HADRON2017

Photoproduction of $\pi^-\Delta^{++}$ and $\pi^+\Delta^0$ on the proton for the comparison of $\bar{u}u$ and $\bar{d}d$ productions

Sep / 28 / 2017

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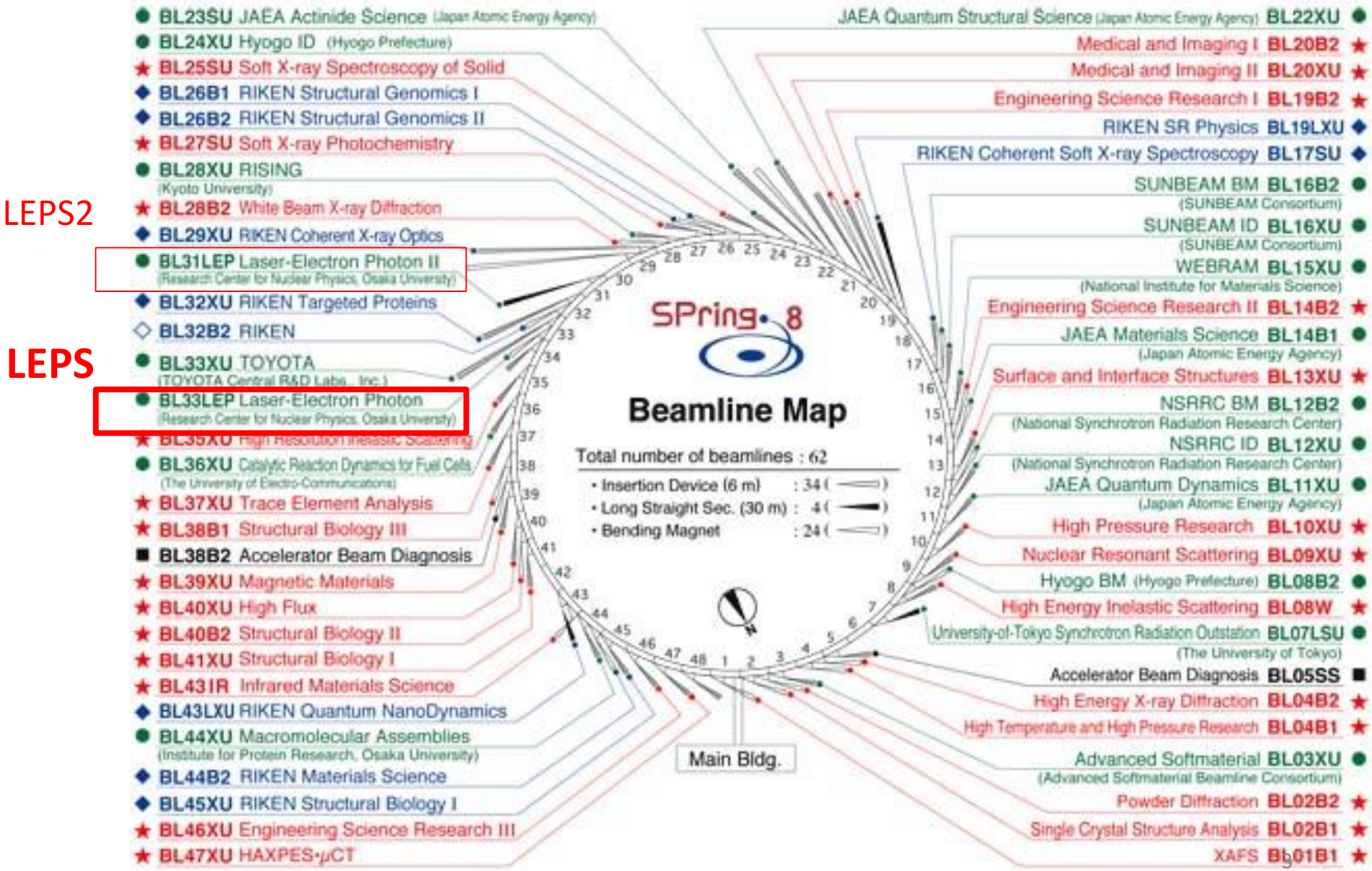
Super Photon ring - 8 GeV

Electron storage ring

- 8 GeV electron beam
- Diameter ≈457 m
- RF 508 MHz
- 1-bunch spread is within σ＝12 psec.
- Beam Current = 100 mA

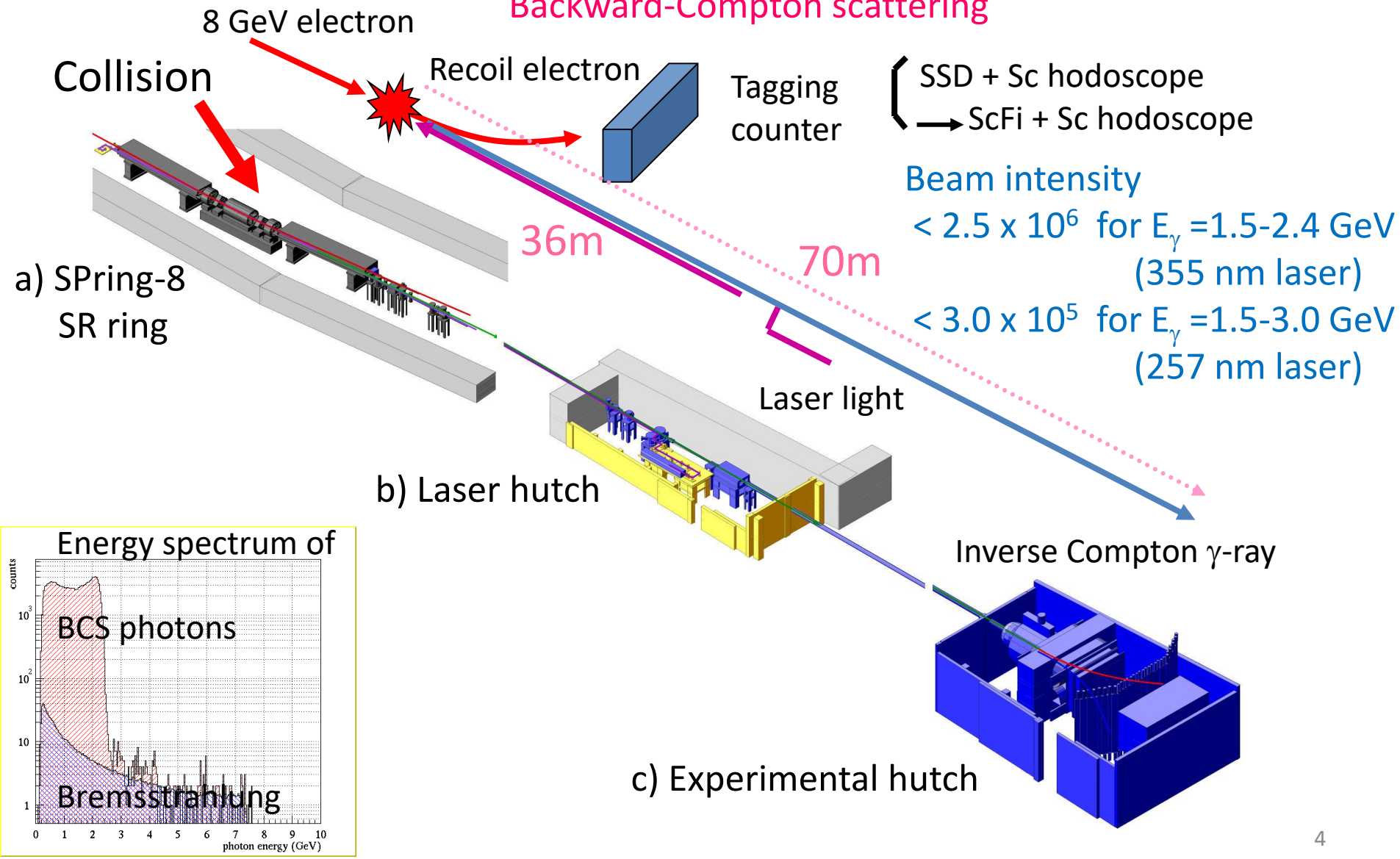
120 km distant from Osaka

SPring-8 beamline map



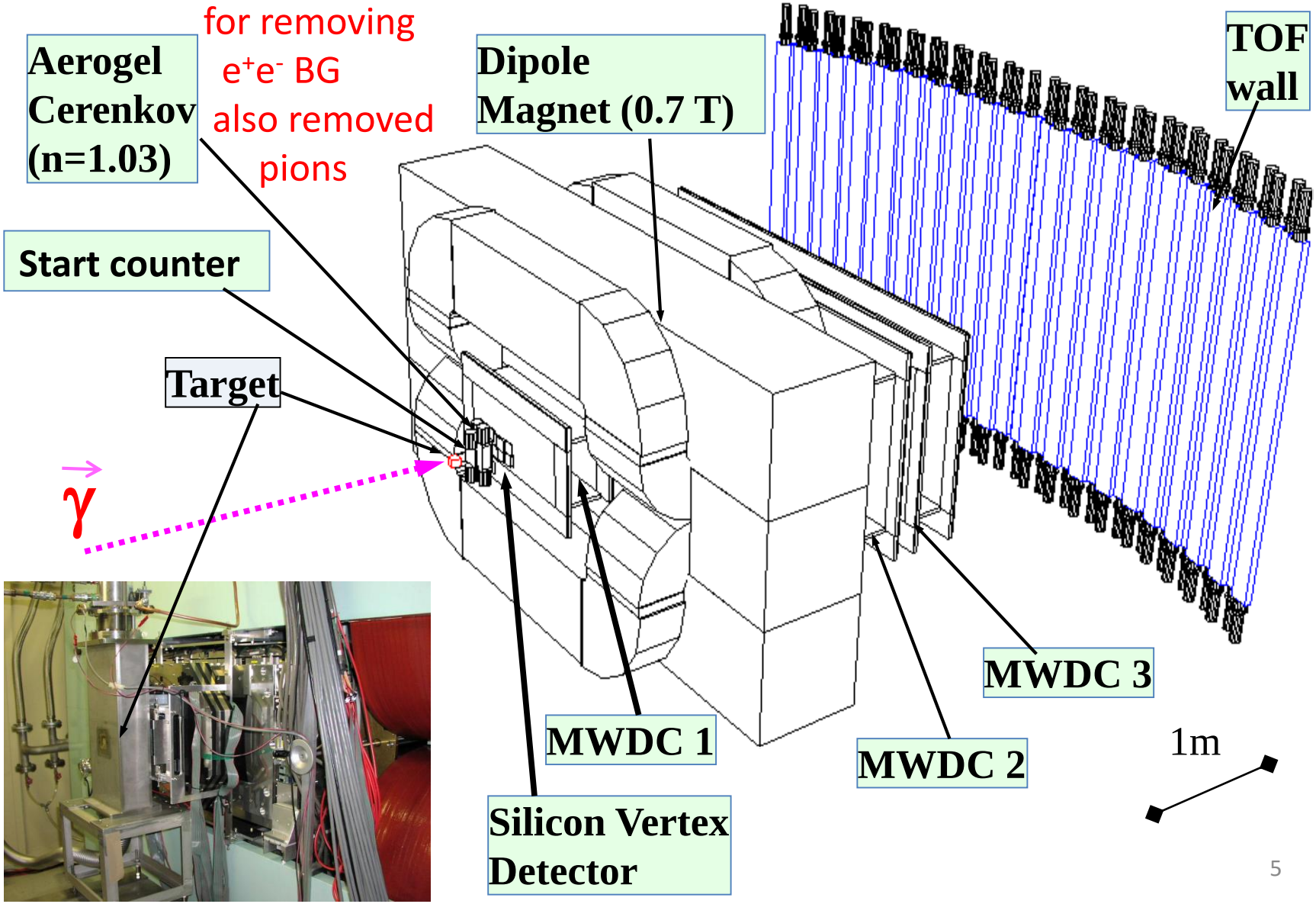
LEPS facility
LEPS experiment started in 2000

Backward-Compton scattering



LEPS detector setup

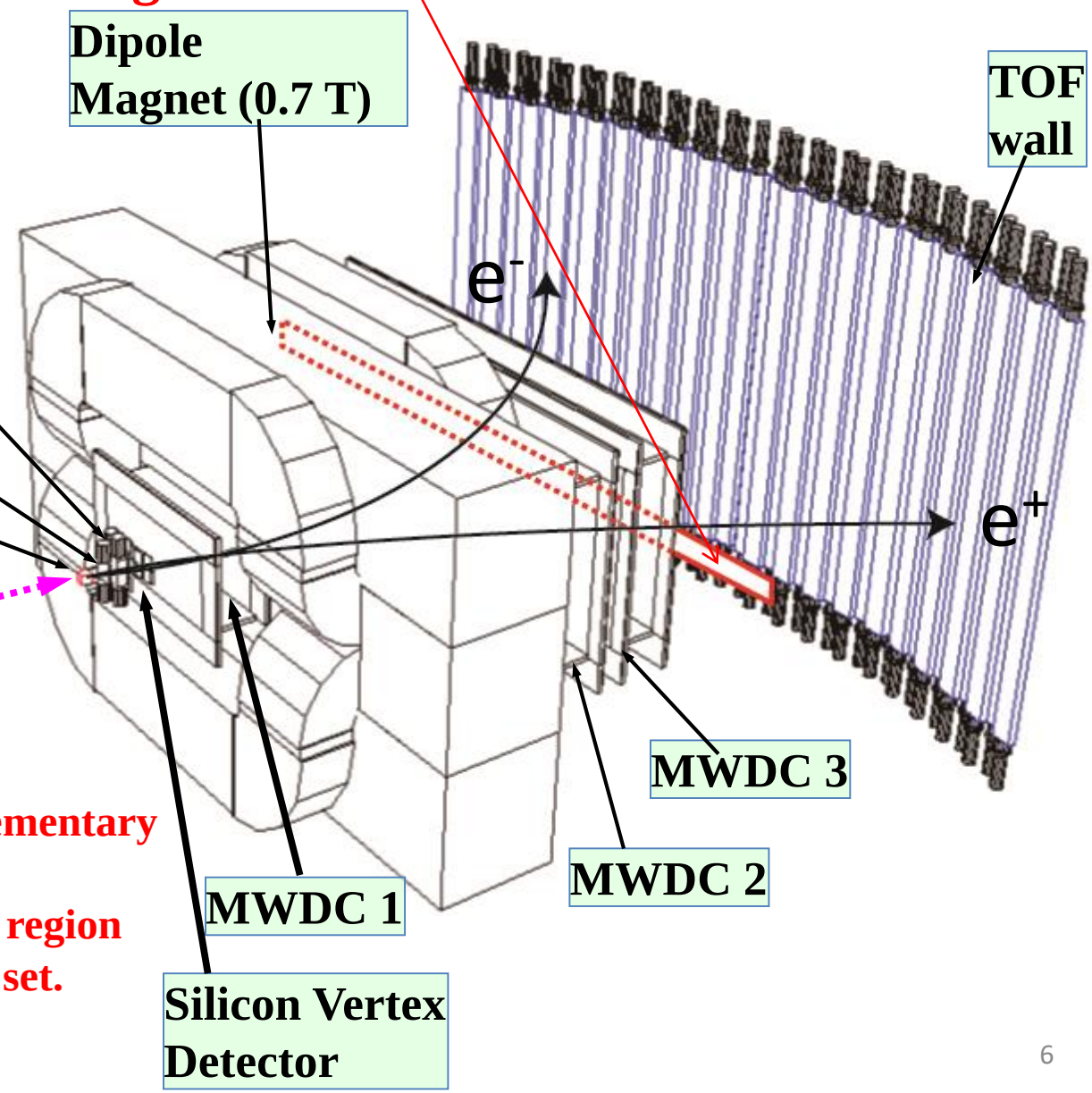
LEPS detector was optimized to detect ϕ meson decaying to K^+K^- at forward angles



New experimental setup for high momentum π

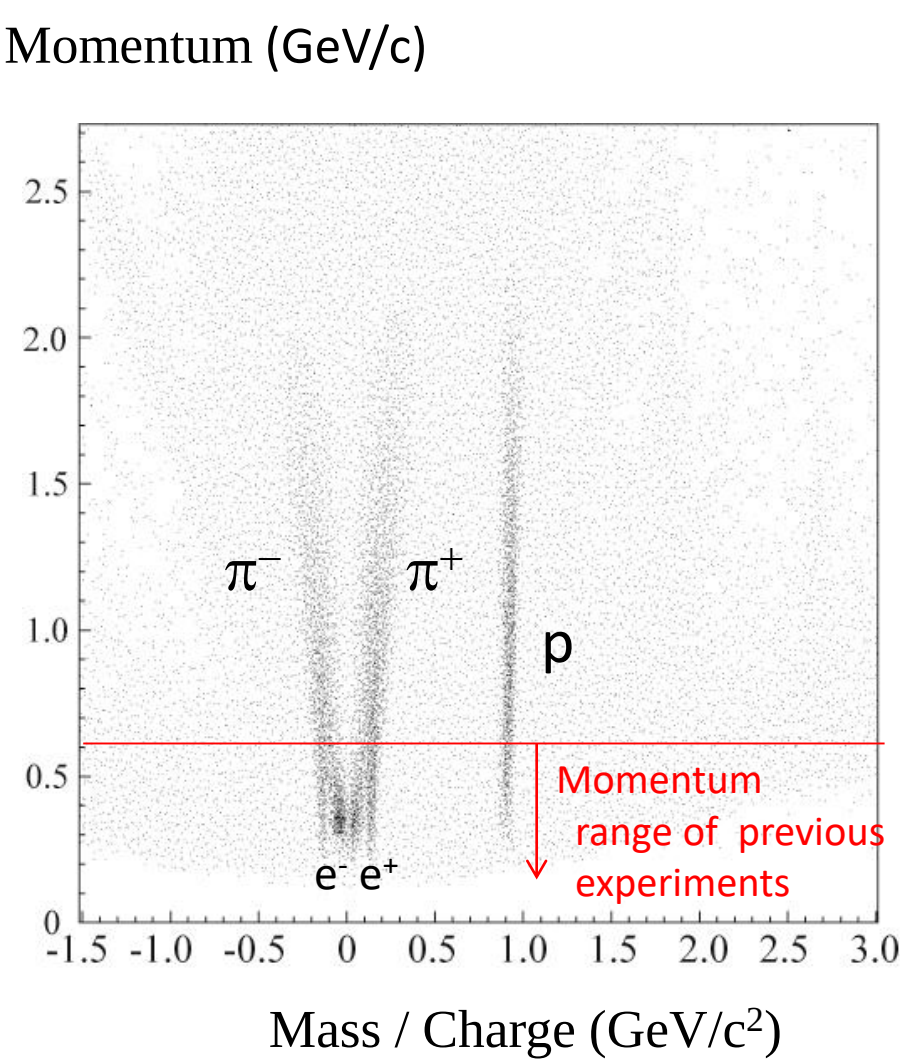
Plastic counter for vetoing e^+e^- was used

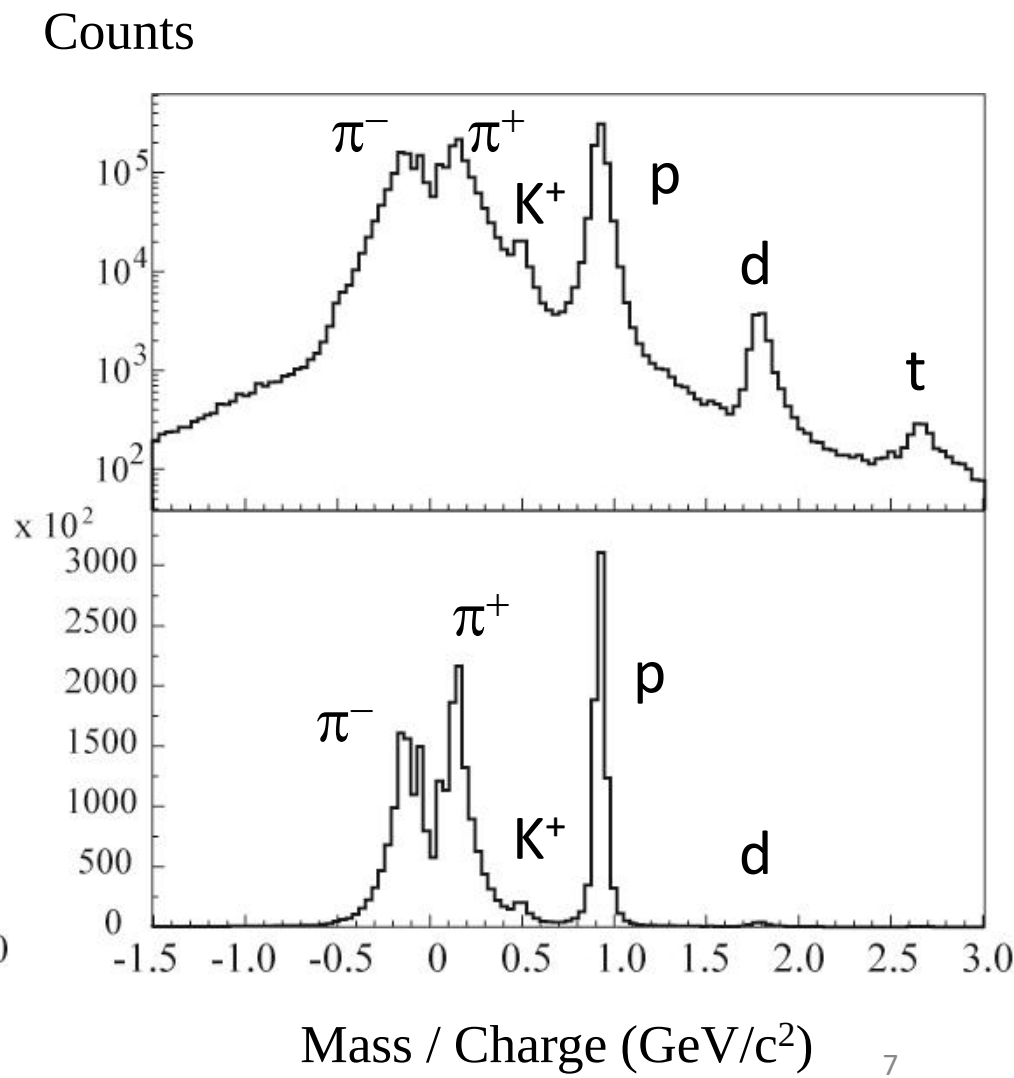
No cherenkov counter



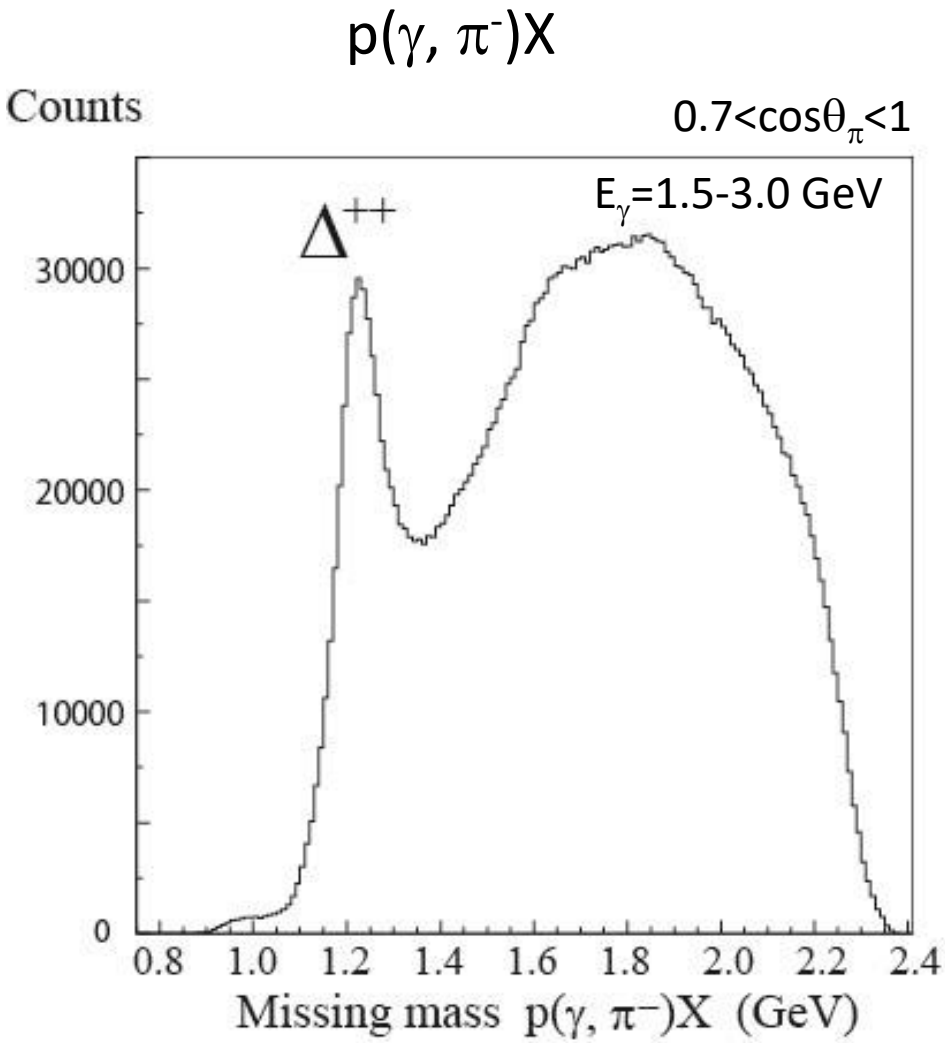
LEPS experiments are complementary to JLAB/CLAS experiments.
Data in the LEPS kinematical region are missing in the world data set.

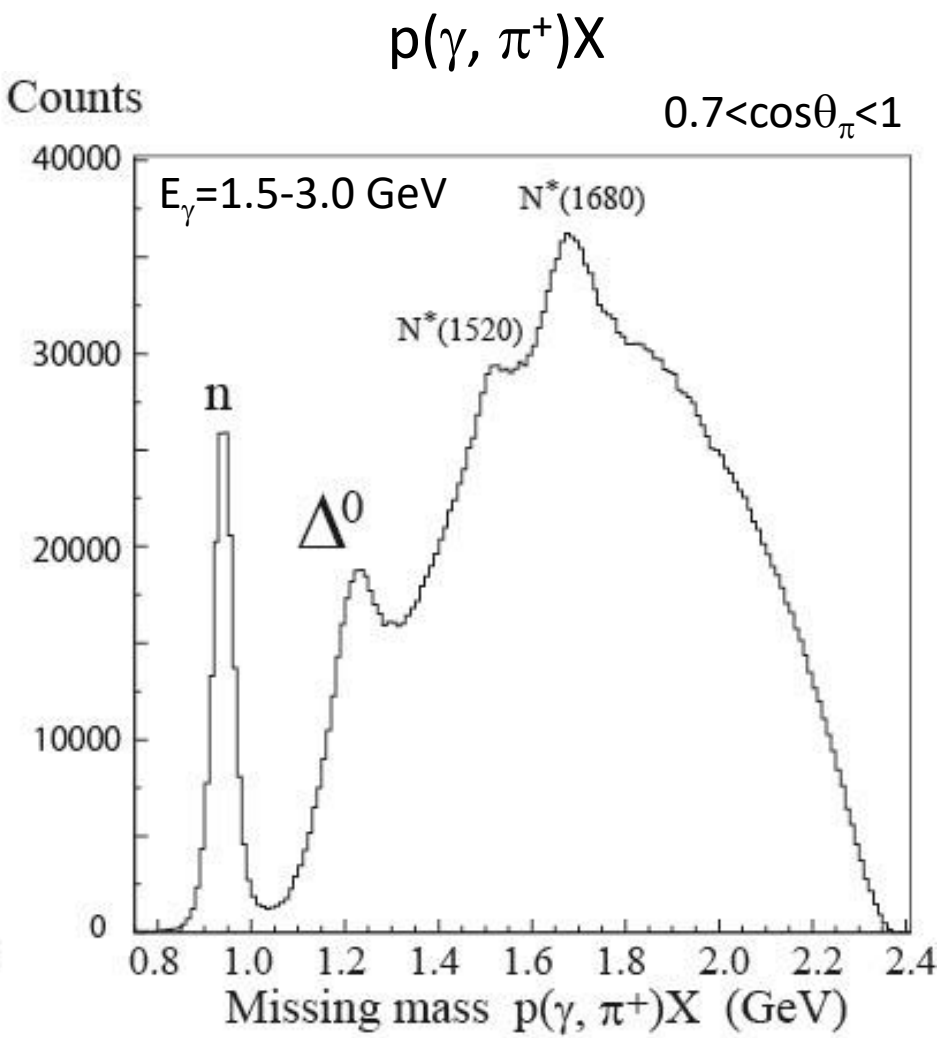
High momentum π data





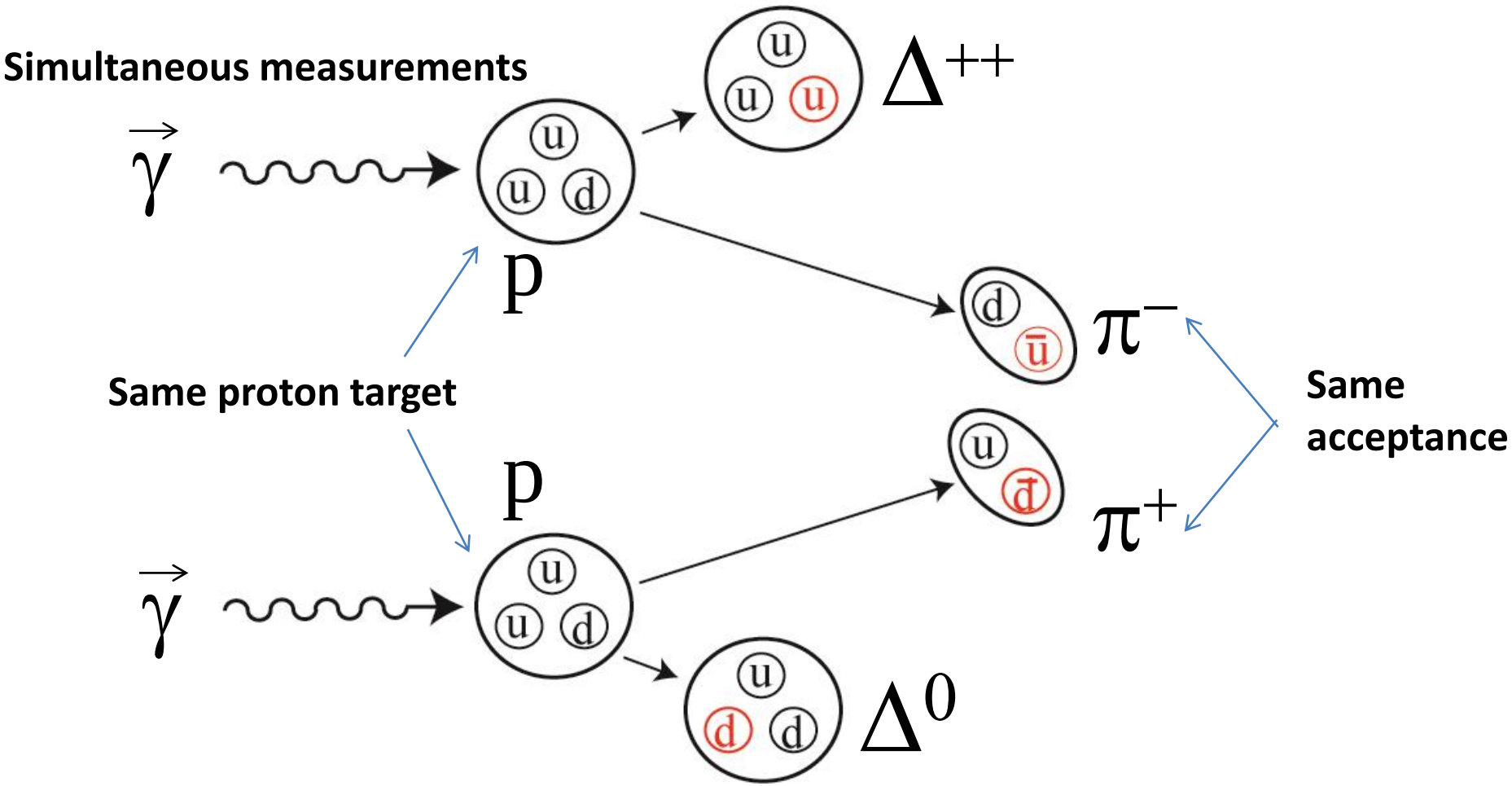
Missing mass of p(γ, π)X





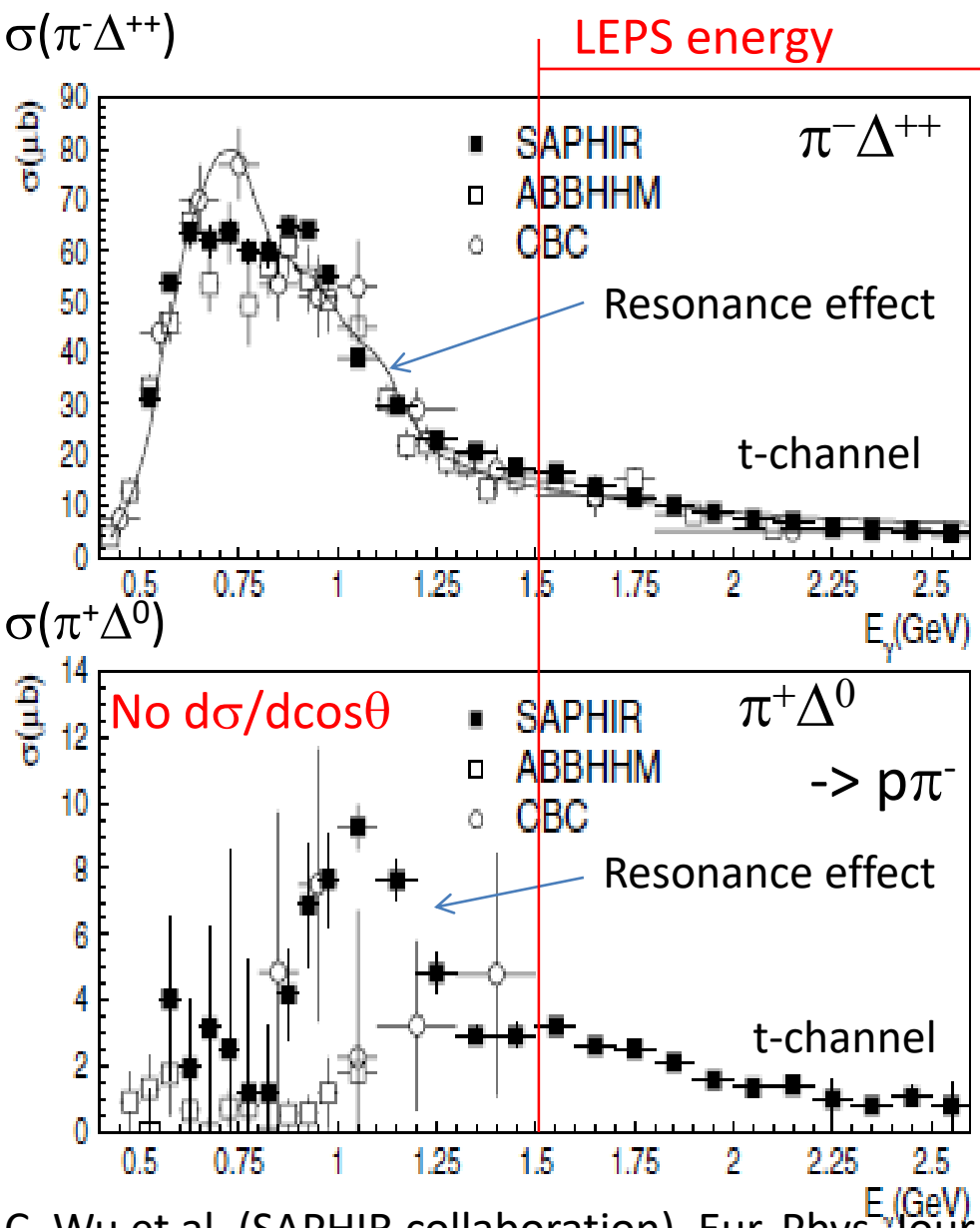
ūu and d̄d productions

ūu production is precisely compared with d̄d production by the γp→ π^- Δ^{++} and $\pi^+\Delta^0$ reactions



I expect this comparison would give important information to understand how hadrons are produced.

SAPHIR data published in 2005

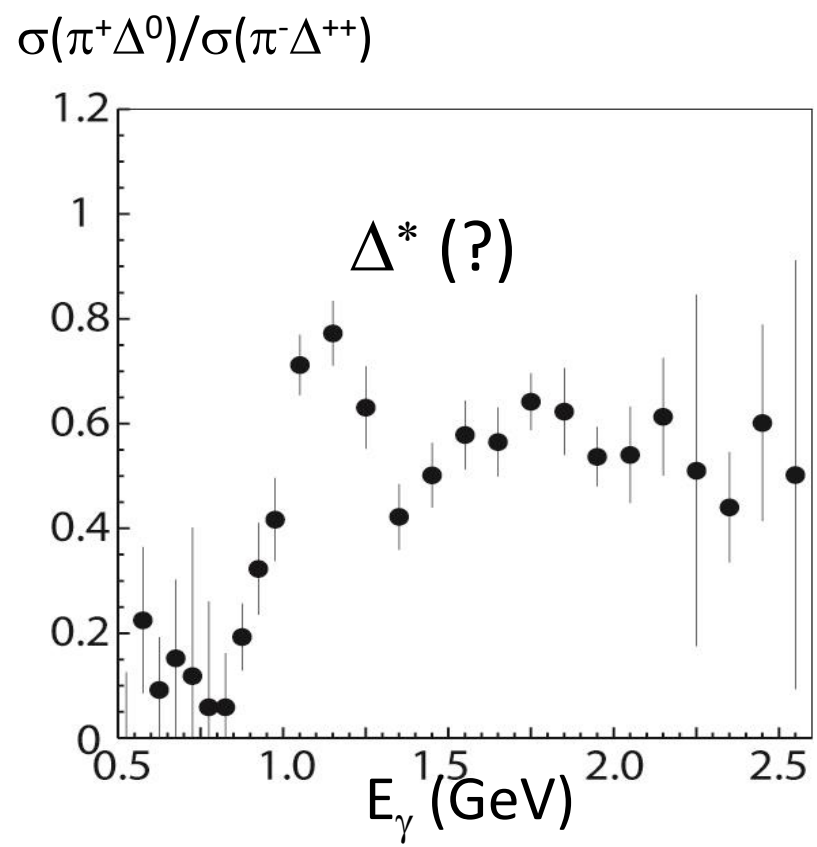


Clebsch-Gordan coefficients

N^* -> 3 $\pi^-\Delta^{++}$: 1 $\pi^+\Delta^0$

Δ^* -> 3 $\pi^-\Delta^{++}$: 4 $\pi^+\Delta^0$

Δ^* favors $\pi^+\Delta^0$ channel



C. Wu et al. (SAPHIR collaboration) Eur. Phys. Jour. A 23 (2005) 317

Physics motivation of $\pi\Delta$ reactions at E_γ=1.5-3.0 GeV

Low energy ~E_γ=1.5 GeV

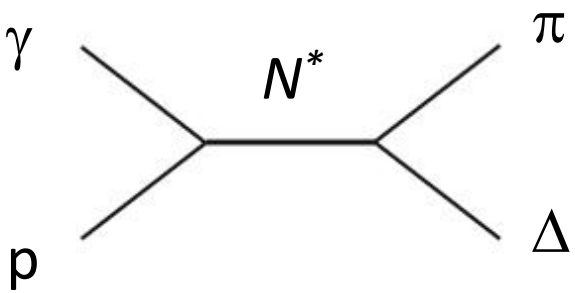
Missing resonance search

s- channel

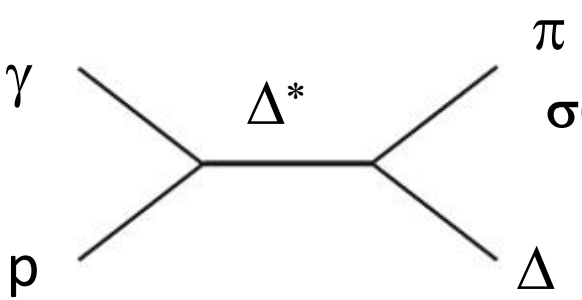
High energy ~E_γ=3.0 GeV

Study other mechanisms than

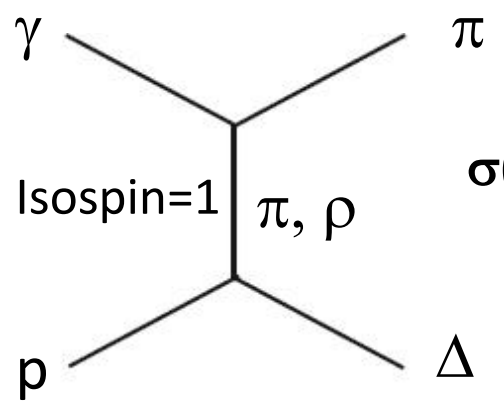
π, ρ -exchange in t- channel



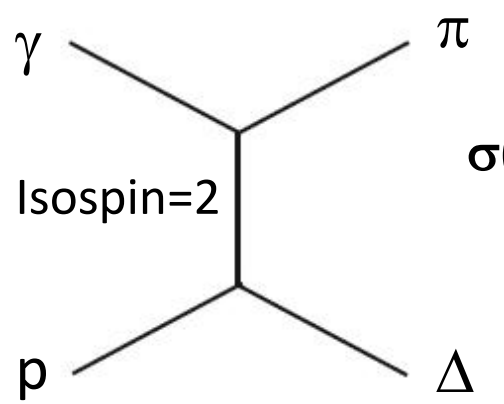
$\sigma(\pi^+\Delta^0)/\sigma(\pi^-\Delta^{++})$ **= 1/3**



$\sigma(\pi^+\Delta^0)/\sigma(\pi^-\Delta^{++})$ **= 4/3**



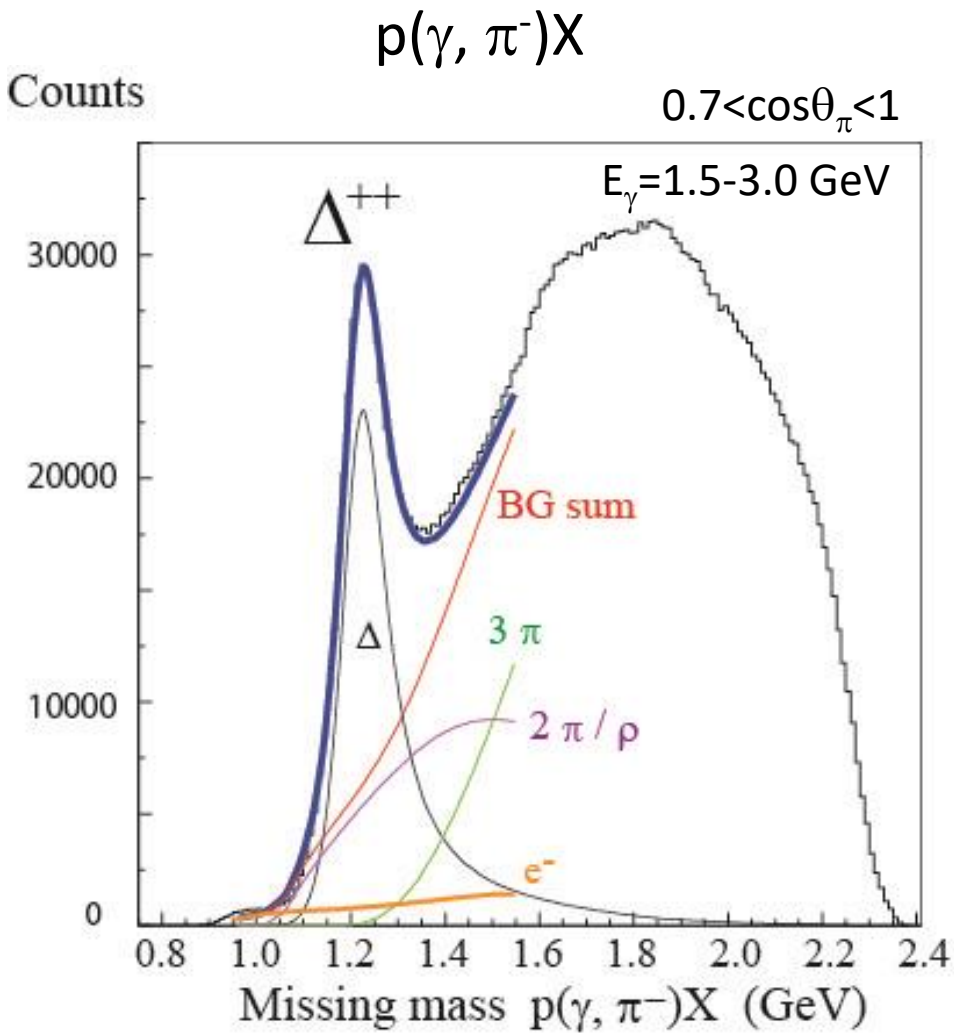
$\sigma(\pi^+\Delta^0)/\sigma(\pi^-\Delta^{++})$ **= 1/3**

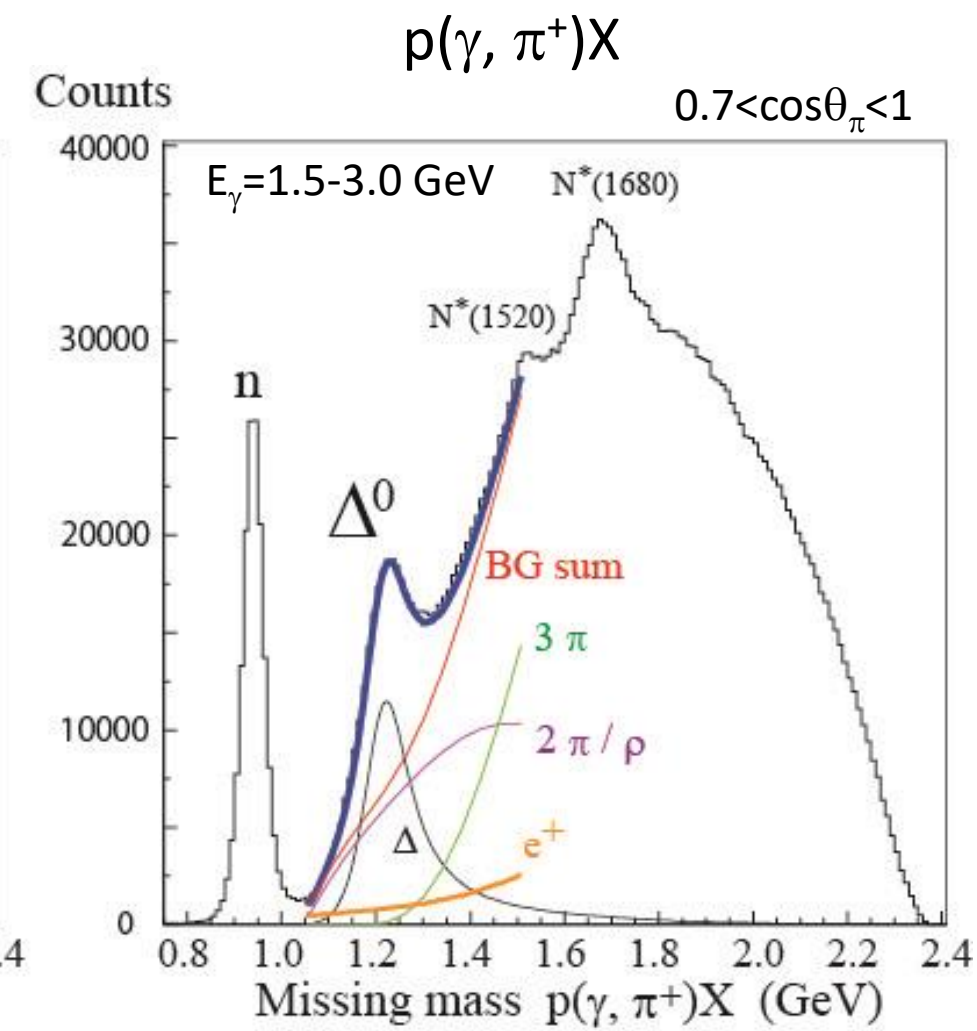


$\sigma(\pi^+\Delta^0)/\sigma(\pi^-\Delta^{++})$ **= 3**

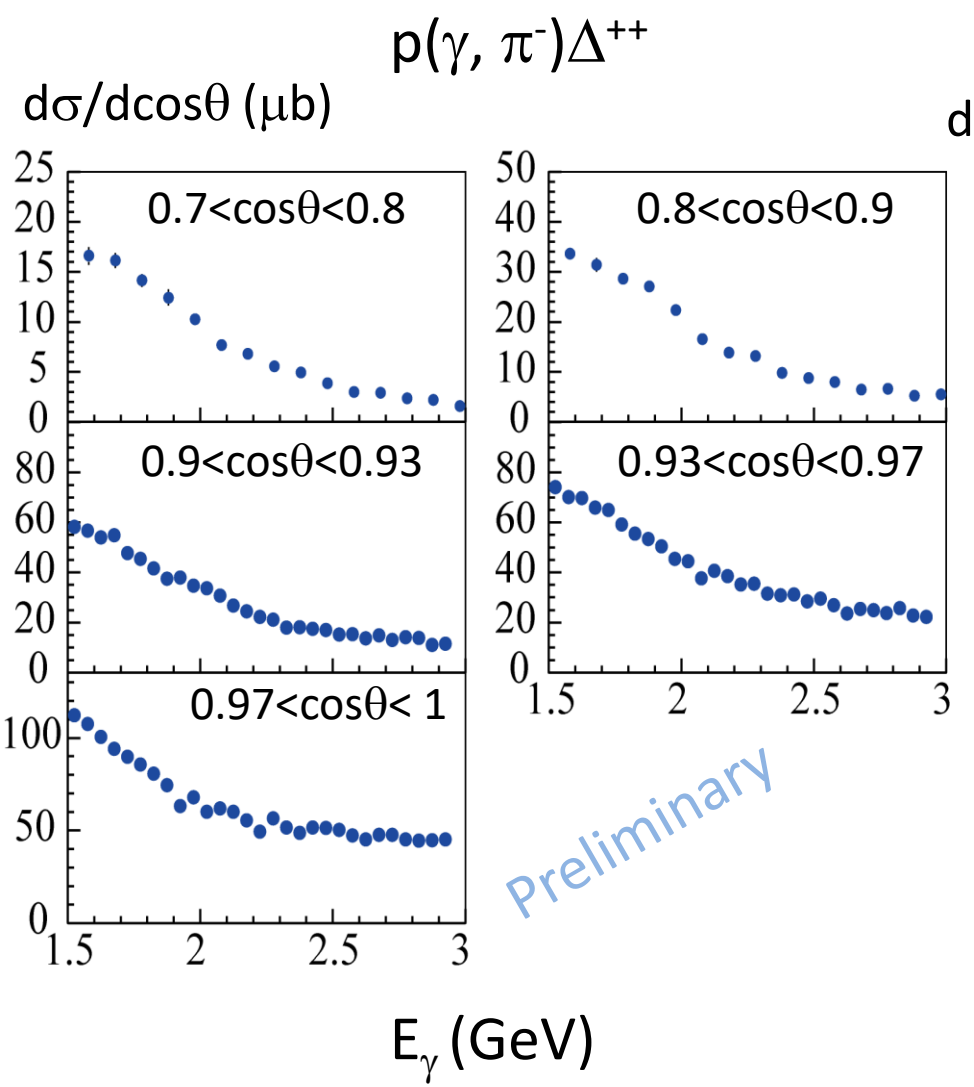
Missing mass p(γ, π)X

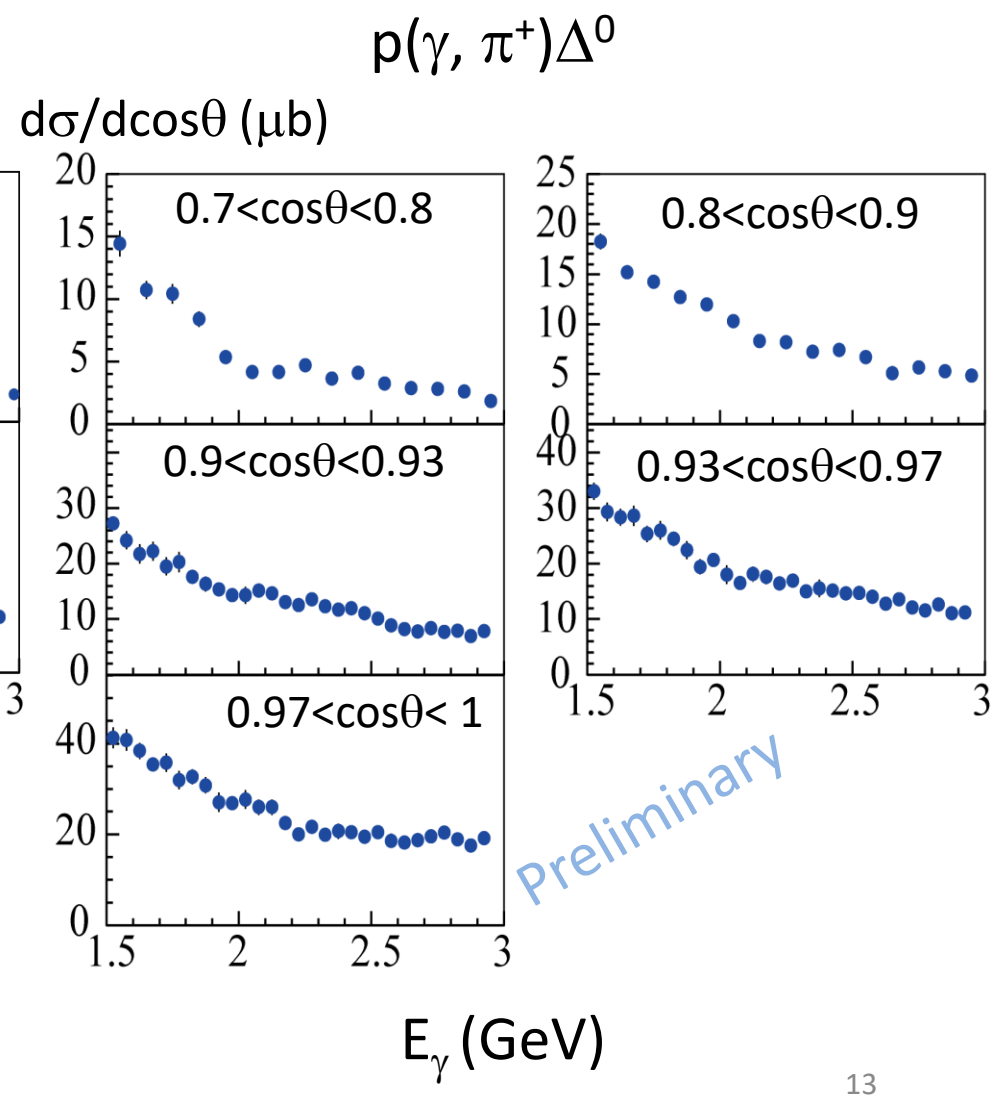
Missing mass spectrum is fitted with relativistic Breit-Wigner shape for Δ, 2π / ρ, 3π, and e^- or e^+ curves.





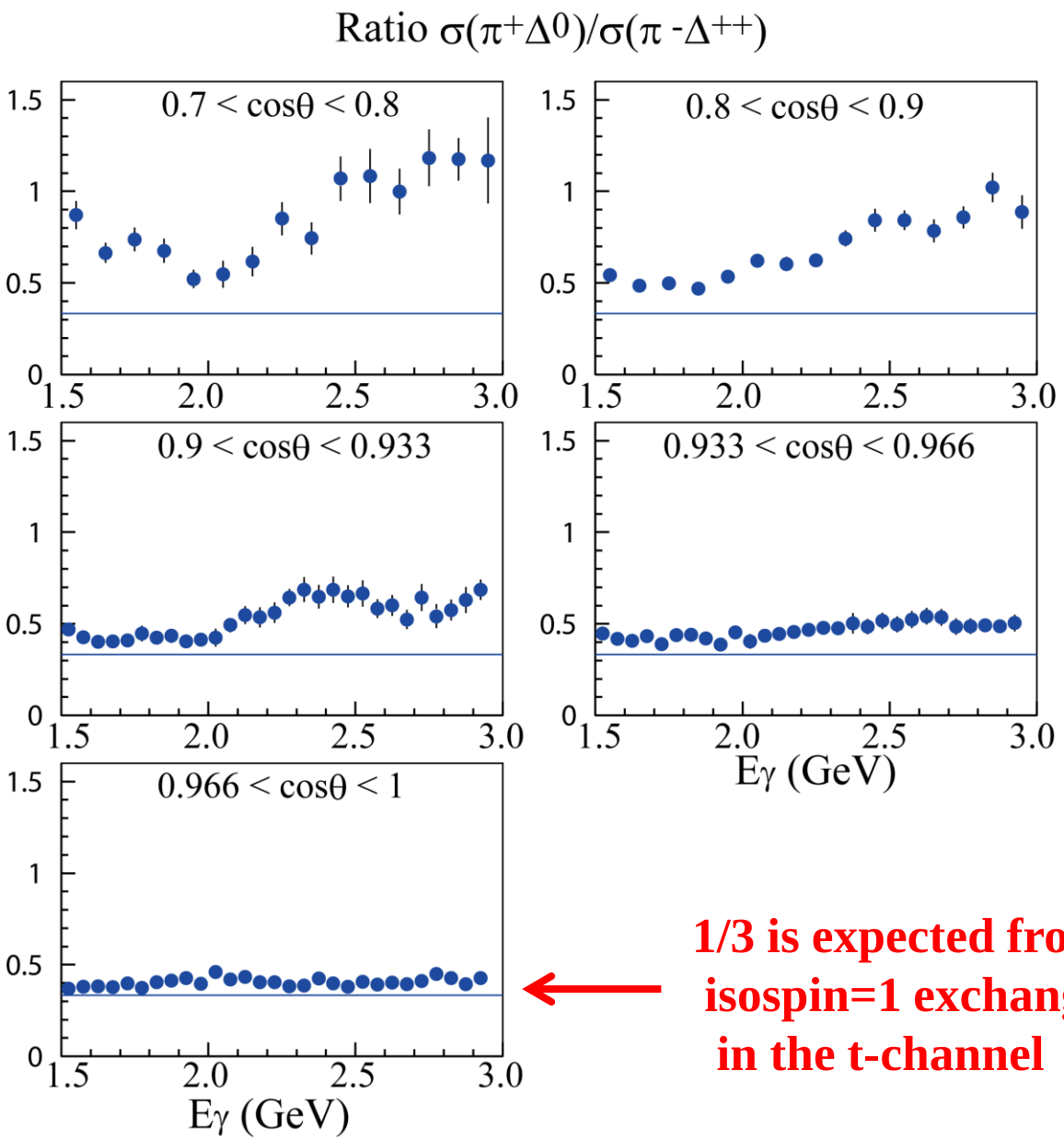
Differential cross sections for $\pi^-\Delta^{++}$ and $\pi^+\Delta^0$





Ratio $\sigma(\pi^+\Delta^0)/\sigma(\pi^-\Delta^{++})$

($\bar{d}d$ production / $\bar{u}u$ production)



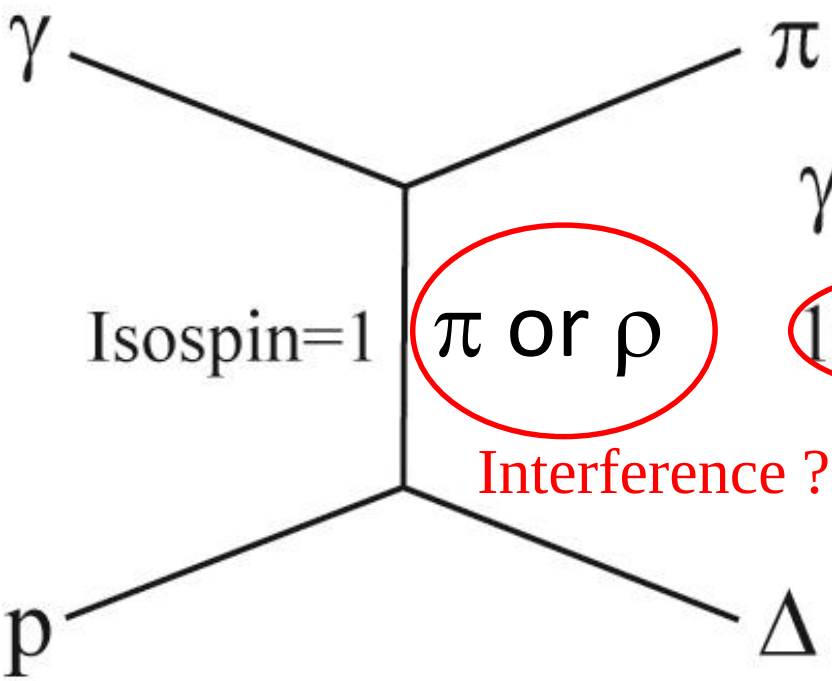
Preliminary

$\bar{d}d$ production is enhanced or $\bar{u}u$ production is suppressed.

1/3 is expected from isospin=1 exchange in the t-channel

If interference between π and ρ exists, the ratio may be changed from 1/3

t-channel



Interference ?

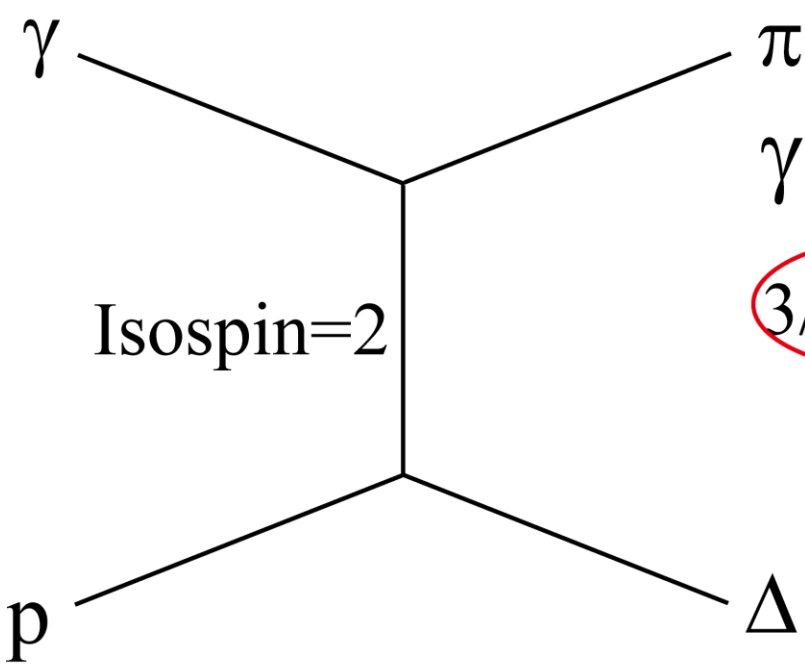
$$\gamma\, p \longrightarrow 1/6\,\pi^{+}\Delta^{0} + 1/3\,\pi^{0}\Delta^{+} + 1/2\,\pi^{-}\Delta^{++}$$

$$\frac{\sigma(\pi^{+}\Delta^{0})}{\sigma(\pi^{-}\Delta^{++})} = \frac{1}{3}$$

The interference between π and ρ exchanges may change the ratio of 1/3.

Isospin=2 exotic meson exchange in the t-channel may increase the ratio if it exists

t-channel

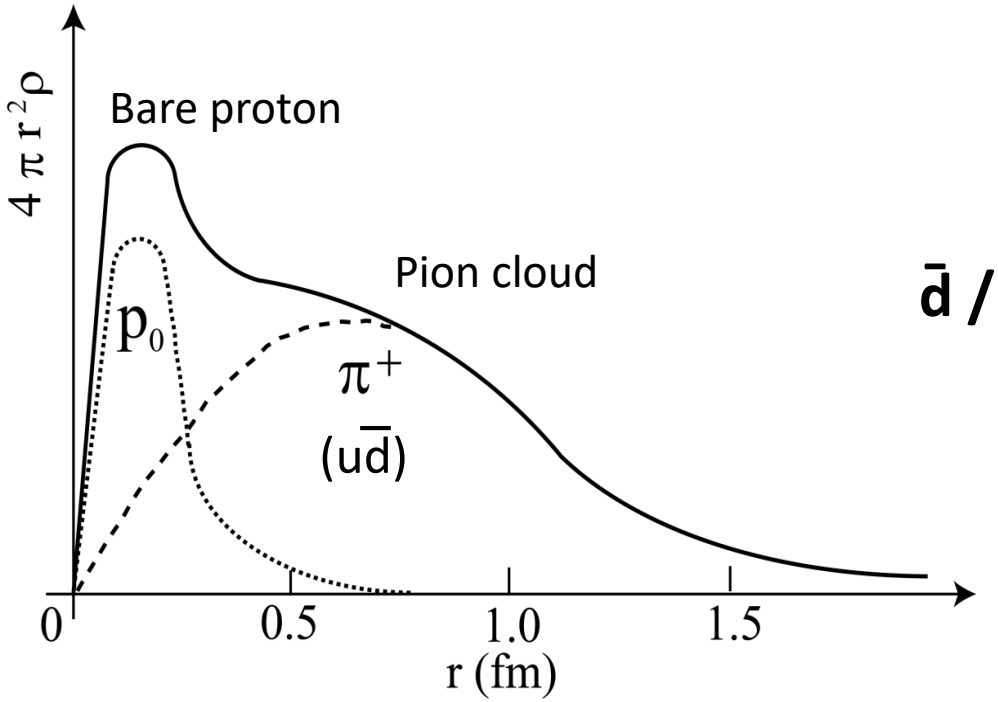


$$\gamma\, p \longrightarrow 3/10\,\pi^{+}\Delta^{0} + 1/5\,\pi^{0}\Delta^{+} + 1/10\,\pi^{-}\Delta^{++}$$

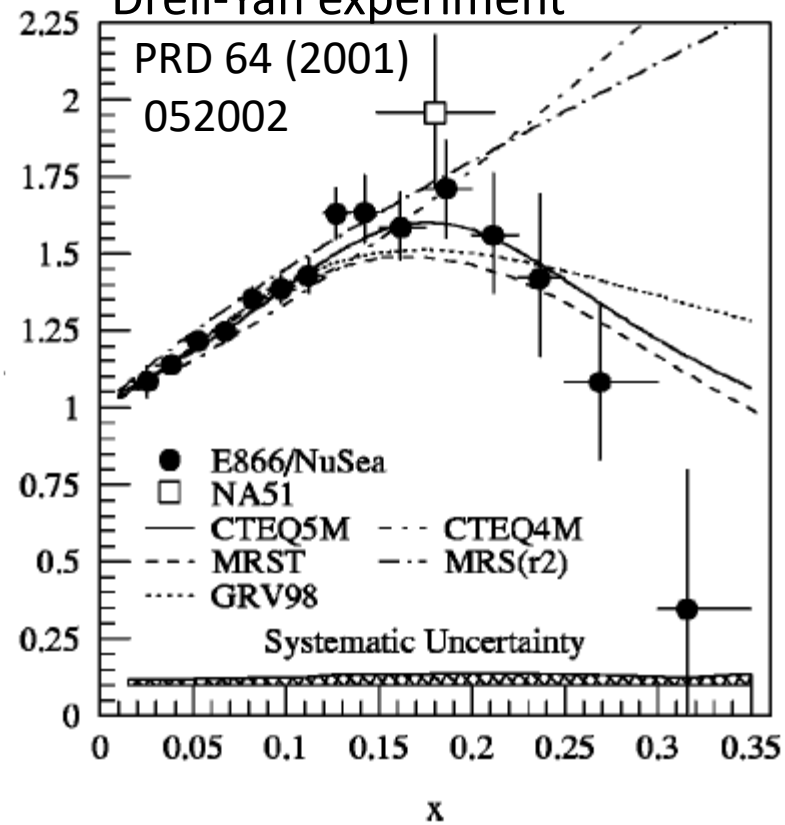
$$\frac{\sigma(\pi^{+}\Delta^{0})}{\sigma(\pi^{-}\Delta^{++})} = 3$$

Another explanation

Proton charge distribution



Drell-Yan experiment



Pion cloud model

$$|p\rangle = \sqrt{Z}\,|p_0\rangle + a_{N\pi/p}\,[-\sqrt{\frac{1}{3}}|p_0\pi^0\rangle + \sqrt{\frac{2}{3}}|n_0\pi^+\rangle]$$

π^+ ($u\bar{d}$) may enhance $\pi^+\Delta^0$ prodution($\bar{d}d$ production)

–> Larger $\sigma(\pi^+\Delta^0)/\sigma(\pi^-\Delta^{++})$

($\bar{d}d$ / $\bar{u}u$)

Possible explanations of the ratio $\sigma(\pi^+\Delta^0)/\sigma(\pi^-\Delta^{++})$

(1) Interference between π and ρ exchanges.

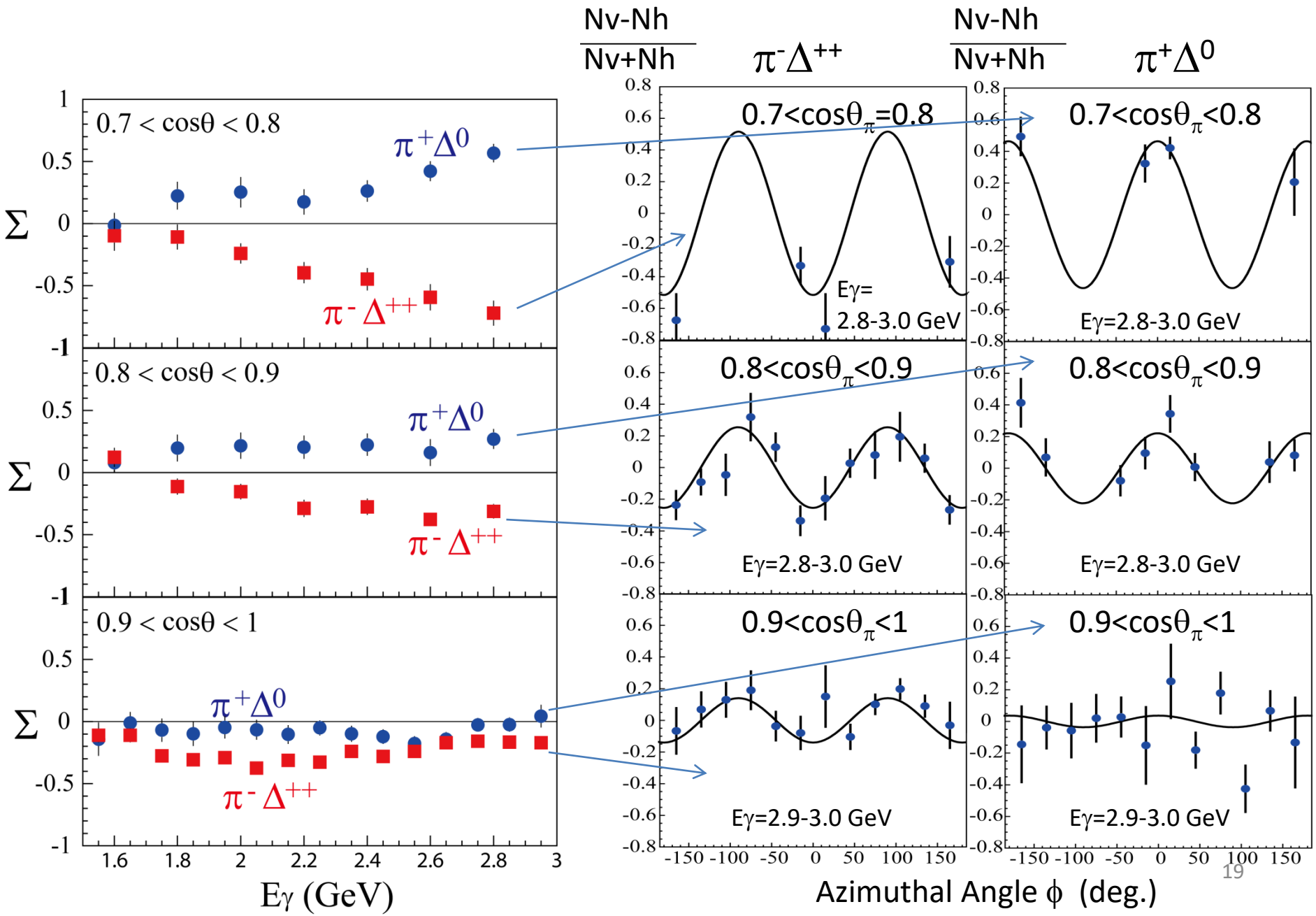
(2) I = 2 exotic meson exchange (ratio = 3)

(3) Pion cloud

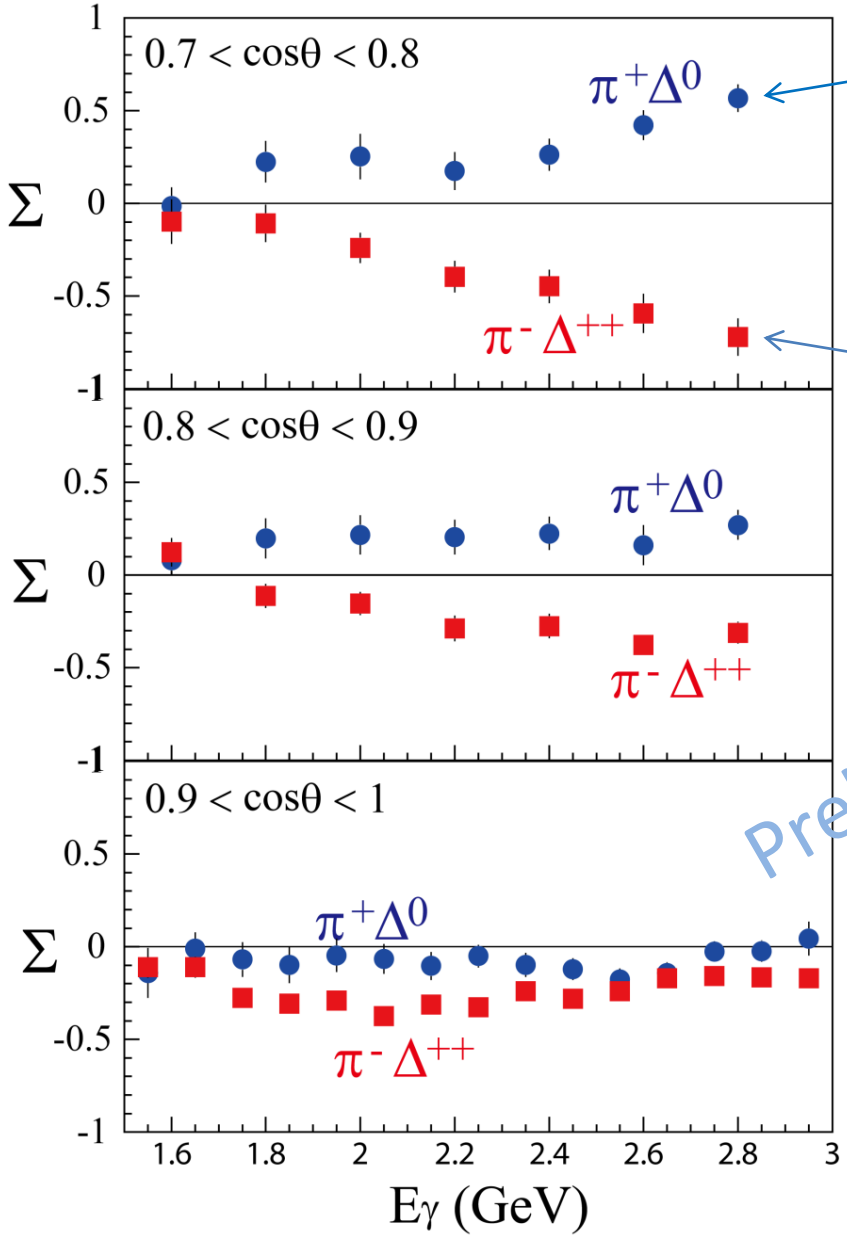
(4) N^*(ratio=1/3) and Δ^*(ratio = 4/3)

I am going to have discussions with theorists to obtain the best explanation.

Photon beam asymmetry using linearly polarized γ beams



Photon beam asymmetry for $\gamma p \to \pi^- \Delta^{++}$ and $\gamma p \to \pi^+ \Delta^0$ reactions



ρ exchange

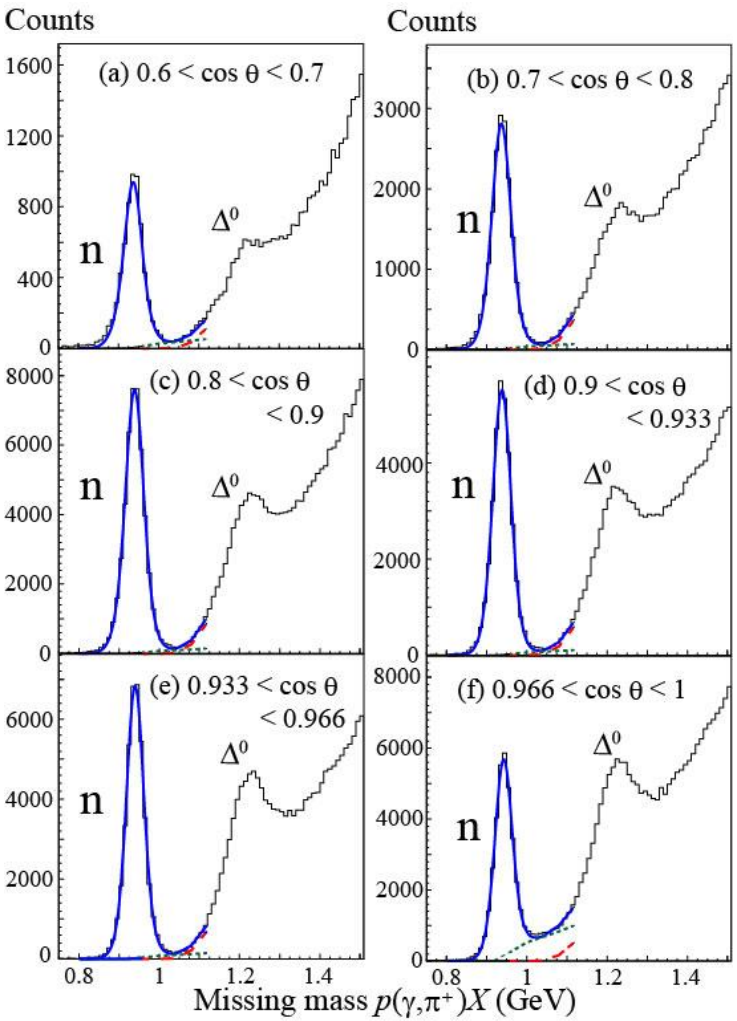
Reaction mechanisms are different at large angles.

π exchange

Preliminary

Both asymmetries are close to each other at small angles.

γ p –> π^+ n results



Before finalizing the πΔ analysis,
the π^+n results should be checked.

Paper

Differential cross section and photon beam asymmetry for the γ p -> π^+ n reaction at forward π^+ angles at E_γ=1.5-2.95 GeV

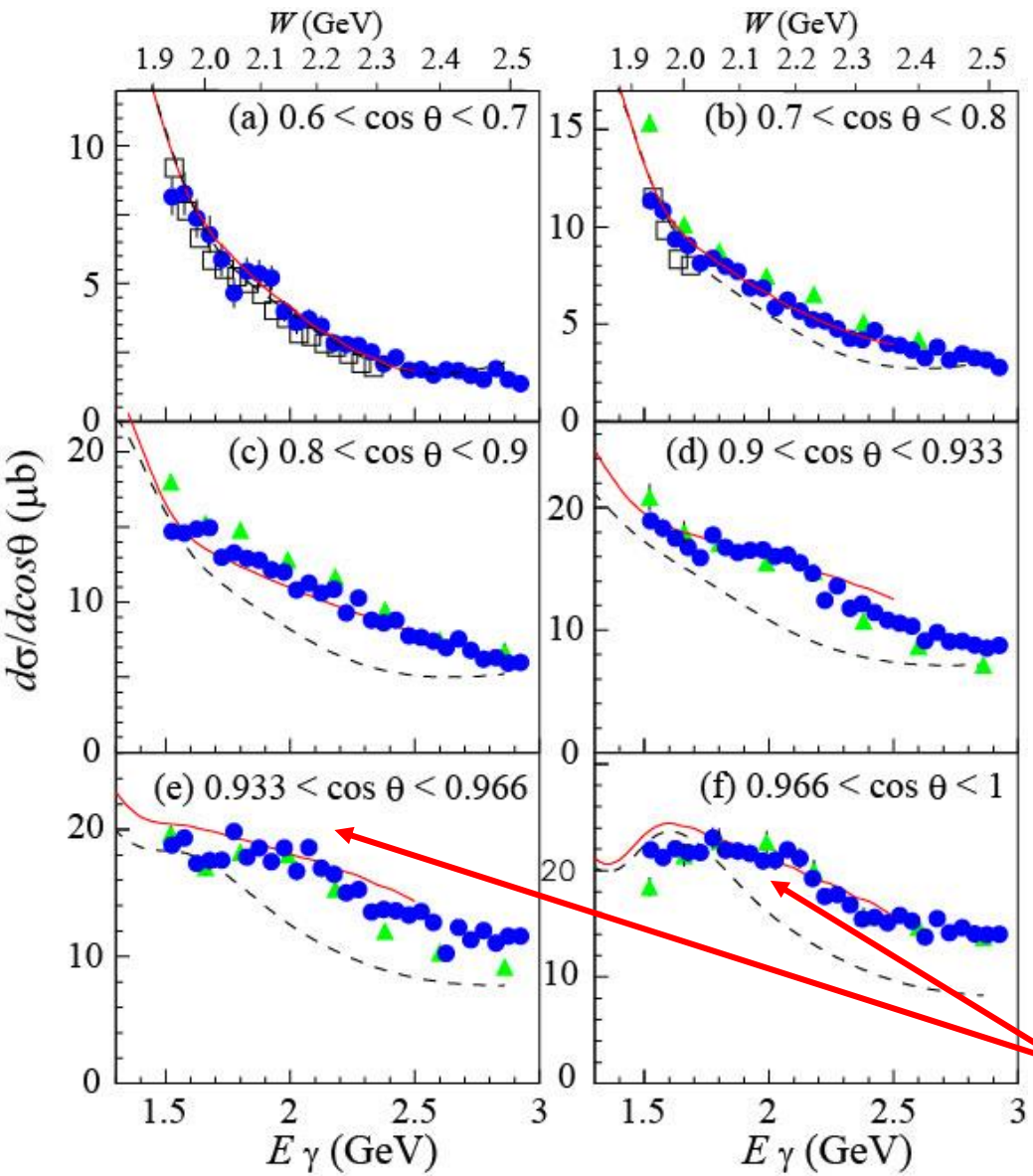
H. Kohri et al. (LEPS collaboration)

Submitted to Phys. Rev. C
on the 29th of Aug. in 2017.

arXiv: 1708.09574

Differential cross sections $\gamma p \to \pi^+ n$

arXiv: 1708.09574



- LEPS
- DESY(1966, 1967)
- CLAS(2009)
- SAID George Washington U.
- Bonn-Gatchina

LEPS data agree with DESY and CLAS data.

SAID reproduces LEPS data well.

Bonn-Gatchina calculations reproduce LEPS data well at $\cos\theta<0.8$.
Differences become large at $0.8<\cos\theta$ because of pure predictions.

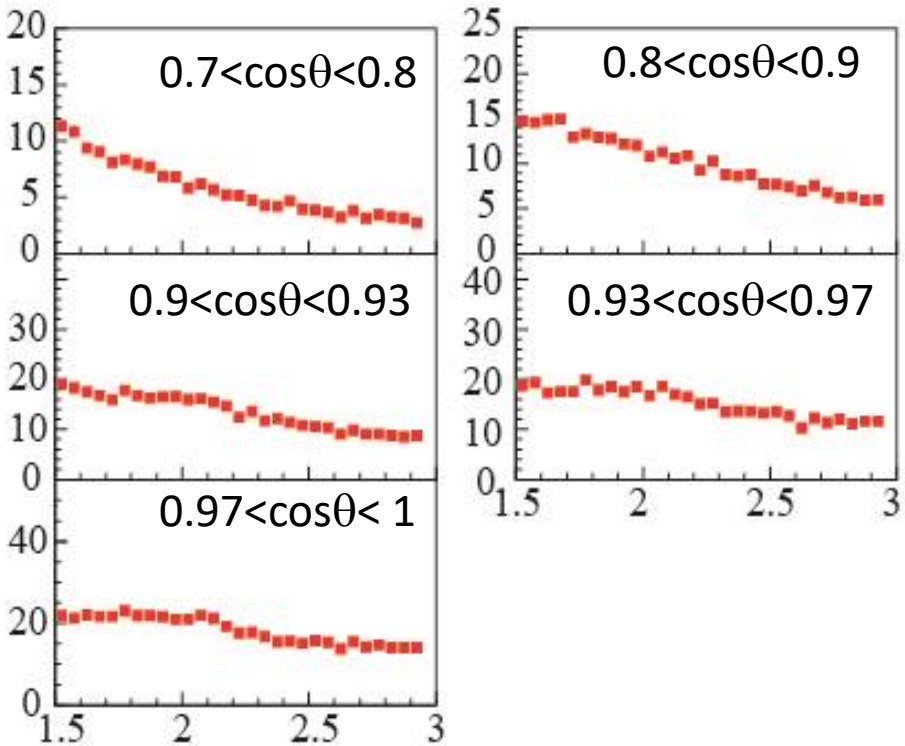
Energy dependence is different at small π^+ angles.
N^* or Δ^* effects ?

Comparison of differential cross sections between π^+n and $\pi^+\Delta^0$

Differential cross sections are similar to each other except for $E\gamma \sim 1.5$ GeV.

$p(\gamma, \pi^+)n$

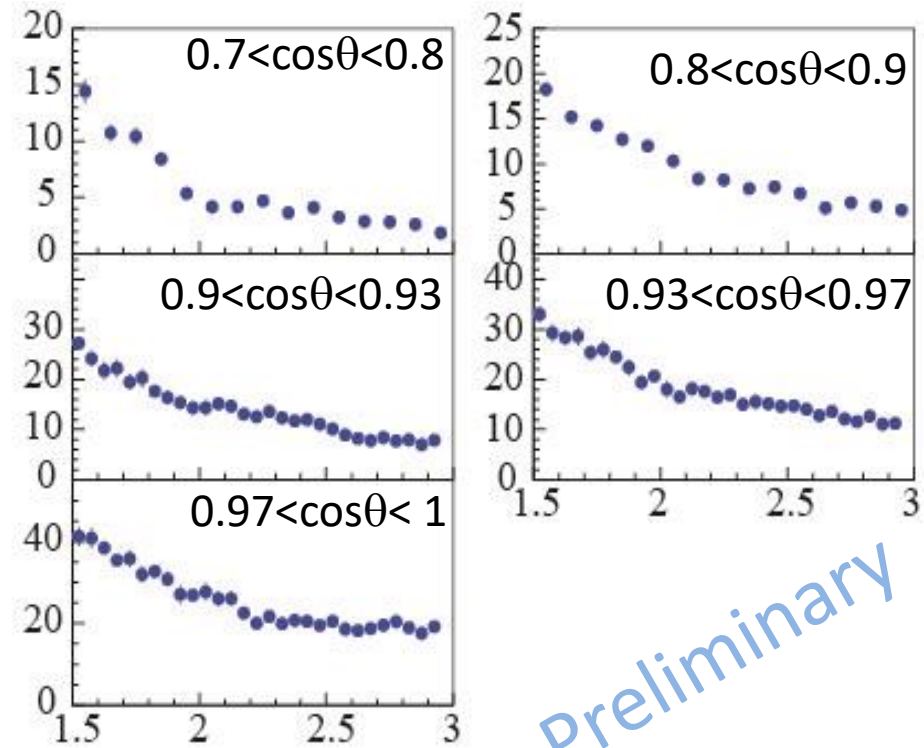
$d\sigma/d\cos\theta$ (μb)



E_γ (GeV)

$p(\gamma, \pi^+)\Delta^0$

$d\sigma/d\cos\theta$ (μb)



Preliminary

E_γ (GeV)

Ratio (Nv-Nh)/(Nv+Nh) for π^+n reaction

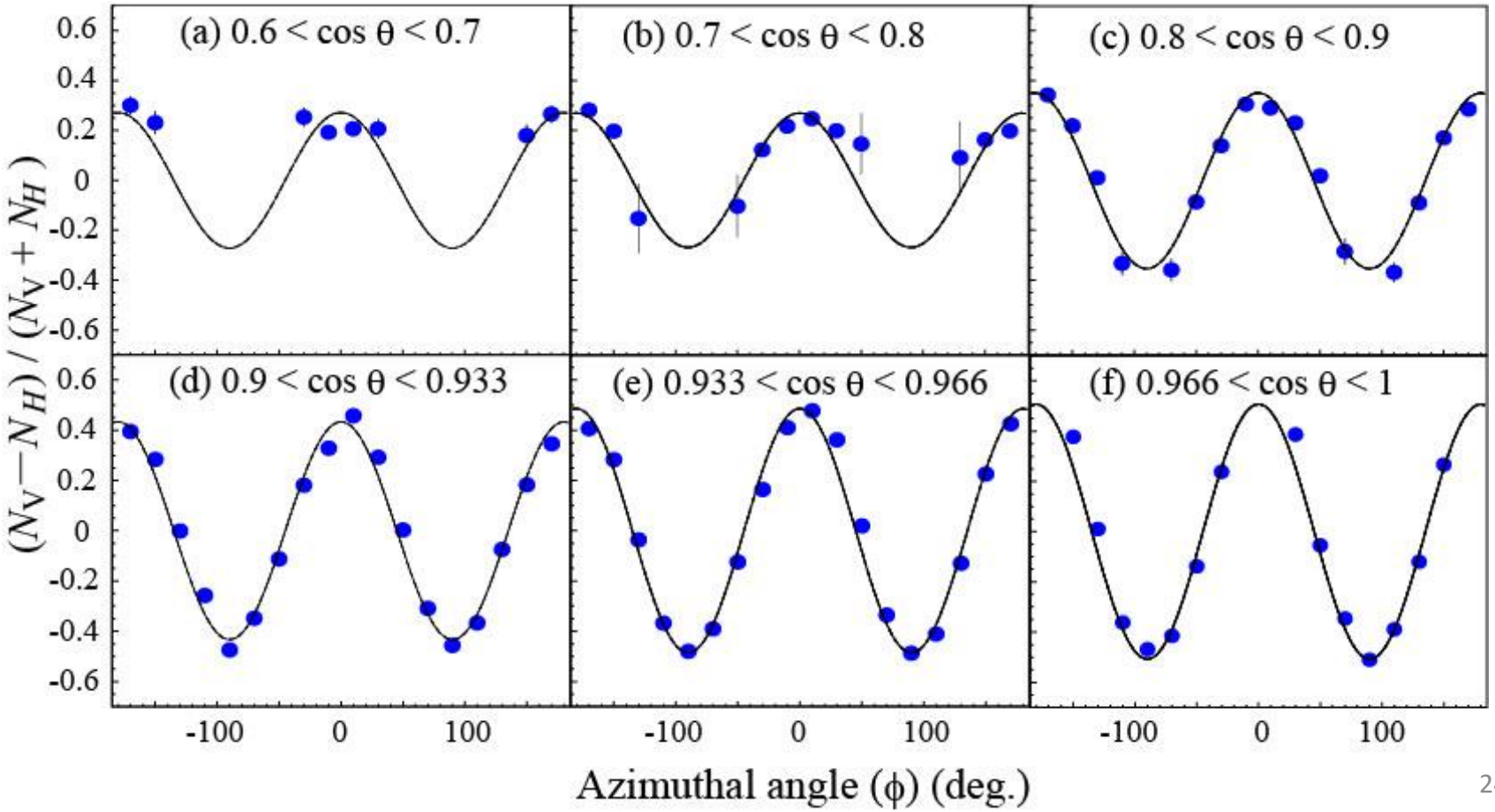
π^+ favors to scatter at ϕ perpendicular to the polarization plane.

-> Asymmetries(Σ) are positive.

$$P_\gamma \Sigma \cos 2\phi_\pi = \frac{N_V - N_H}{N_V + N_H}$$

$P\gamma$: Polarization of photon beam

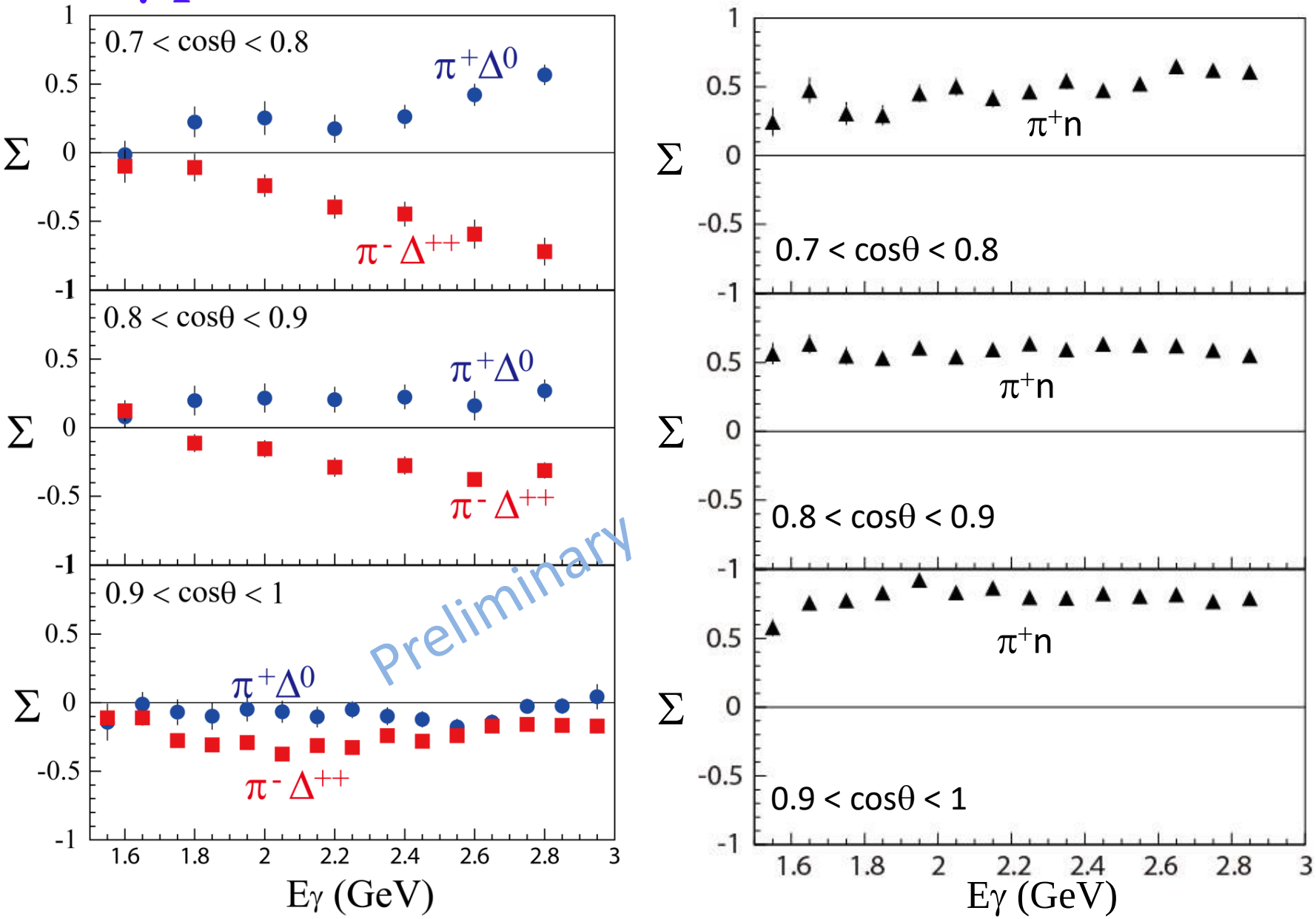
Σ : Asymmetry



Photon beam asymmetry

for γ p -> $\pi^-\Delta^{++}$,$\pi^+\Delta^0$, π^+n reactions

arXiv: 1708.09574



Summary

* We newly took high momentum π data at E_γ=1.5-2.95 GeV.

* Precise comparison between $\bar{u}u$ and $\bar{d}d$ productions is possible in $\gamma\, p \to \pi^- \Delta^{++}$ and $\pi^+ \Delta^0$.
  Cross section ratio $\sigma(\pi^+\Delta^0)/\sigma(\pi^-\Delta^{++})$ is found to be close to 1/3 at small angles and larger than 1/3 at large angles.
  $\bar{d}d$ production is enhanced or $\bar{u}u$ production is suppressed.
  Photon beam asymmetry is typically found to be negative for $\pi^-\Delta^{++}$ and positive for $\pi^+\Delta^0$.

* Differential cross sections for $\gamma p \to \pi^+ n$ are close to those for $\pi^+\Delta^0$.
  Asymmetries for $\pi^+ n$ are large positive values.
  Cross sections and asymmetries agree with previous data.

LEPS/LEPS2 collaboration

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Thank you