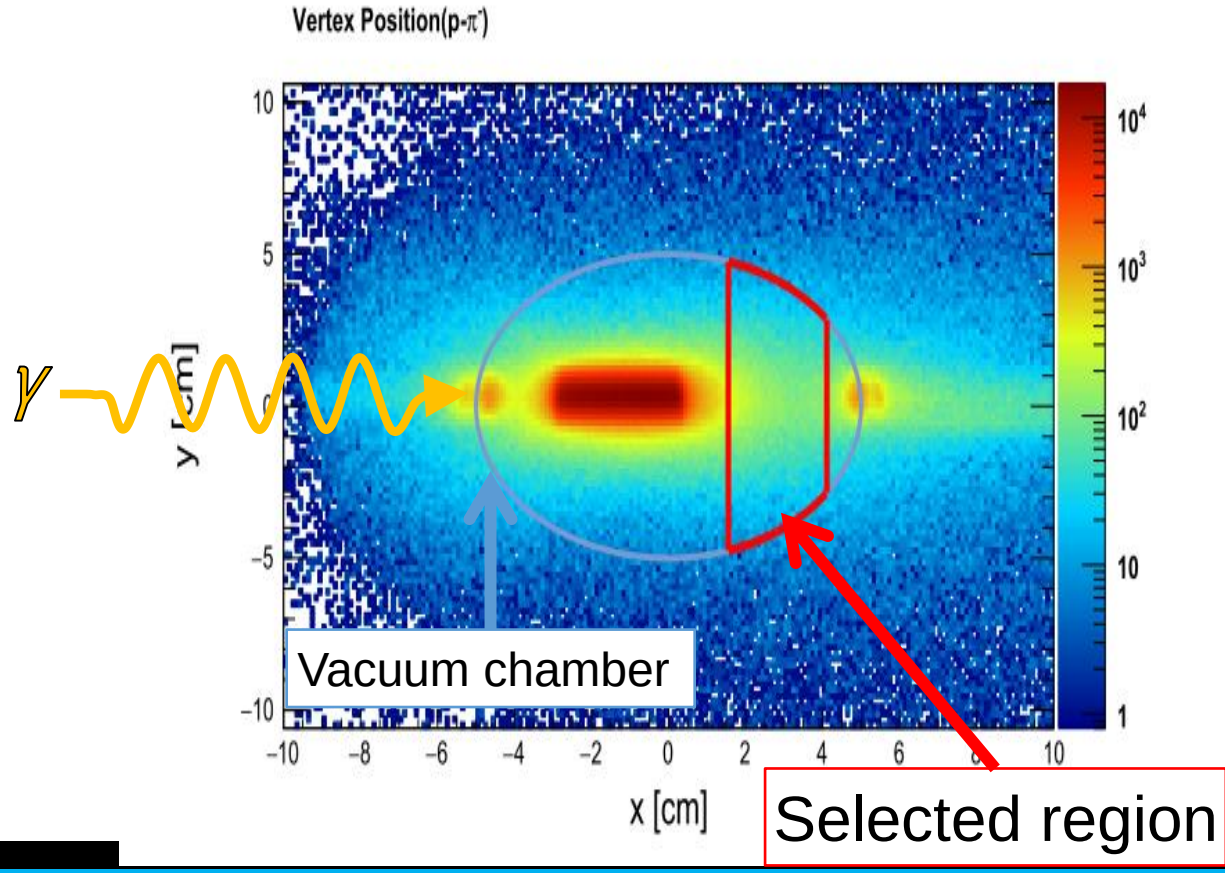


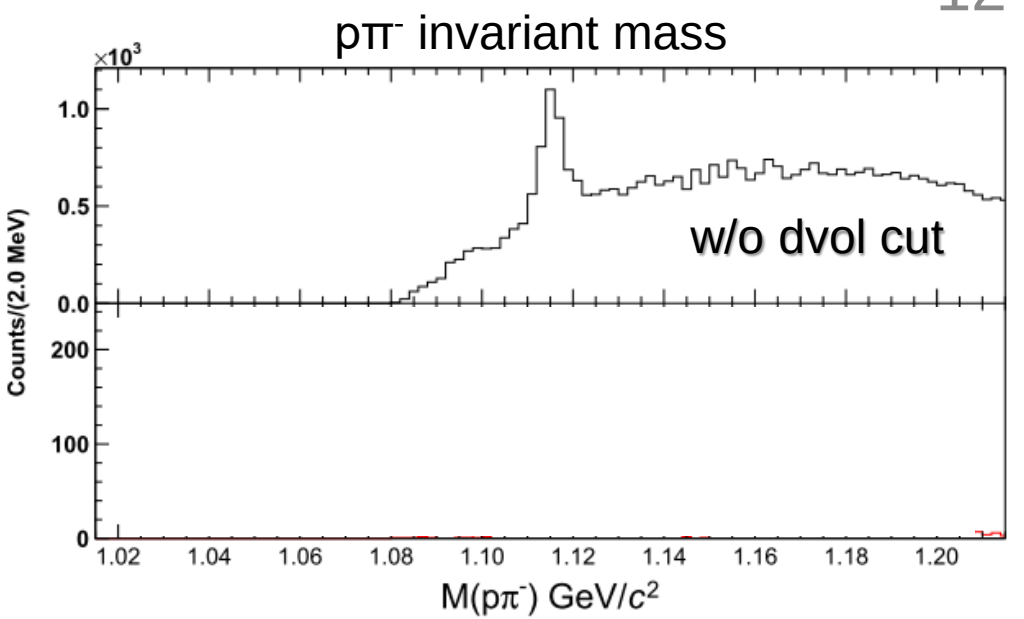


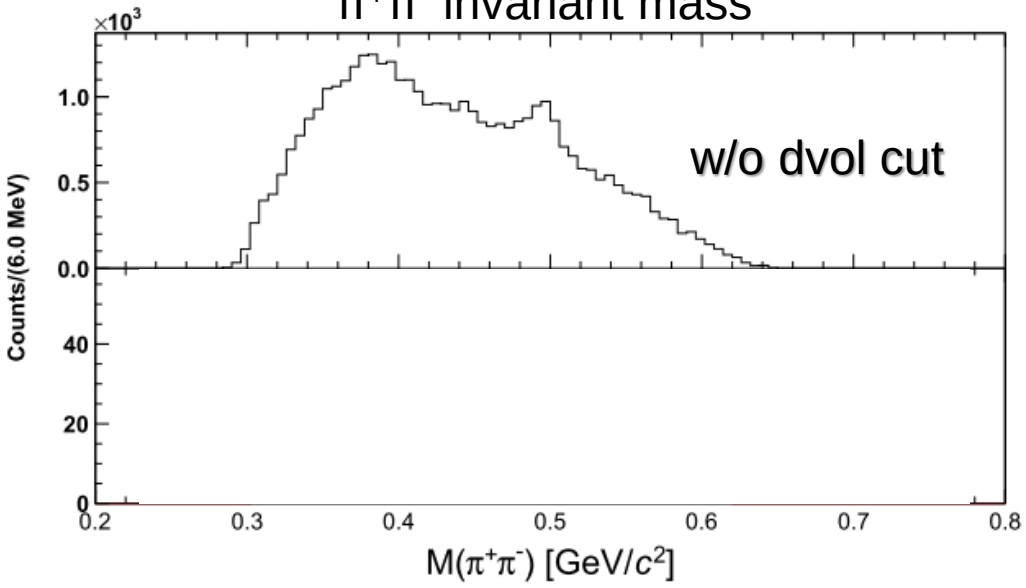
- 2track vertex events
  - w/ several cuts for good track
- 1/β from Hodoscopes (and DCs)
- Mom. from drift chambers
  - Runge-Kutta

Vertex & weakly decay events

- Λ, K^0 : good reference of the momentum calib.
- Decay volume cut (weak decay)







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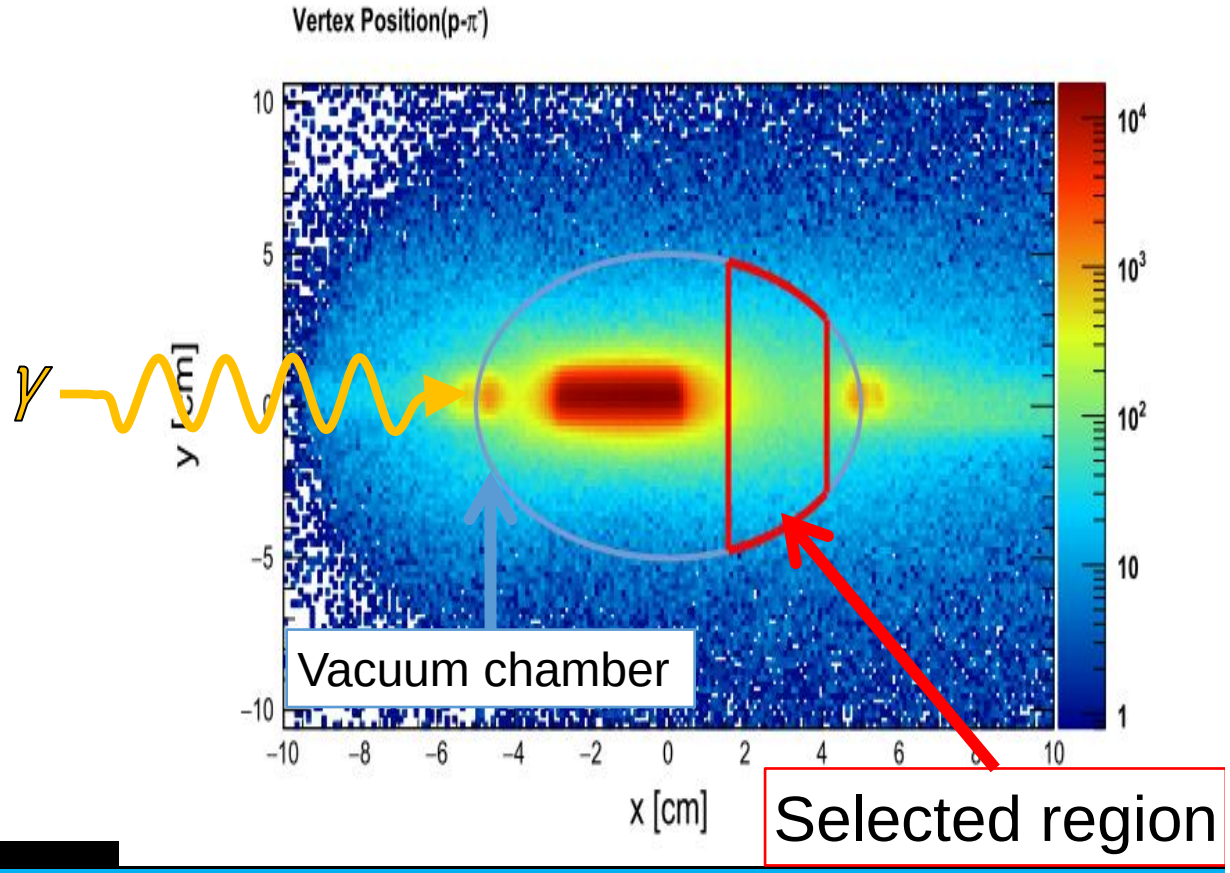
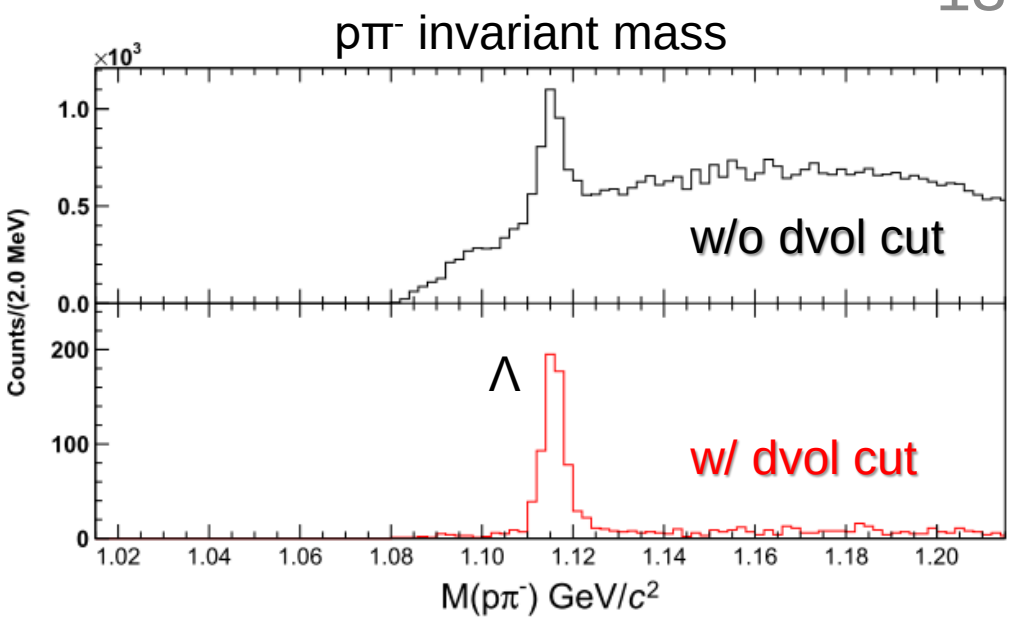
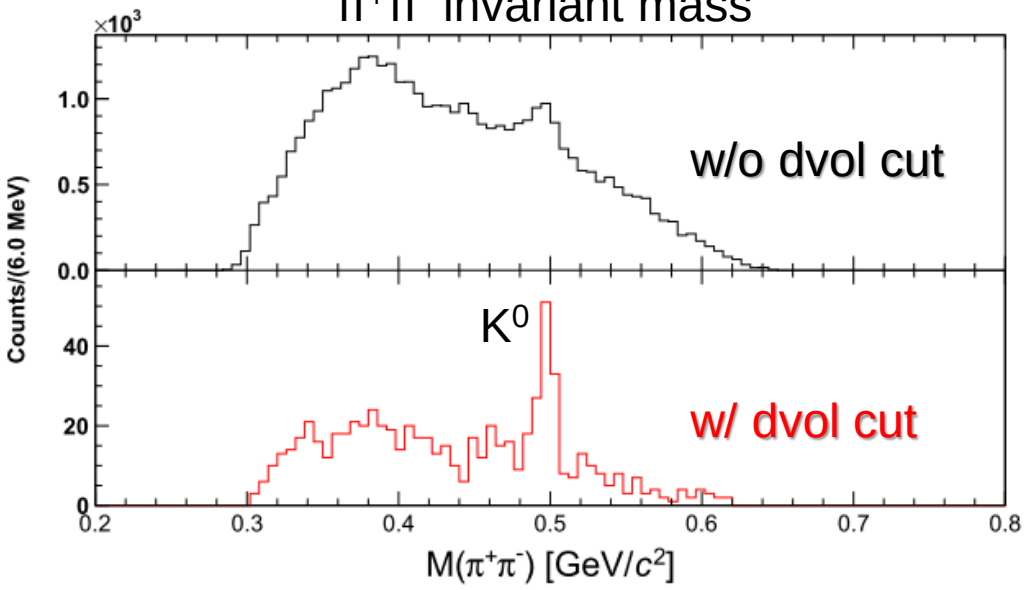
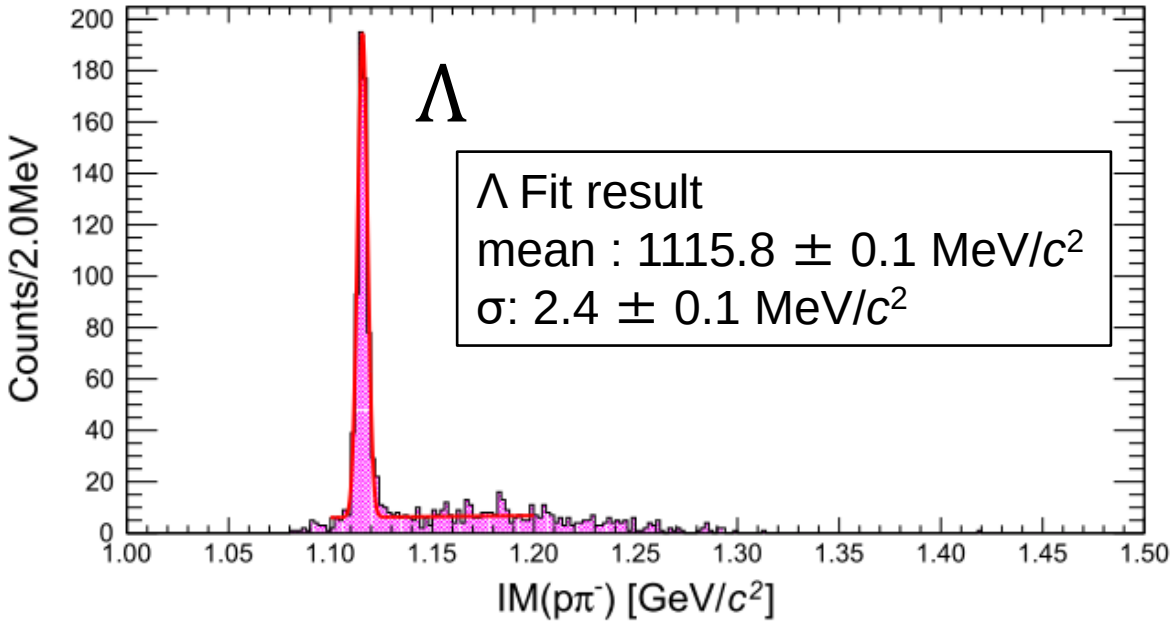




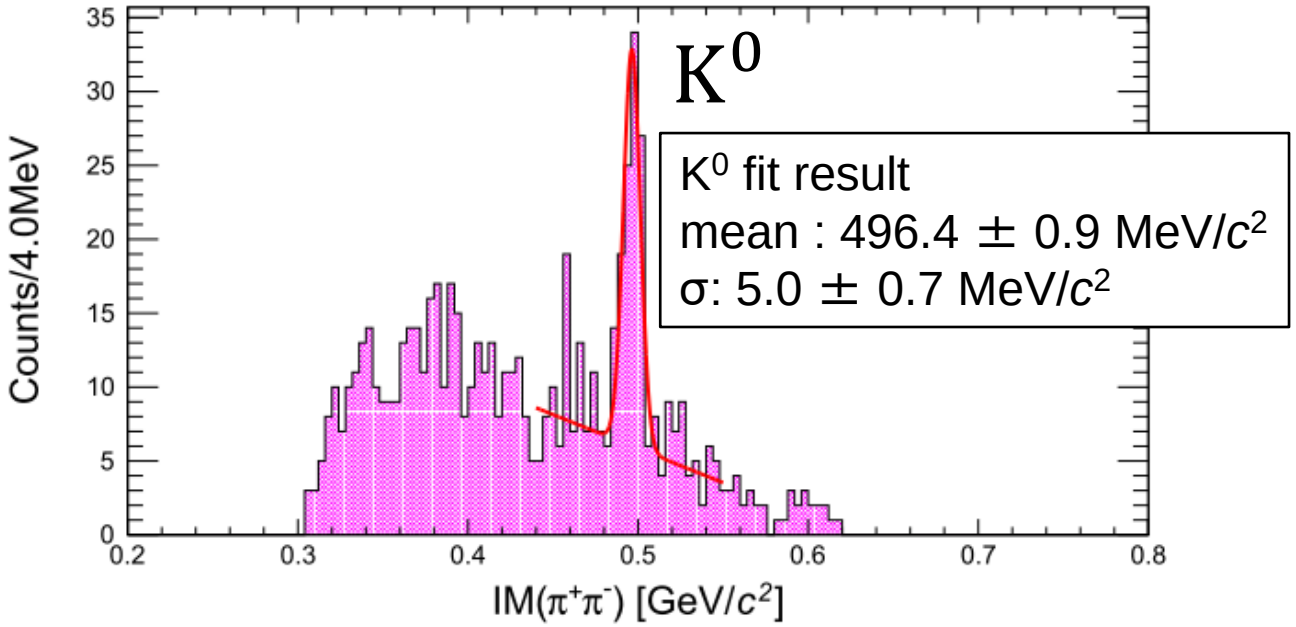


Λ, K^0 inclusive measurement

$p\pi^-$ invariant mass



$\pi^+\pi^-$ invariant mass



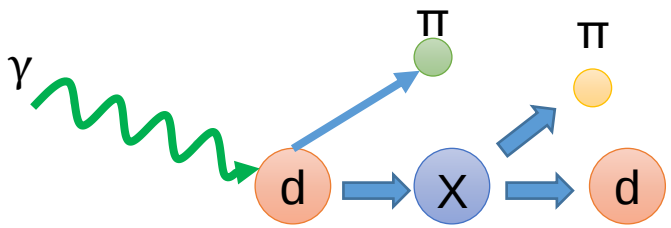
Momentum calibration was successfully done.
Cross section analysis is ongoing.

Search for NΔ dibaryon

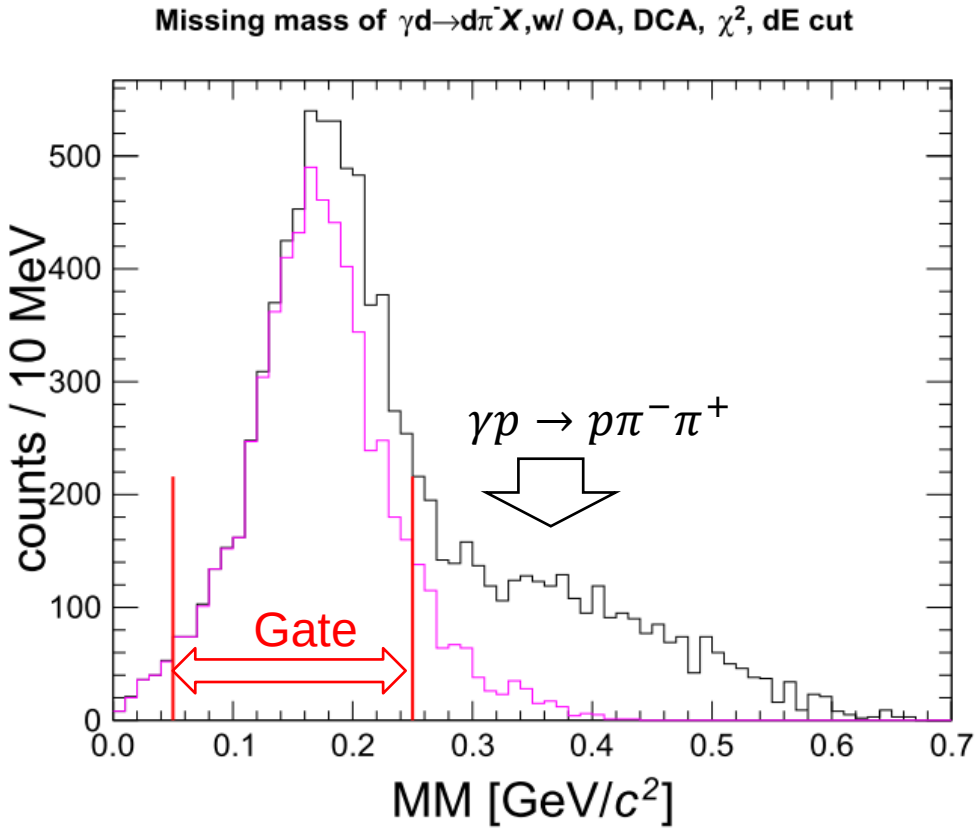
Event selection

Target state : D_{12} (NΔ)

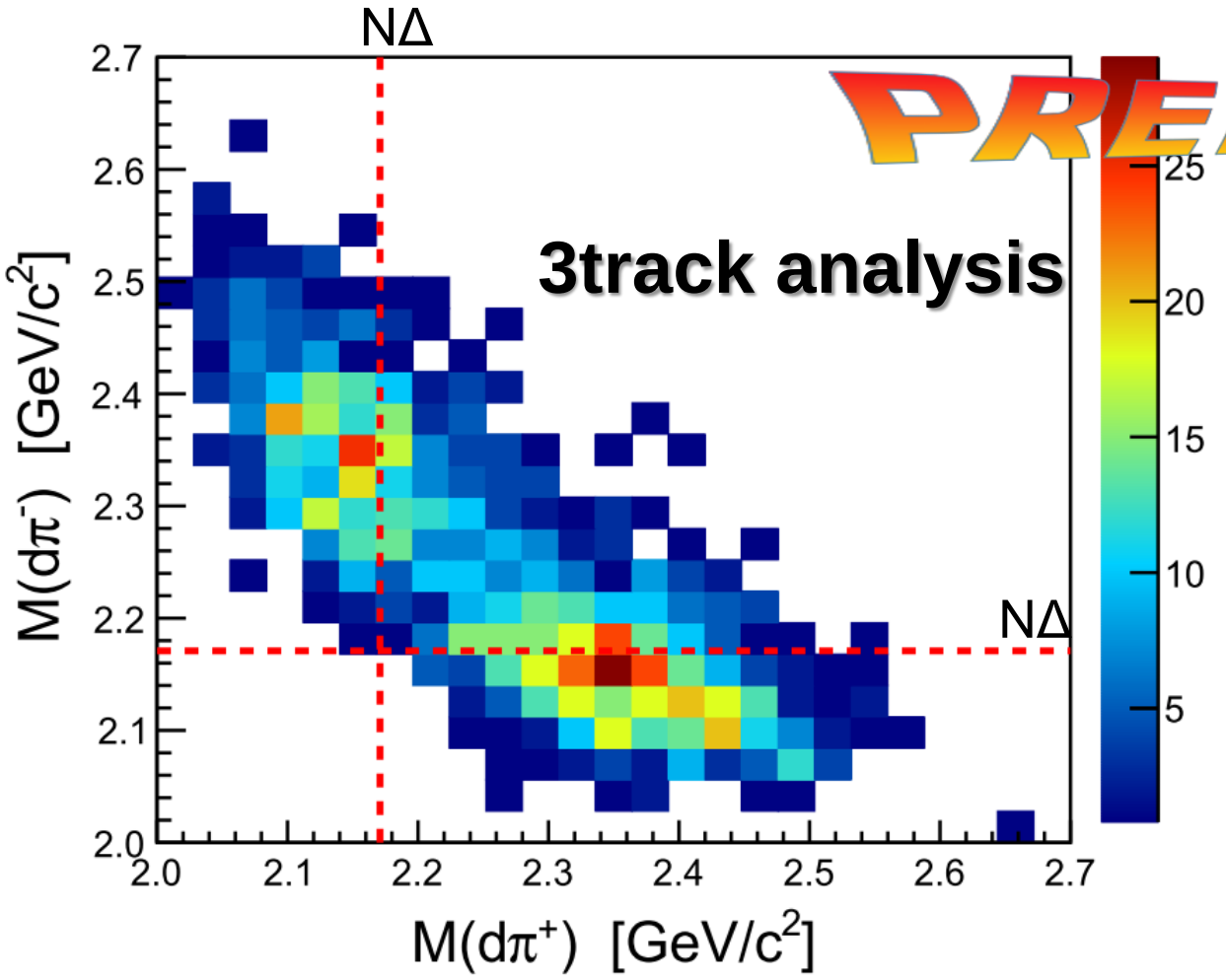
$$\gamma + d \rightarrow d + \pi^+ + \pi^-$$

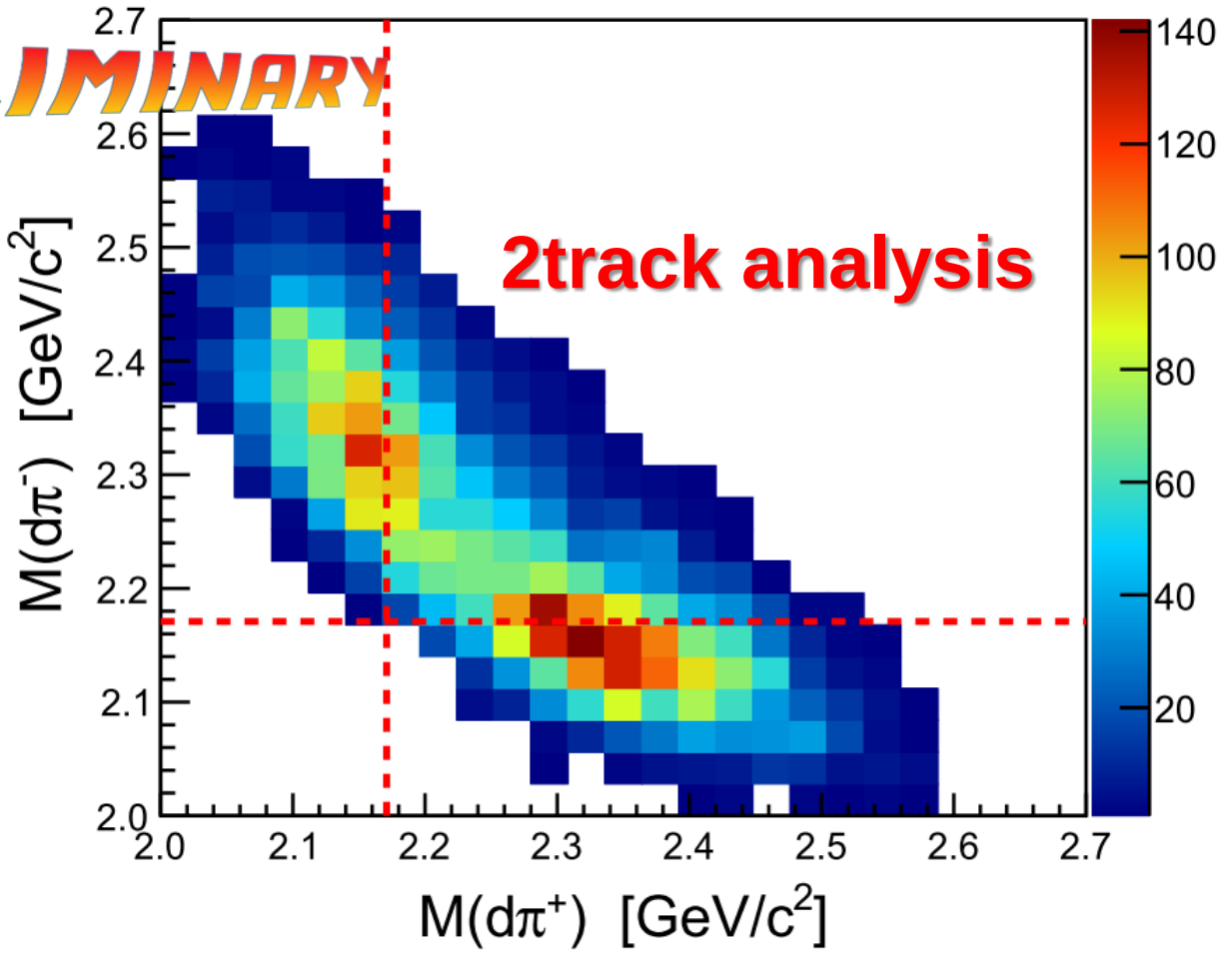


- 3 track analysis
  - Detect 3 charged particles, $d\pi^+\pi^-$
- 2 track analysis
  - Detect 2 charged particles, $d\pi^+$ or $d\pi^-$
  - Missing mass for $\pi^{+/-}$



Invariant mass spectra (dπ)





- Bump around NΔ mass

Invariant mass spectra (W binned)

2track analysis

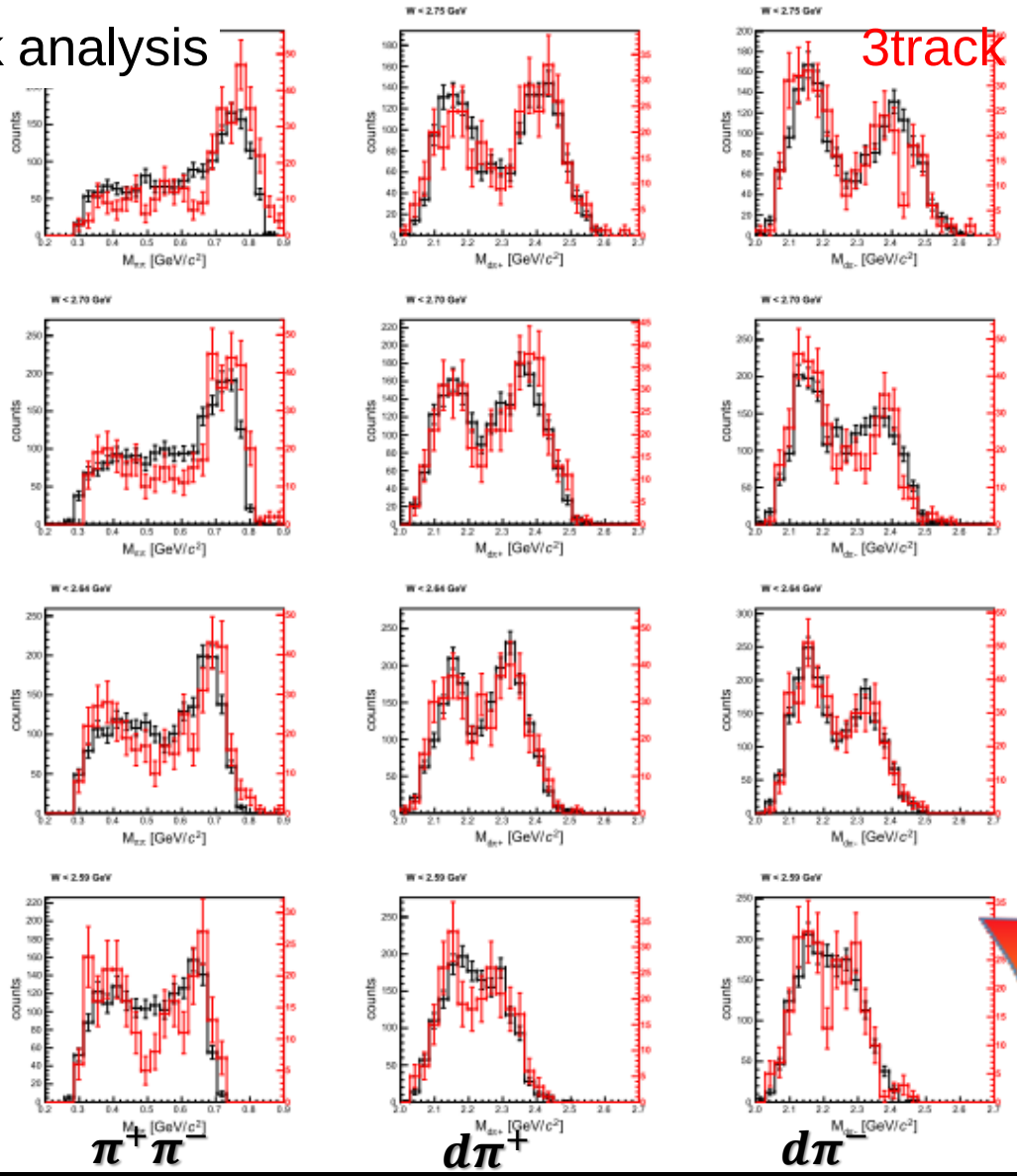
3track analysis

2.70<W<2.75 [GeV]

2.64<W<2.70

2.59<W<2.64

2.54<W<2.59



- Bump around NΔ mass (2.15 GeV) threshold
- ρ^0 contribution ($M_{\pi\pi}$ ~0.7 GeV)
- 2 different analysis procedures are consistent

PRELIMINARY

Invariant mass spectra (W binned, vs phase space sim.)

2.70<W<2.75 [GeV]

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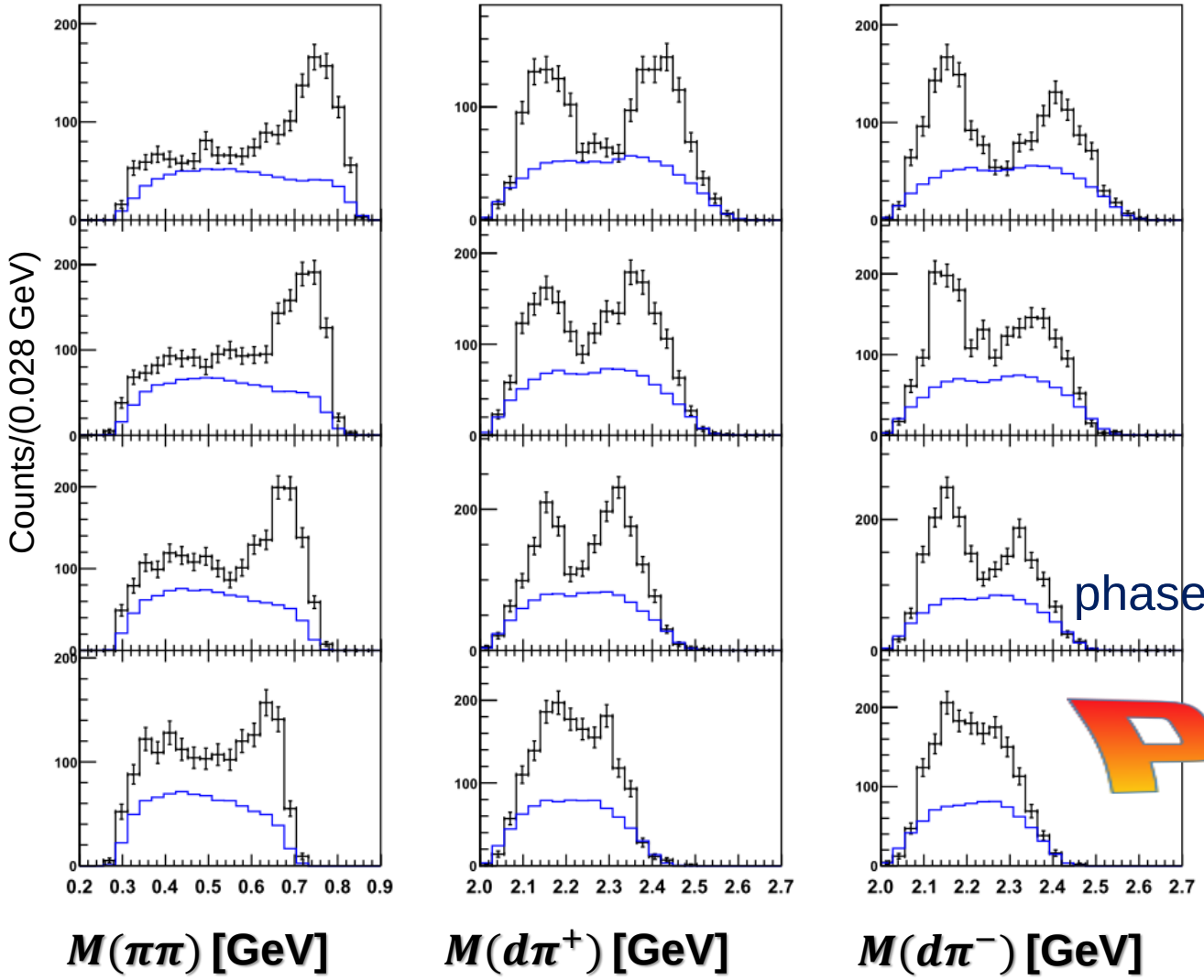

2track analysis

- Bump around NΔ mass (2.15 GeV) threshold
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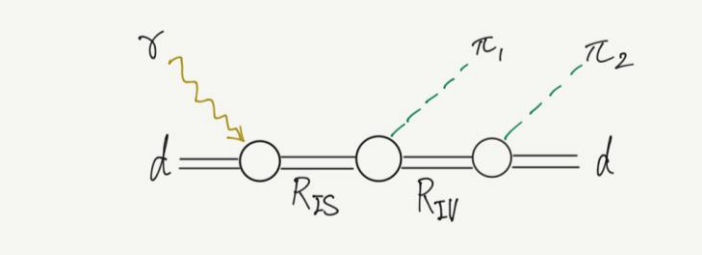
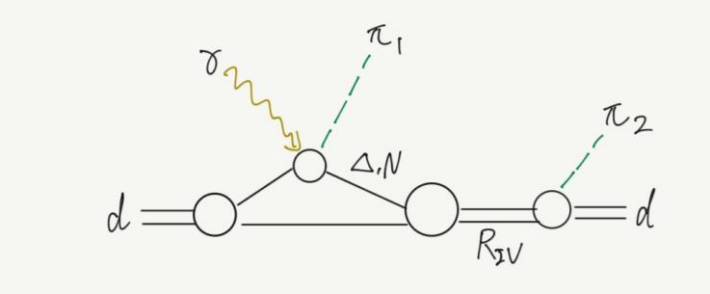
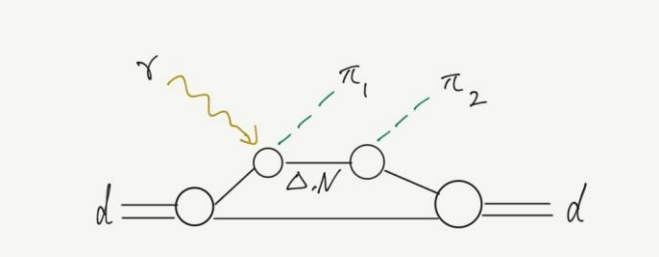
phase space

PRELIMINARY

Possible mechanisms of coherent $\pi^+\pi^-$ production

	d emission angle (γd CM frame)	$d\pi_2$ emission angle ($d\pi_2$ rest frame)	
1) Iso scaler dibaryon production 	almost flat	L=1	Claimed in $\gamma d \to d\pi^0\pi^0$ reaction (exp.) T. Ishikawa et al., PLB789, 413 (2019)
2) QF π production ➡ Iso vector dibaryon 	sideway peaking	L=1	
3) QF ππ production 	backward peaking		FA calc. (a.k.a. 2-PION MAID) A. Fix, H. Arenhövel, EPJA25 (2005) 115.

Invariant mass spectra (W binned, vs phase space sim.)

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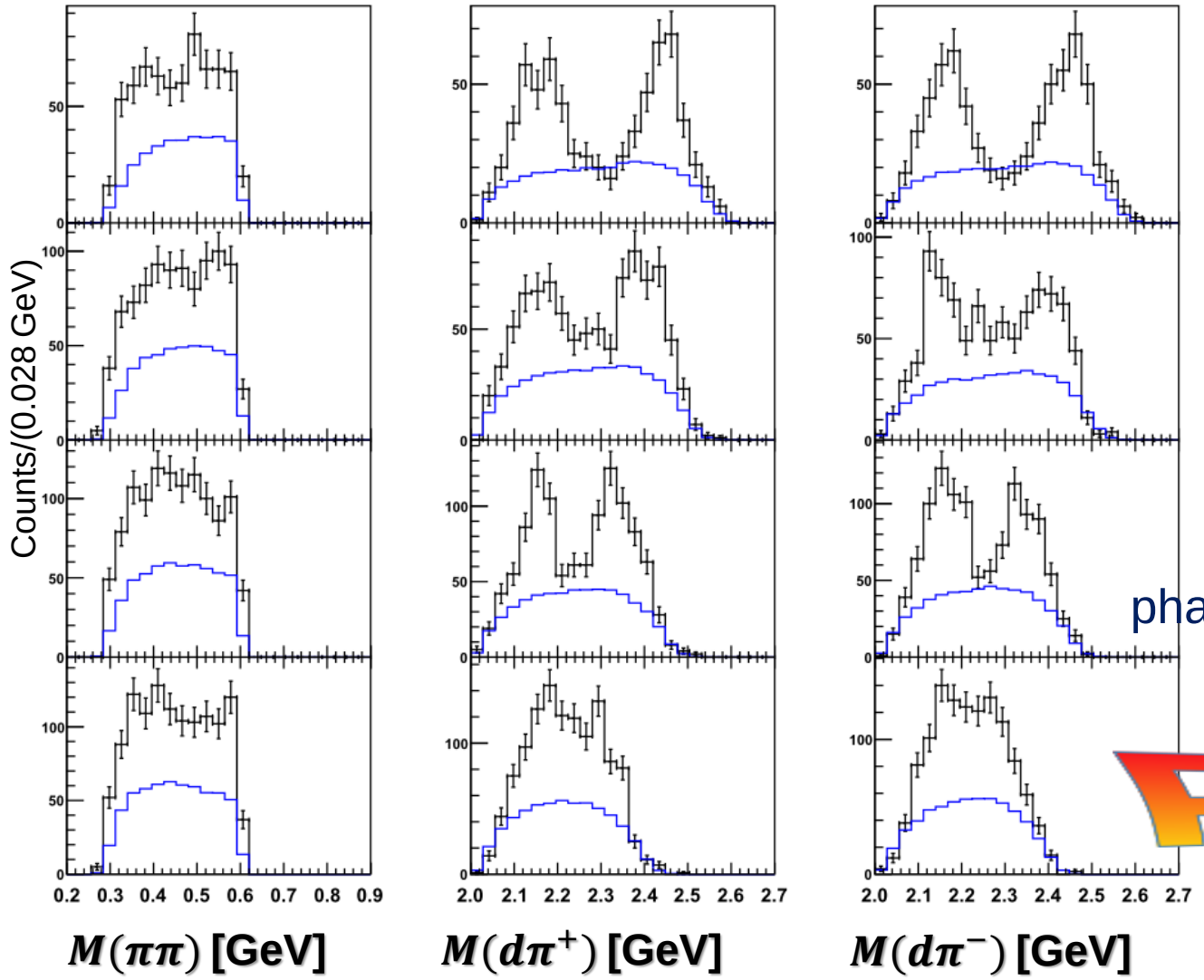


- $M_{\pi\pi} < 0.6$ GeV

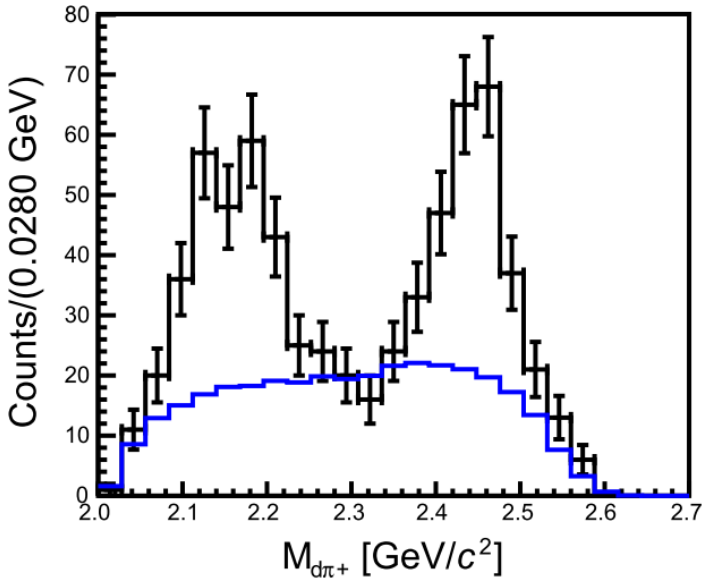
phase space

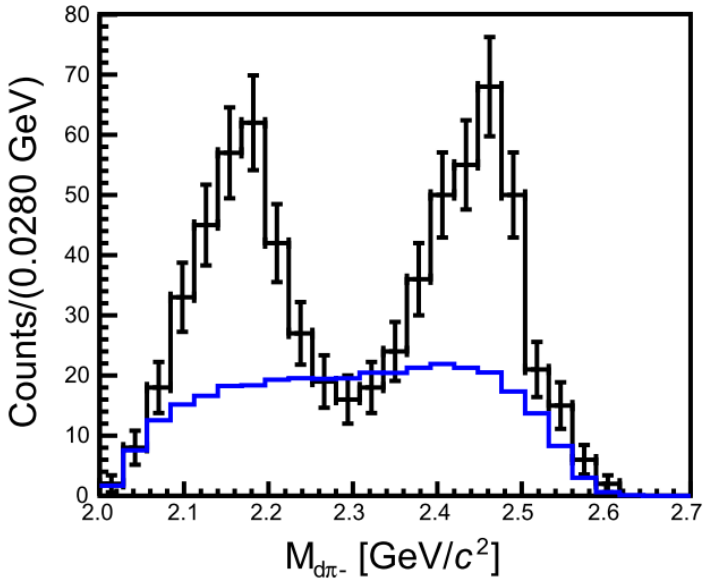
PRELIMINARY

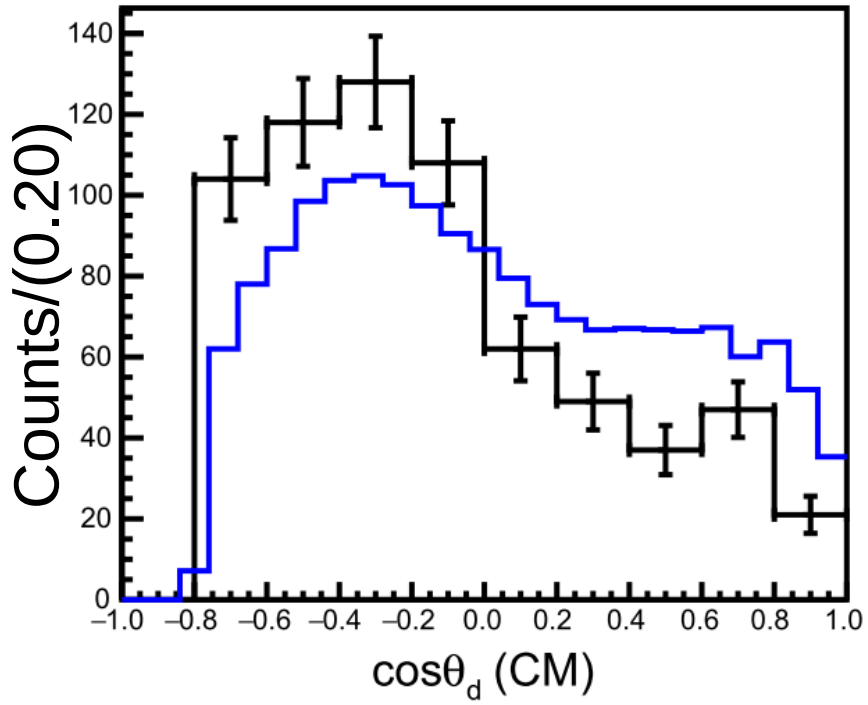
Angular distribution (v.s. phase space b.g.)

Highest energy region
2.70<W<2.75 GeV

$M_{\pi\pi} < 0.6$ GeV







PRELIMINARY

Future prospects

For my PhD. thesis

- Cross section
  - Acceptance correction
  - Efficiencies
  - Contaminations (pππ)

Further more...

- Deuteron missing analysis
  - Recovers backward deuteron emission events (QF ππ dominant region)
- Further statistics as biproducts of Λn FSI and η'd exp. in the future (2022?)
  - Λn FSI by Dr. M. Kaneta
  - η'd exp. by Prof. H. Fujioka, Tokyo Tech.

Summary

- NΔ dibaryon search via the $\gamma d \rightarrow d\pi^+\pi^-$
- Resonance like structure in dπ$^{+/-}$ invariant mass at 2.15 GeV (Γ ~ 0.1 GeV)
- Further discussion about angular dist.

d missing analysis

Request of current analysis : deuteron OH hit

- Low mom. d (< 400 MeV/*c* , backward in CM frame) cannot be measured (out of acceptance)
- Backward d is dominant in QF calc. (A. Fix)

New Idea : deuteron ID w/ ToF btwn a vertex point of ππ and IH_d

- Increasing deuteron acceptance not only kinematically but also geometrically

☐ How effective is it?

☐ Separation from $p\pi^+\pi^-$ (~100 times larger b.g.)