Hadron Physics with Photon Beam at LEPS/ LEPS2

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Outline

LEPS

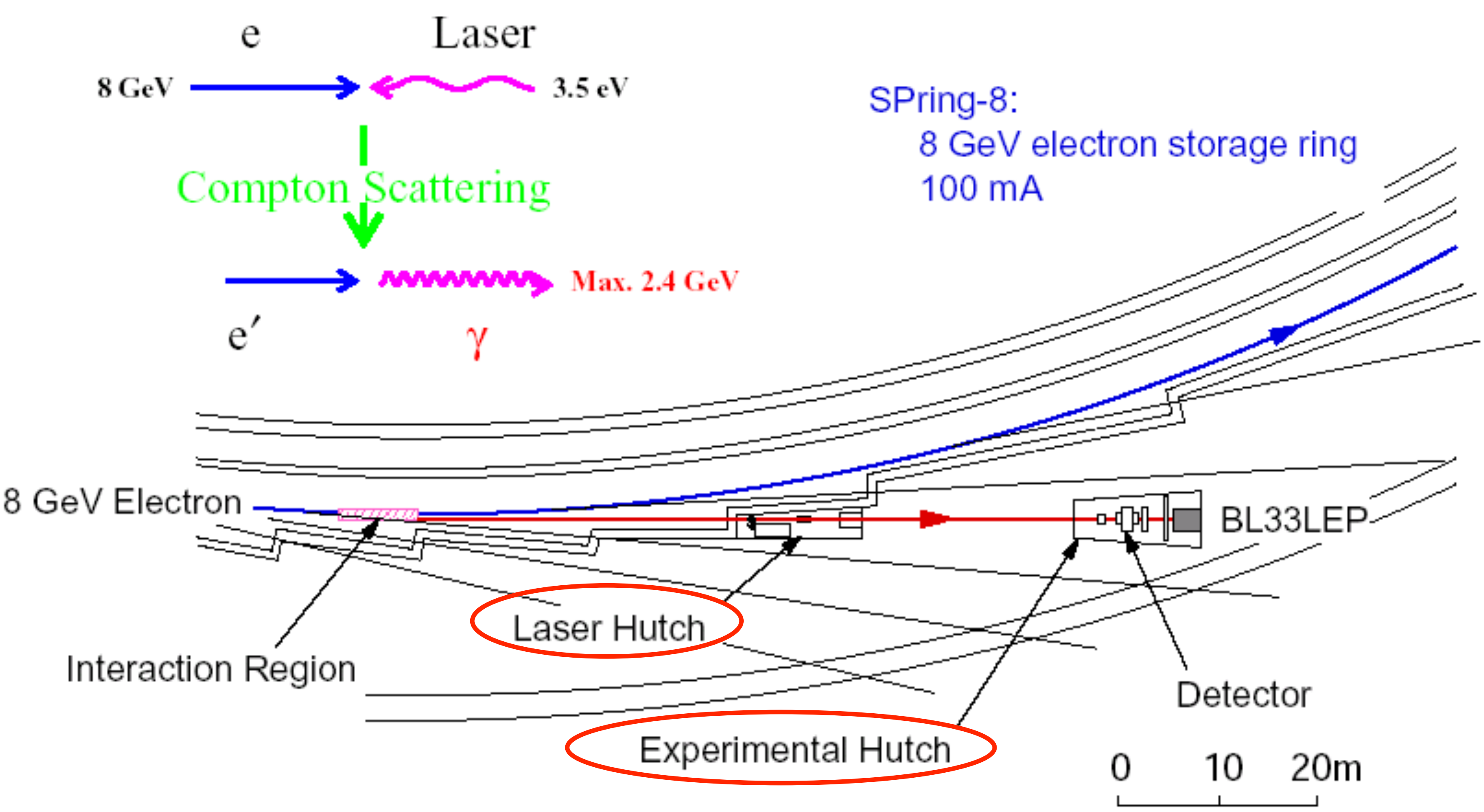
- **Overview**
- **Some recent results**

LEPS2

- **Physics Motivation**
- **Overview**
- **First experiment**

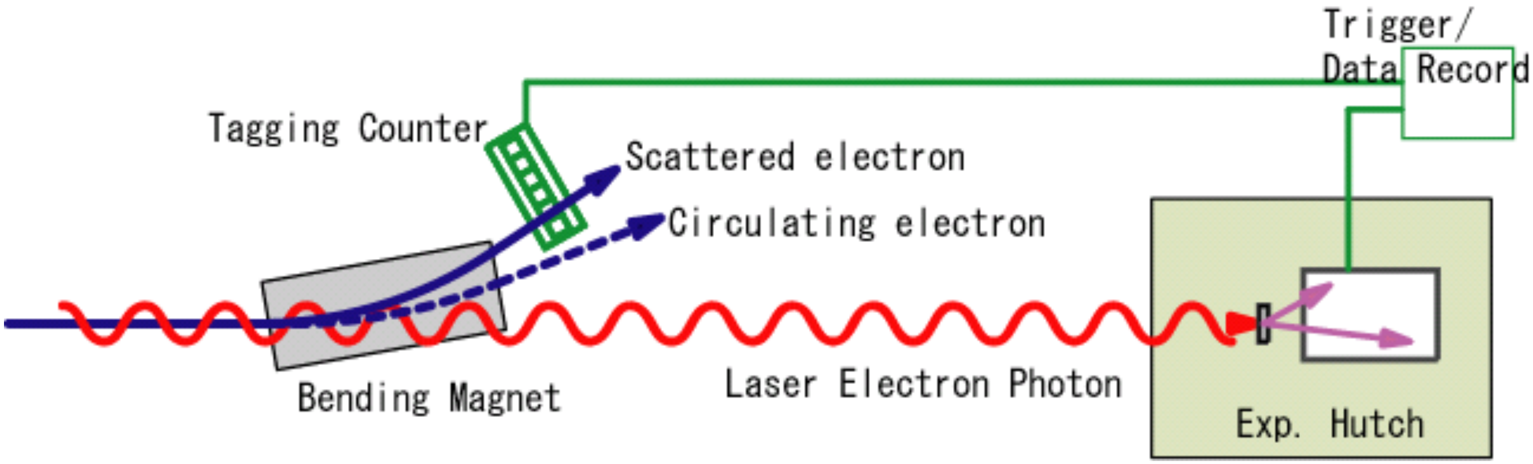
Summary

Laser Electron Photon beamline at SPring-8



Operated since 2000.

Photon tagging and experiment



Timing and position of a scattered electron is measured at a counting rate of ~1 M /sec.

- **$E_\gamma \geq 1.5$ GeV : about 40% of ($0<E_\gamma<E^{max}$) photons**
- **For incident photon number normalization**
- **For trigger : rate ~ 100 /sec**

Backward-Compton Scattered Photon

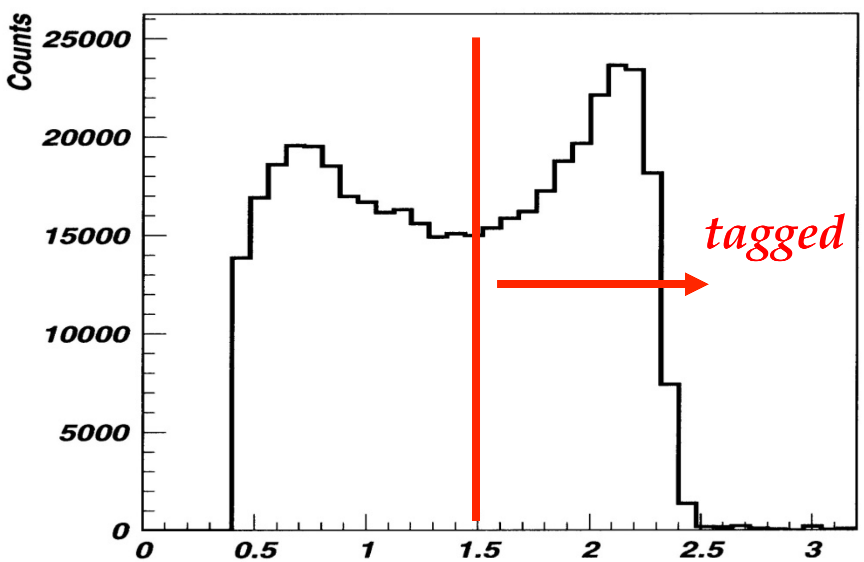
8 GeV electrons in SPring-8 + 350nm(260nm) laser
➔ maximum 2.4 GeV(2.9 GeV) photon

Laser Power ~6 W ➔ Photon Flux ~1 Mcps

Eγ measured by tagging a recoil electron ➔ Eγ>1.4 GeV, ΔEγ ~10 MeV

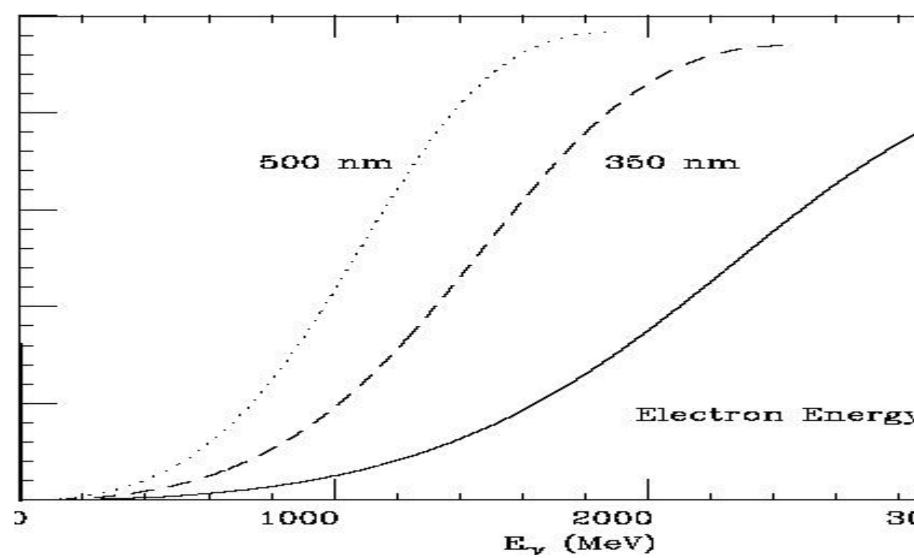
Laser linear polarization 95-100% ⇒ Highly polarized γ beam

PWO measurement



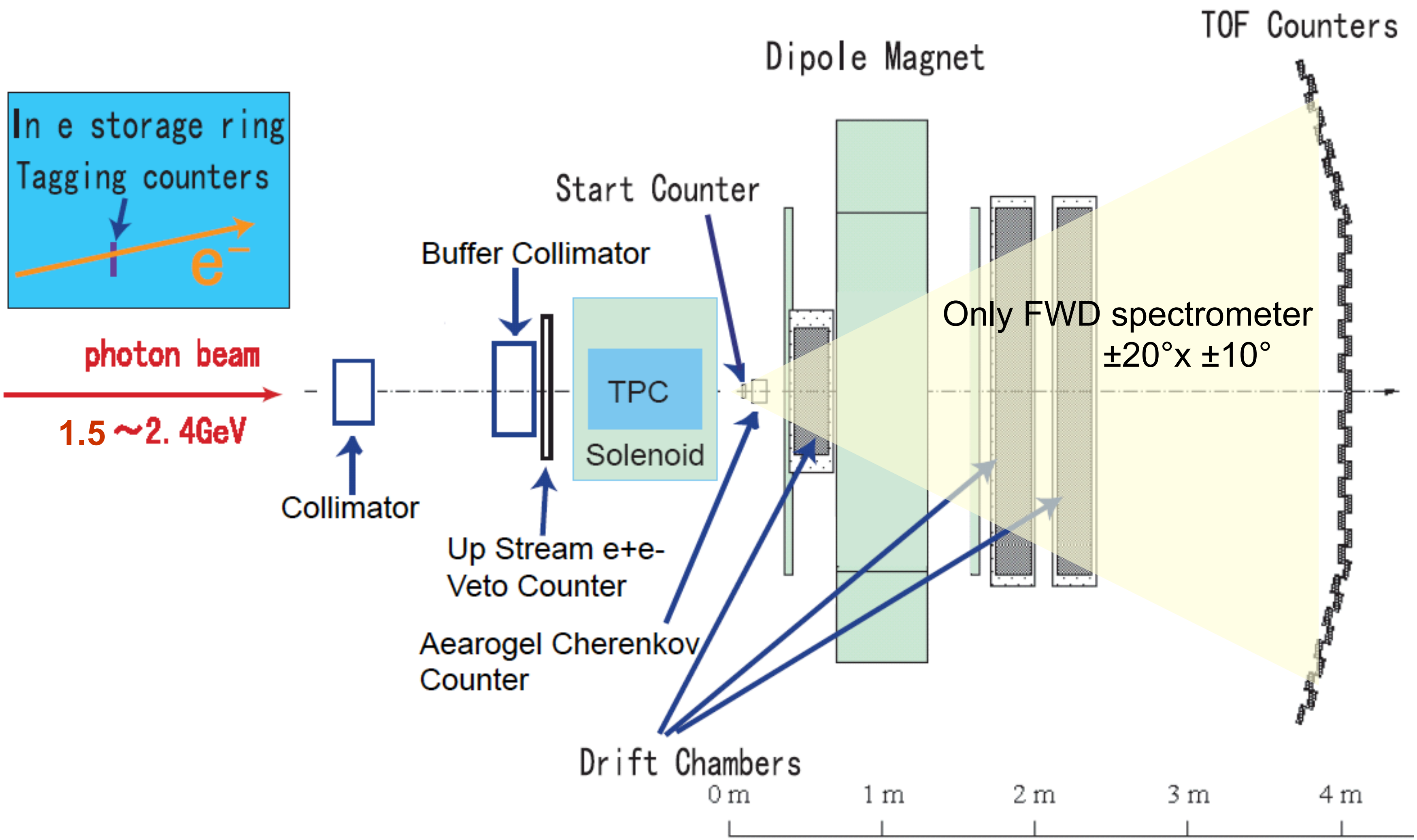
photon energy [GeV]

Linear Polarization of γ beam

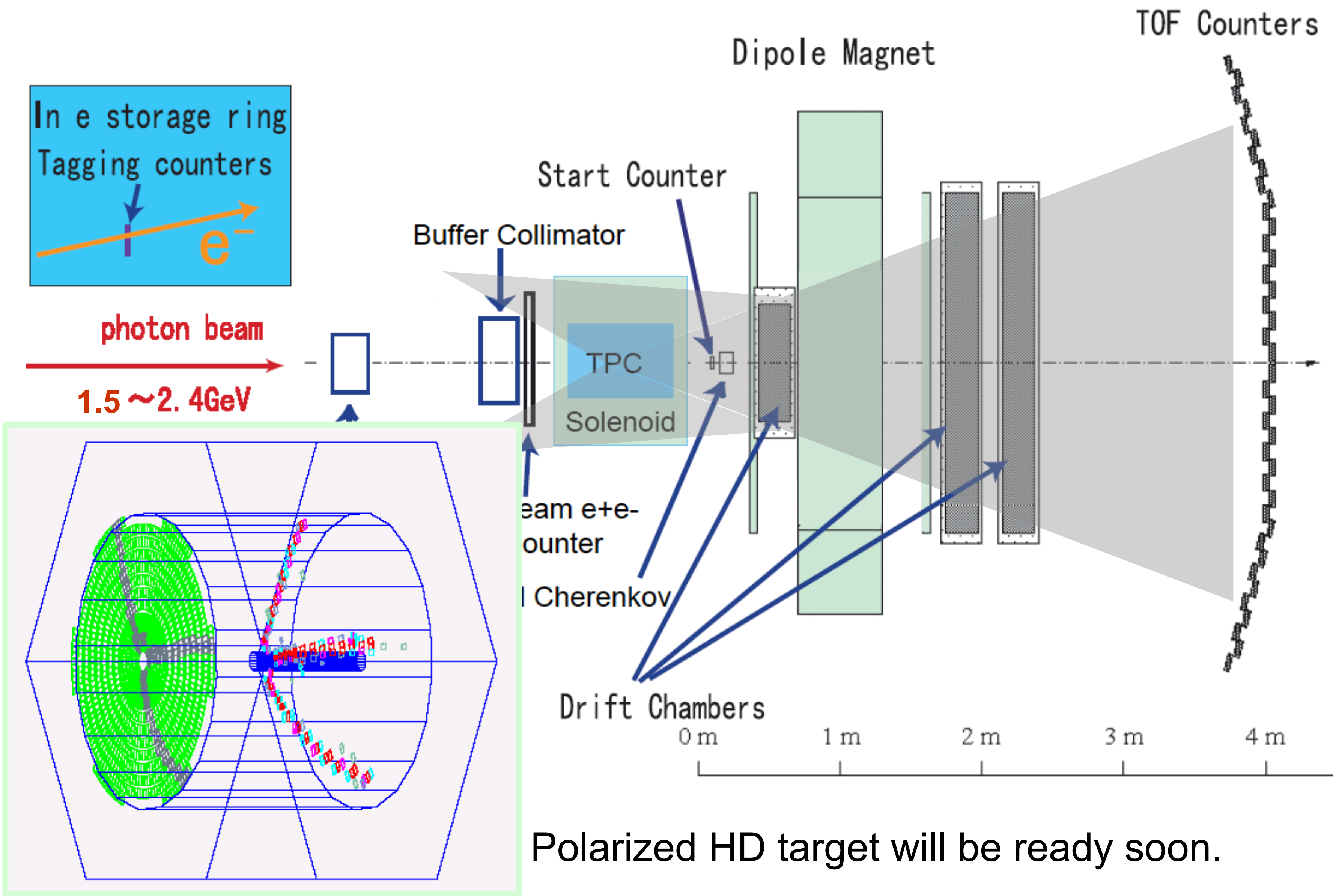


photon energy [MeV]

Setup of LEPS

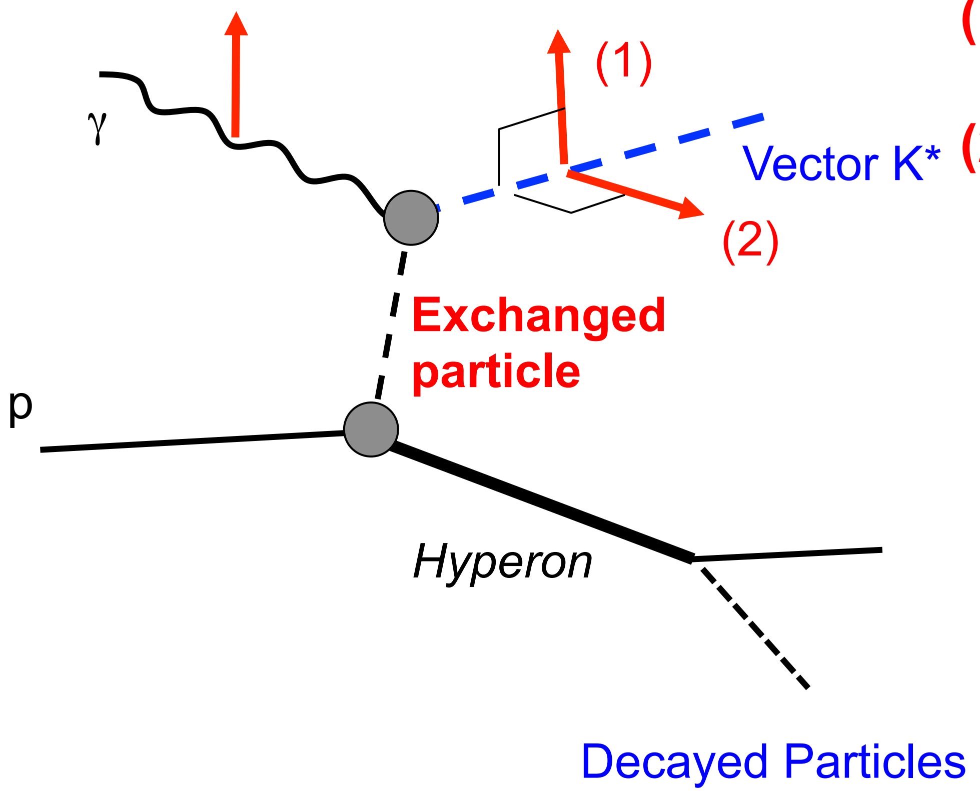


Setup of LEPS



Polarized HD target will be ready soon.

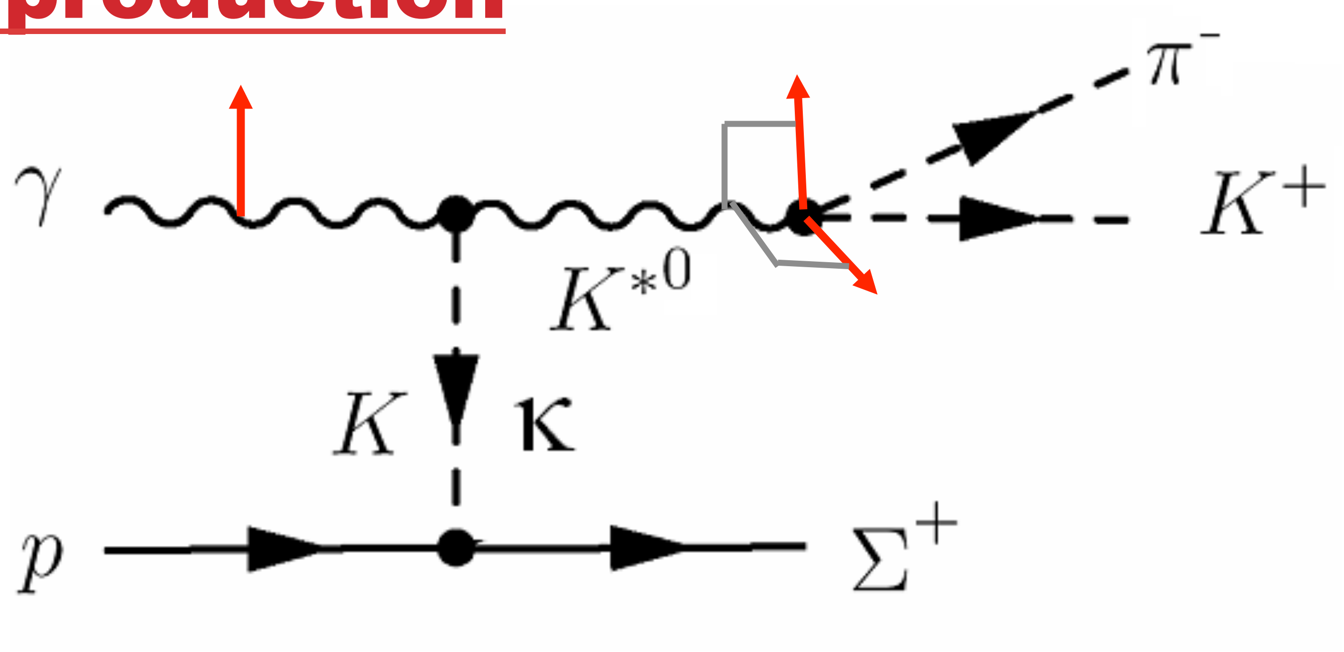
Linearly Polarized Photons



(1) Natural parity

(2) Unnatural parity

Scaler κ exchange in Σ^+ production

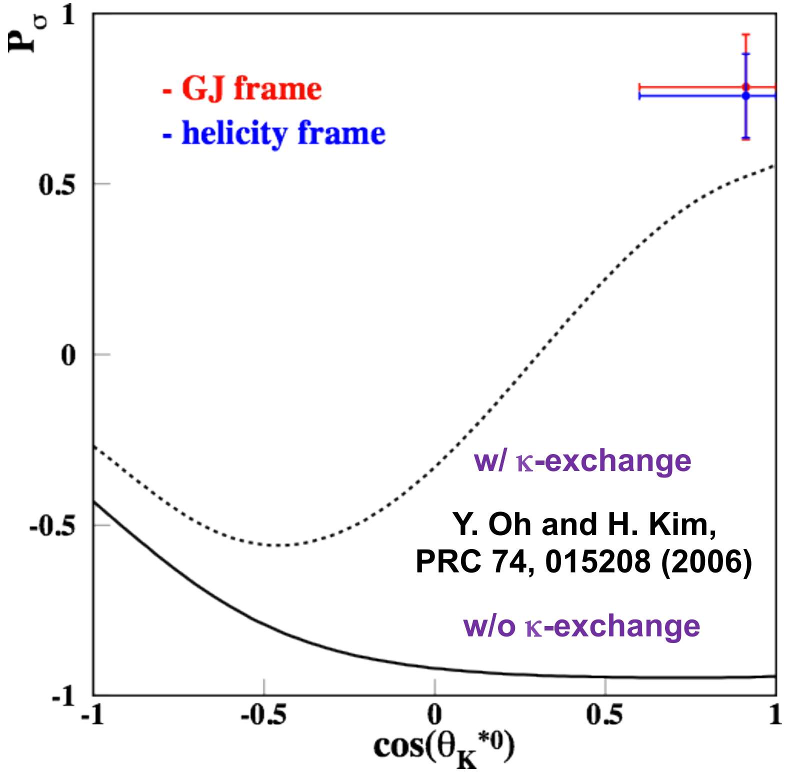


K : Pseudoscalar meson → unnatural exchange

κ: Scalar meson → natural exchange

Parity Spin Asymmetry

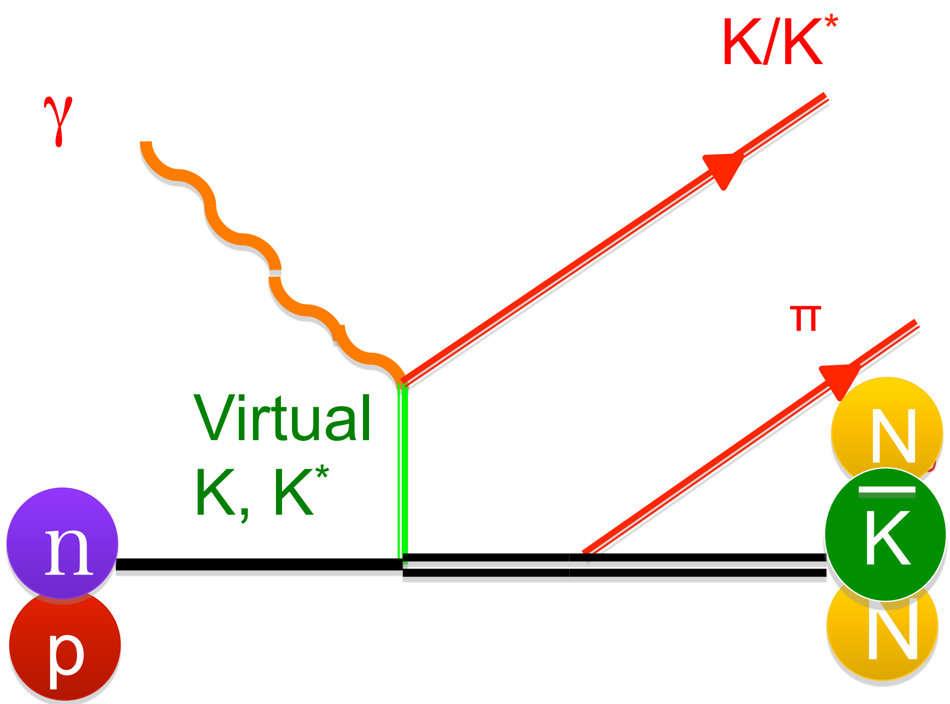
PRL 108, 092001 (2012)

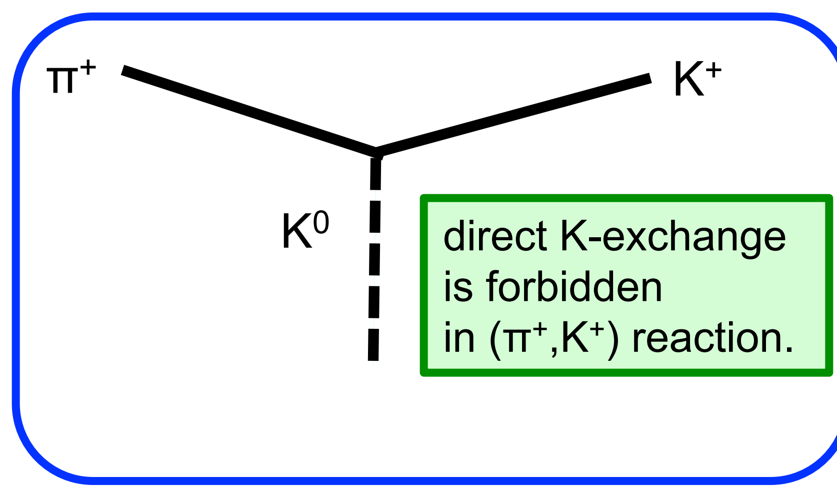


Dominance of natural-parity exchange is indicated at forward angles.

⇒ Consistent with κ(800) meson exchange.

Kaonic nuclei search





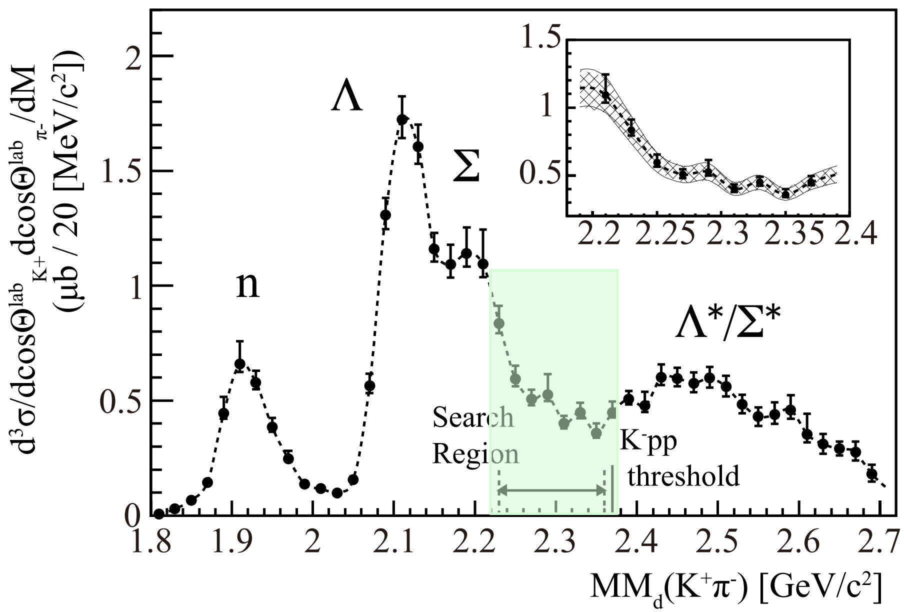
Physics motivation

- $\bar{K}$-N interaction is strongly attractive (I=0).
  weakly attractive (I=1).
  → $\bar{K}$NN bound state ($\underline{K^-pp}$, K^-pn, K^-nn)
  the strongest bound state

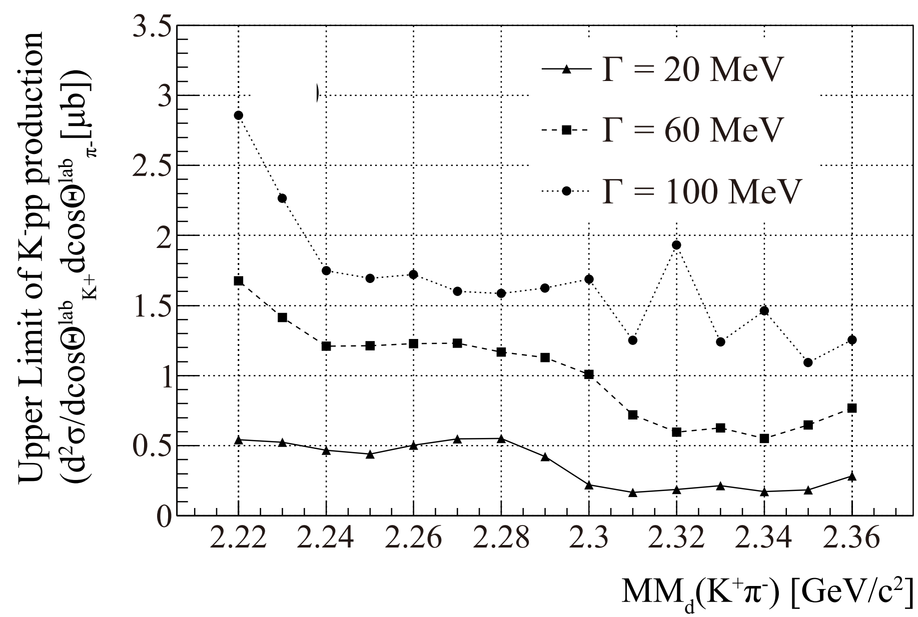
- K^-pp
  - Theory: B.E. = 20 - 120 MeV, Γ=60 – 110 MeV
  - Experiment : FINUDA (B.E. =115 MeV, Γ = 67MeV)
    DISTO (B.E. =103 MeV, Γ = 118MeV)

$K^{-}pp$ search via $\gamma + d \rightarrow K^{+} + \pi^{-} + X$

MM($K^{+}\pi^{-}$)



Upper limit of cross section (95% C.L.)



Search reg

Significant

→ ~ 10% of Q.F. processes

So far, no peak was observed in inclusive modes.
We will try to detect decay products.
→ Larger acceptance, LEPS2.

tio method;

.17 - 0.55 μb

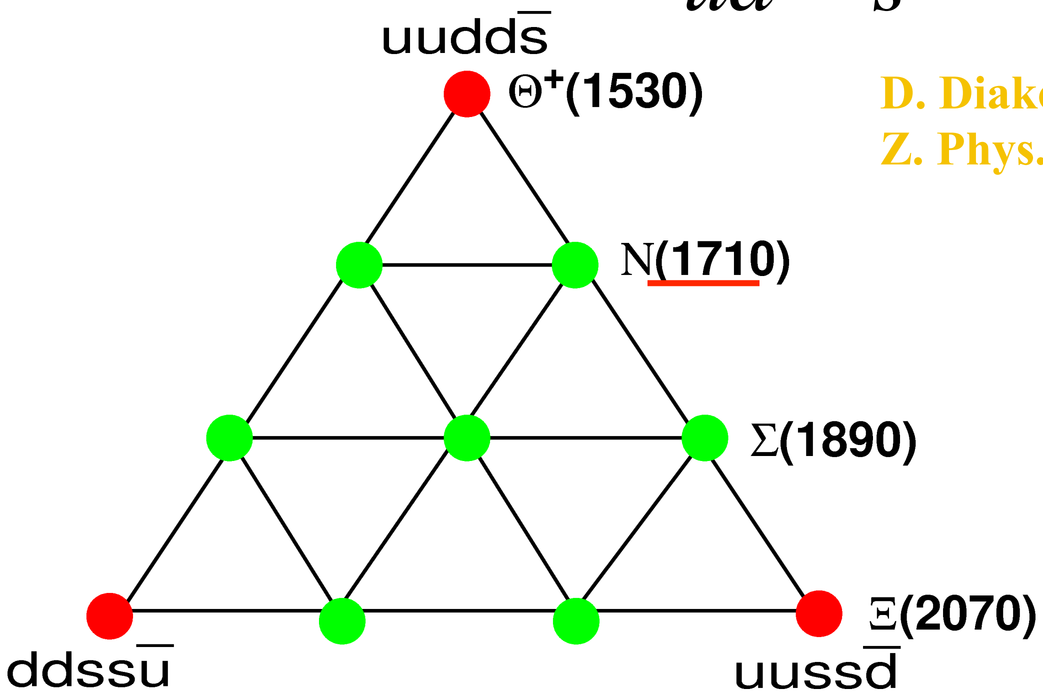
.55 - 1.7 μb

Γ = 100 MeV : 1.1 - 2.9 μb

~10% of Q.F. processes

Prediction of the Θ^+ Baryon

$$ud \sim \bar{s}$$



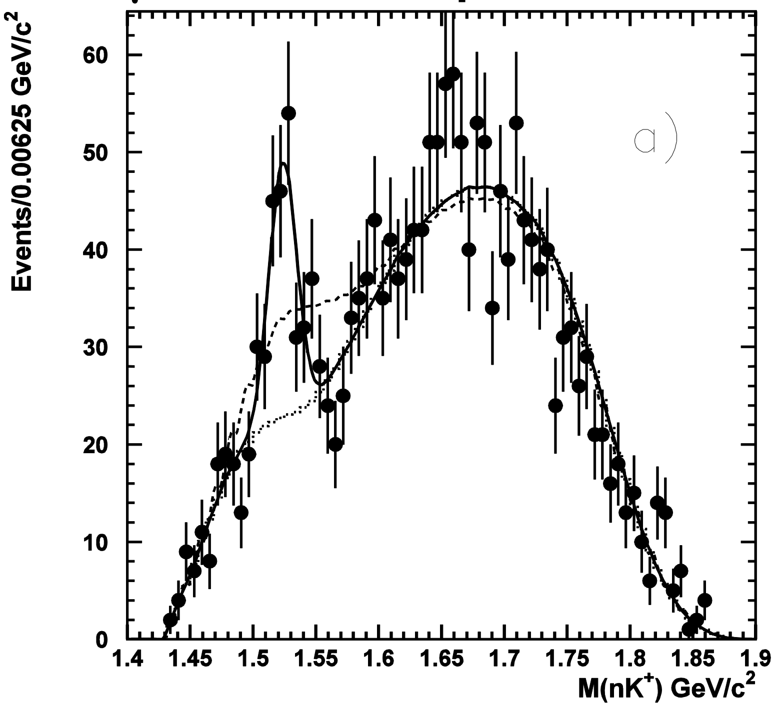
M = [1890-180*Y] MeV

D. Diakonov, V. Petrov, and M. Polyakov, Z. Phys. A 359 (1997) 305.

- Exotic: S=+1
- Low mass: 1530 MeV
- Narrow width: < 15 MeV
- $J^p=1/2^+$

Previous result

γ d $\rightarrow K^+K^-pn$ reaction



- Data taken in 2002-2003.
- $2.0<E_\gamma<2.4$ GeV.
- Significance of 5.1σ from shape analysis. (Δ(-2lnL) with/without signal)
- Mass=1524±2＋3MeV/c².

If the peak is real,

✓ It should be reproducible.

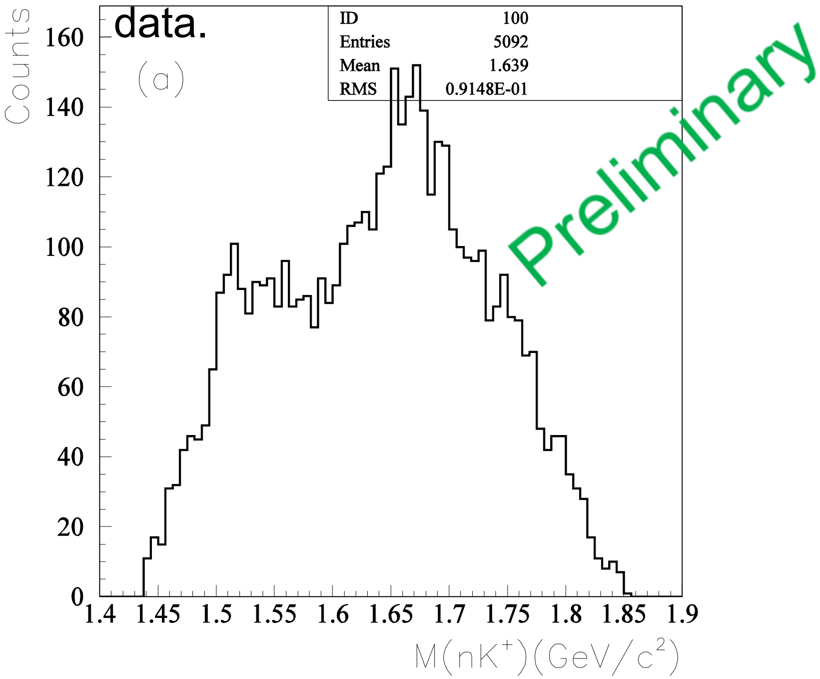
✓ It should appear in $M(nK^+)$.

✓ It should not appear in $M(nK^-)$ nor in $M(pK^+)$.

Results of Inclusive Analysis

New data

contains 2.6 times more statistics than the previous data.

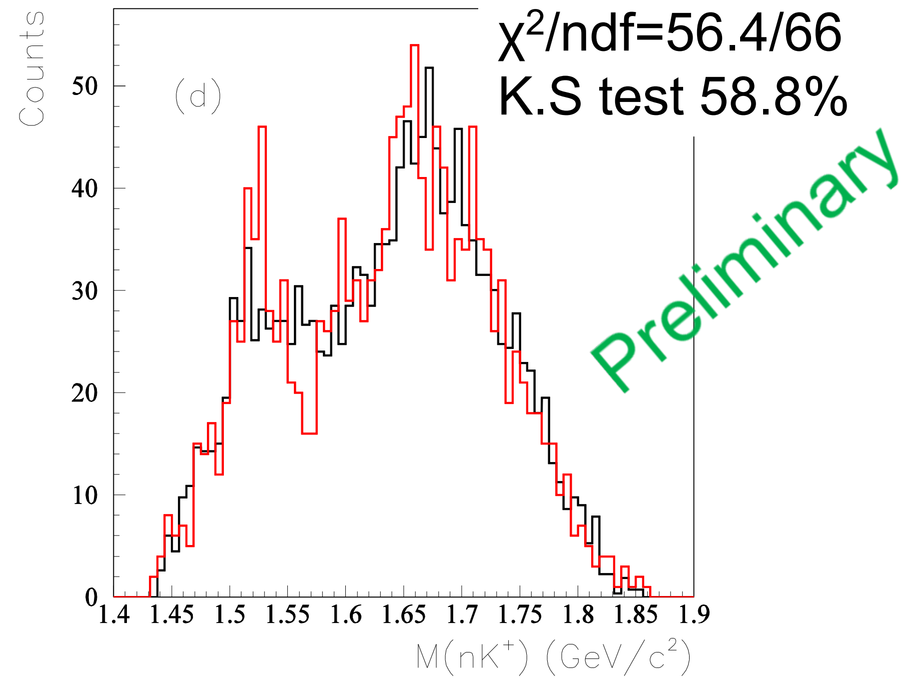


New data

previous data

χ^2/ndf=56.4/66

K.S test 58.8%



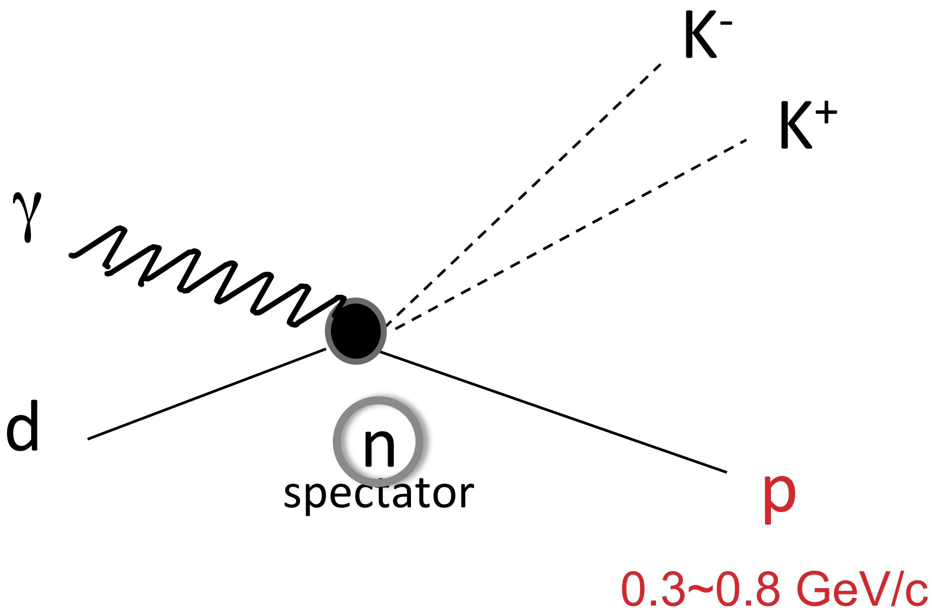
- Blind analysis: Cuts are pre-determined.
- Narrow strong structure is not seen in the signal region.
- The significance is ~ 2σ if we perform the same shape analysis as the previous analysis.

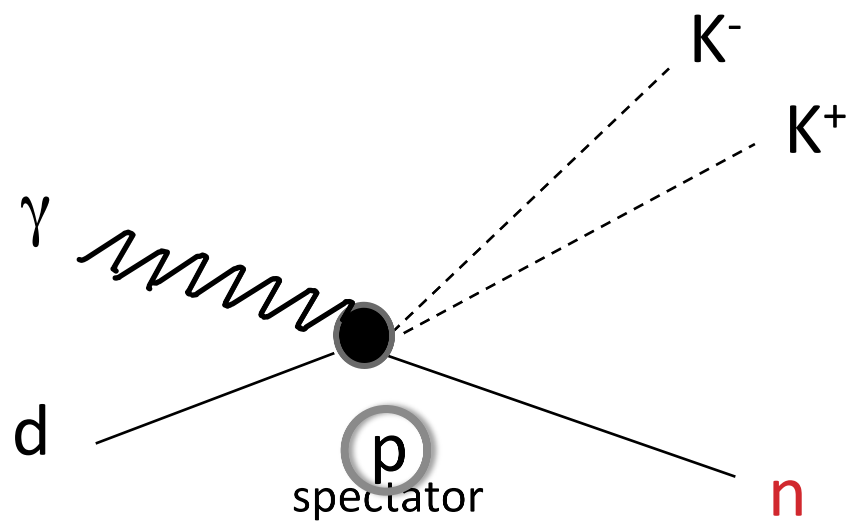
- Two data sets are normalized by the entry.
- In total, two data sets are consistent.

Fluctuation?
Human bias?
Over/under-estimation?

→ Exclusive analysis

Exclusive Analysis

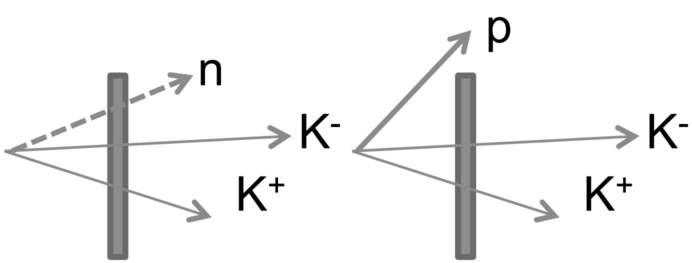




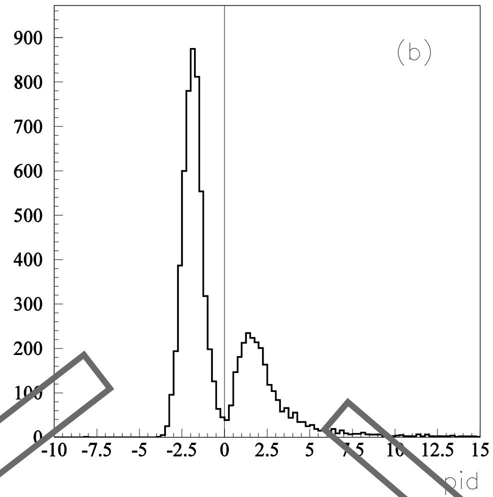
$\Lambda(1520)$, ϕ, ...

Θ^+, ϕ, ...

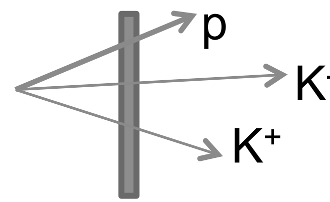
Proton detection by using dE/dx in Start Counter



or



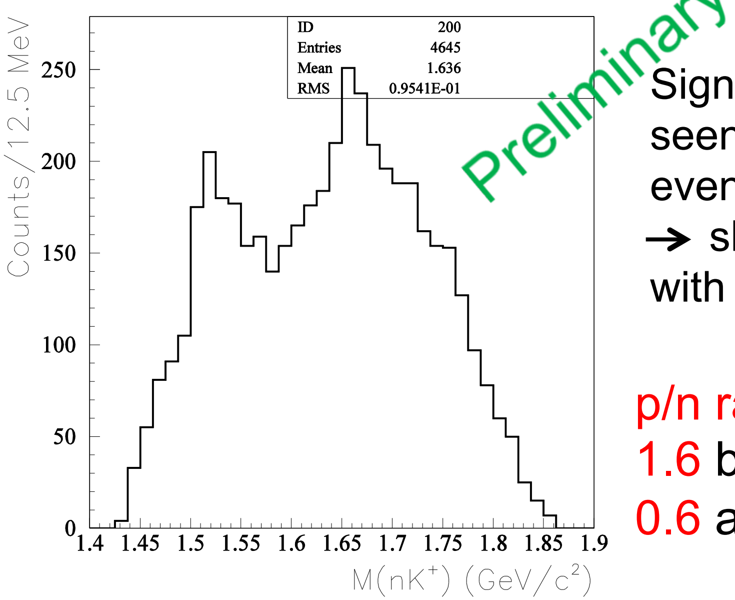
Pid = (Measured energy loss in SC)
– (Expectation of KK)
– (Half of expectation of proton)



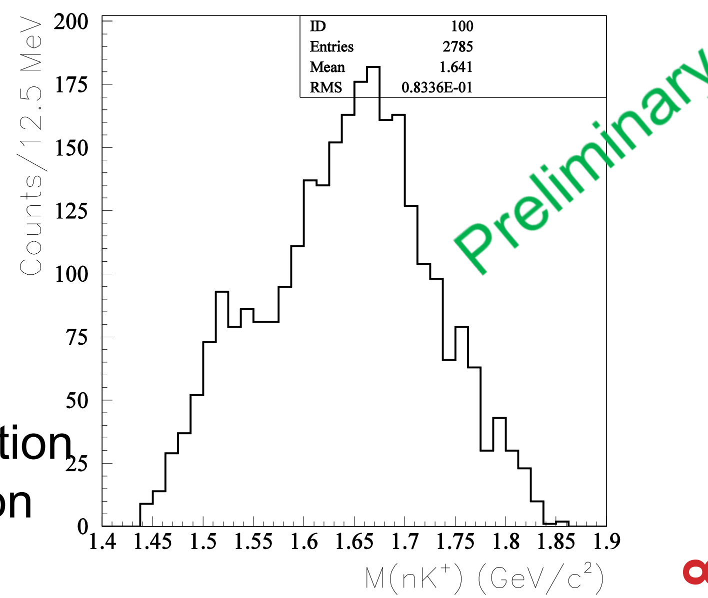
Proton not tagged (Proton rejected)

Proton tagged (ε ~60%)

KKn and a part of KKp



KKp only



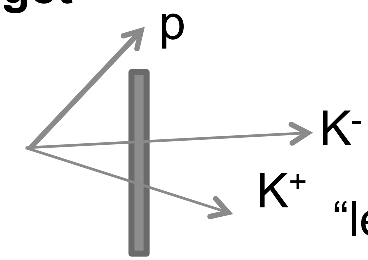
Signal enhancement is seen in proton rejected events.
→ should be associated with γn reaction.

p/n ratio:
1.6 before proton rejection
0.6 after proton rejection

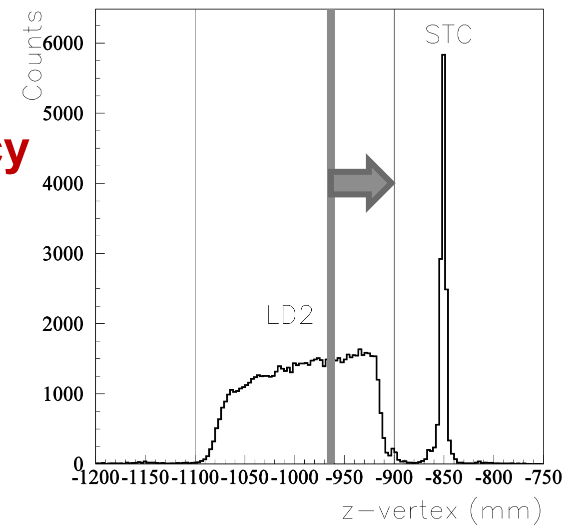
Two methods to reduce "leaked" proton BG

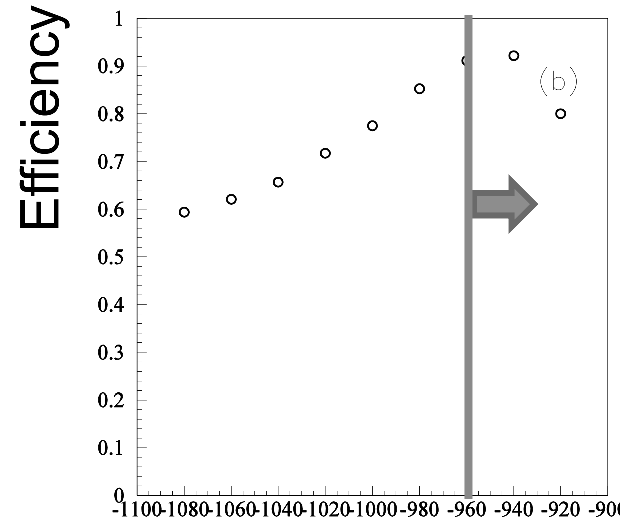
1. dE/dx-based exclusive analysis

Proton **rejection efficiency** becomes **60%→90%** by selecting downstream of target



"leaked" proton BG



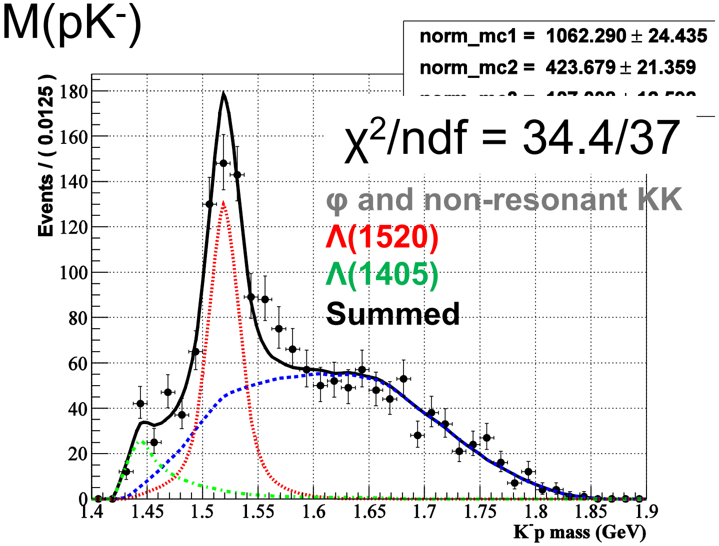


2. MC-based exclusive analysis

・Proton contribution is estimated by fitting realistic MC distributions to proton-tagged spectra.

・The **estimated leaked proton contributions** are subtracted from full data sample (without z-vertex).

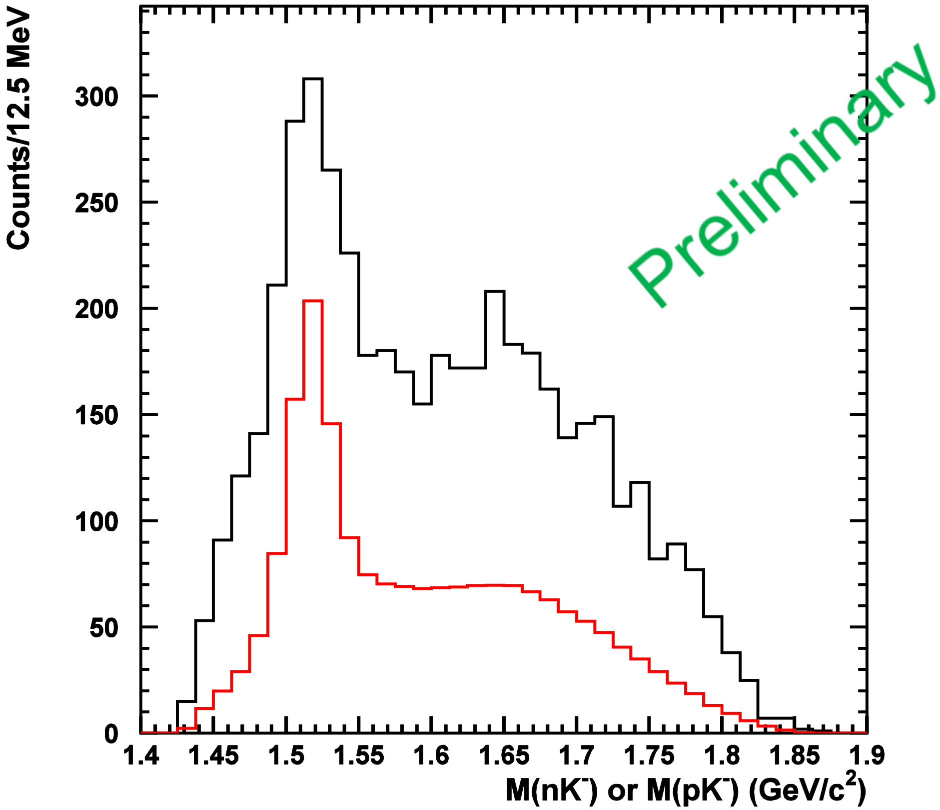
M(pK-)



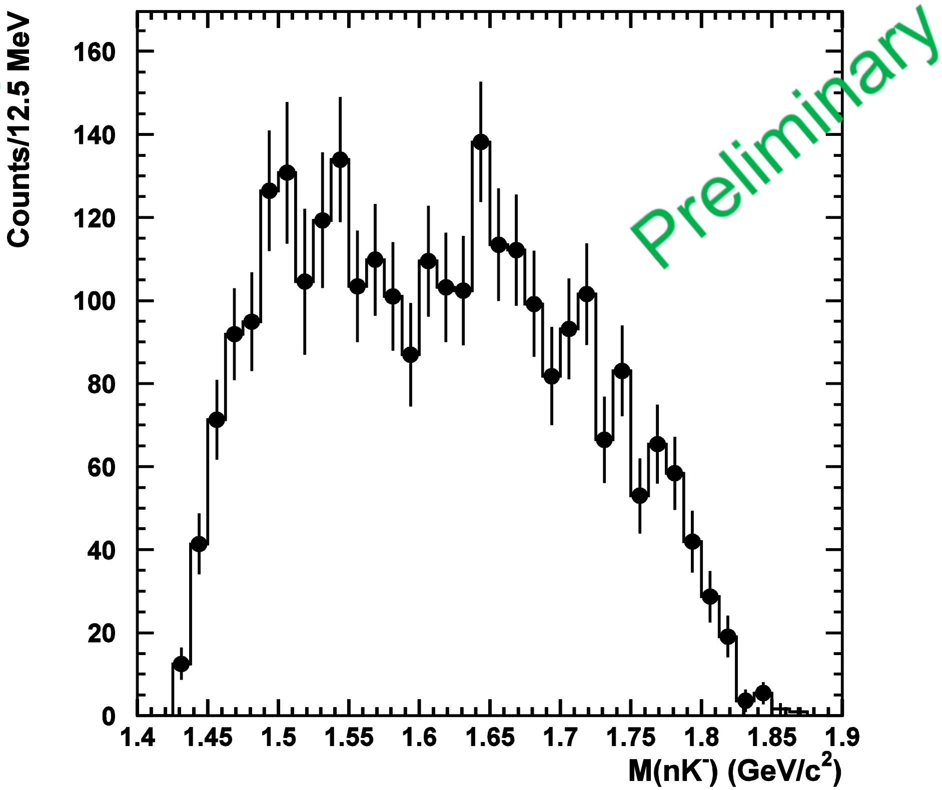
M(nK⁻) distribution

✓The peak did not appear in M(nK⁻)

n and p(leaked)

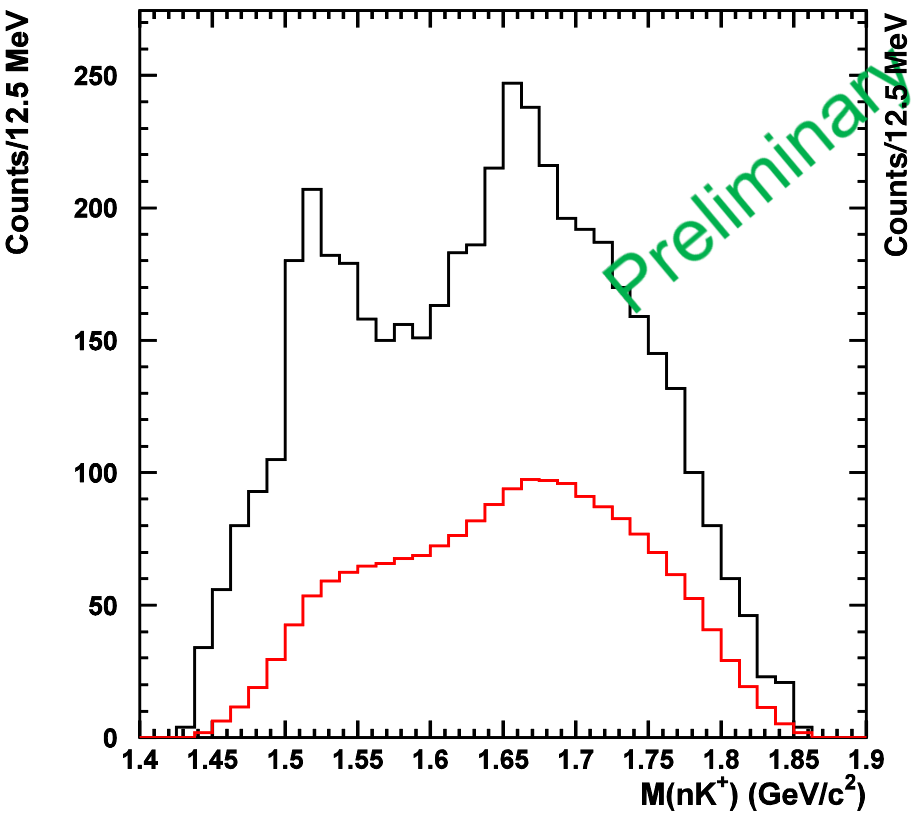


subtracted

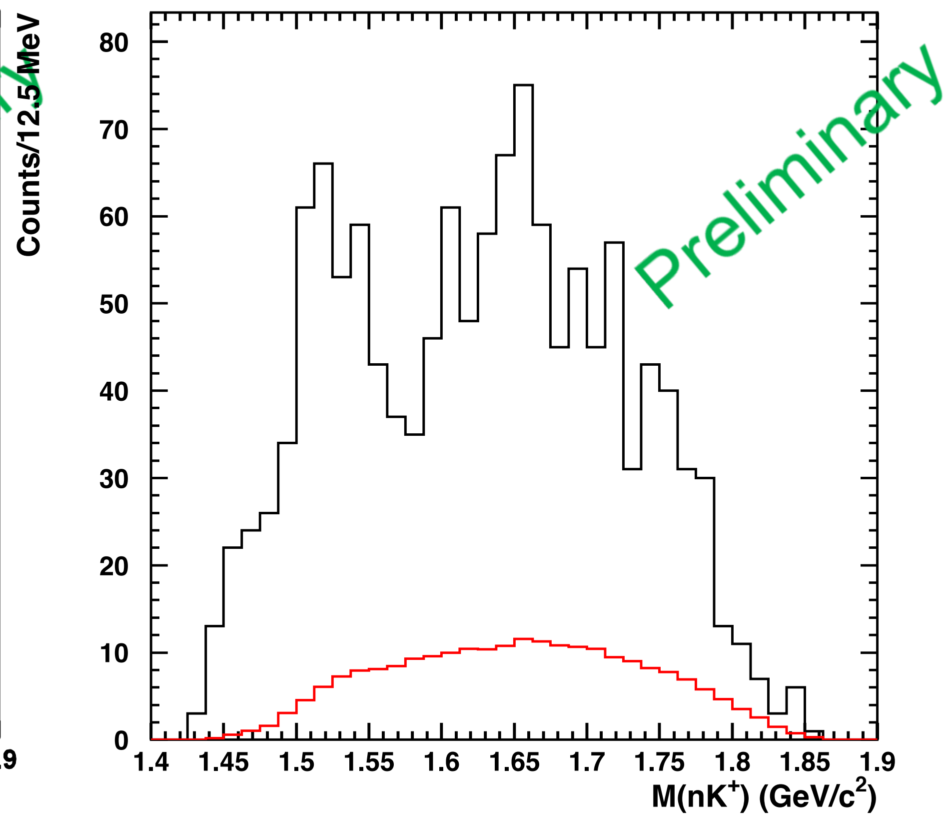


M(nK⁺) with two methods

MC-based exclusive events

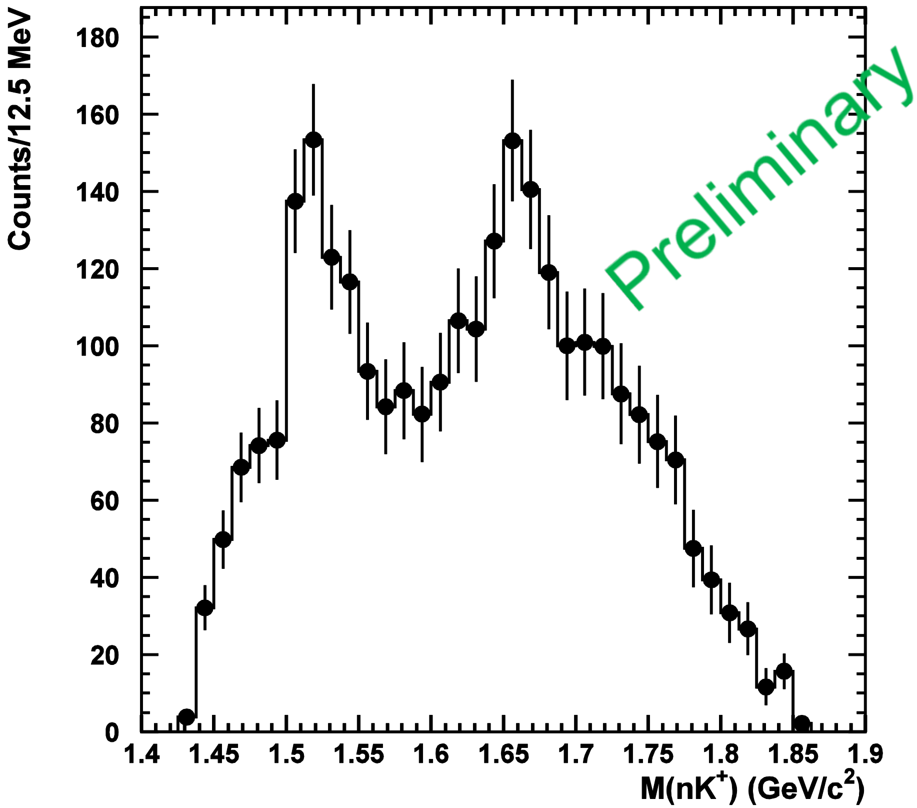


dE/dX-based exclusive events

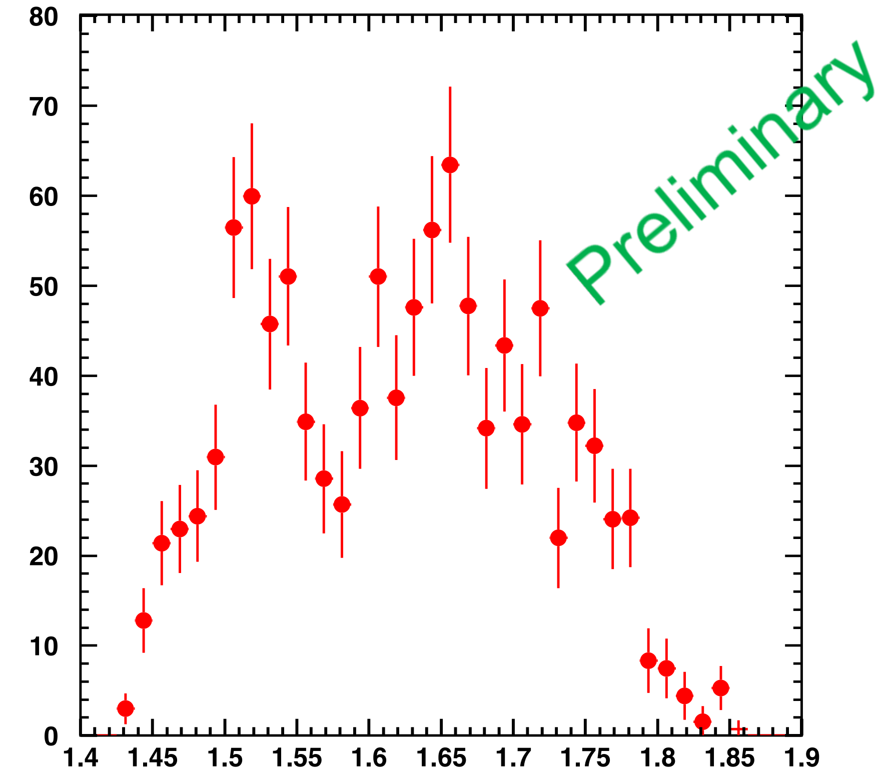


M(nK⁺) with two methods

MC-based exclusive events



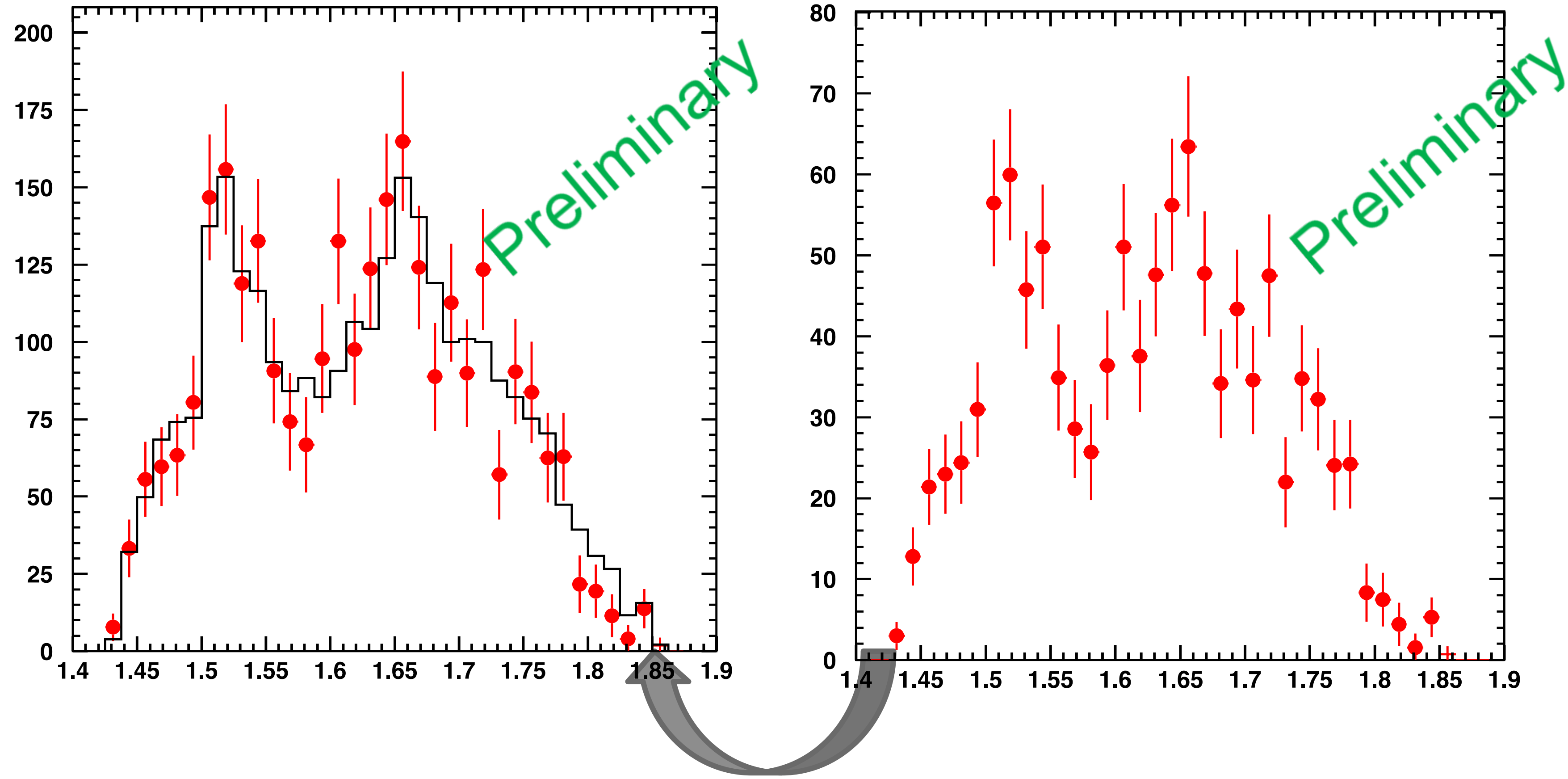
dE/dX-based exclusive events



Subtract proton contribution.

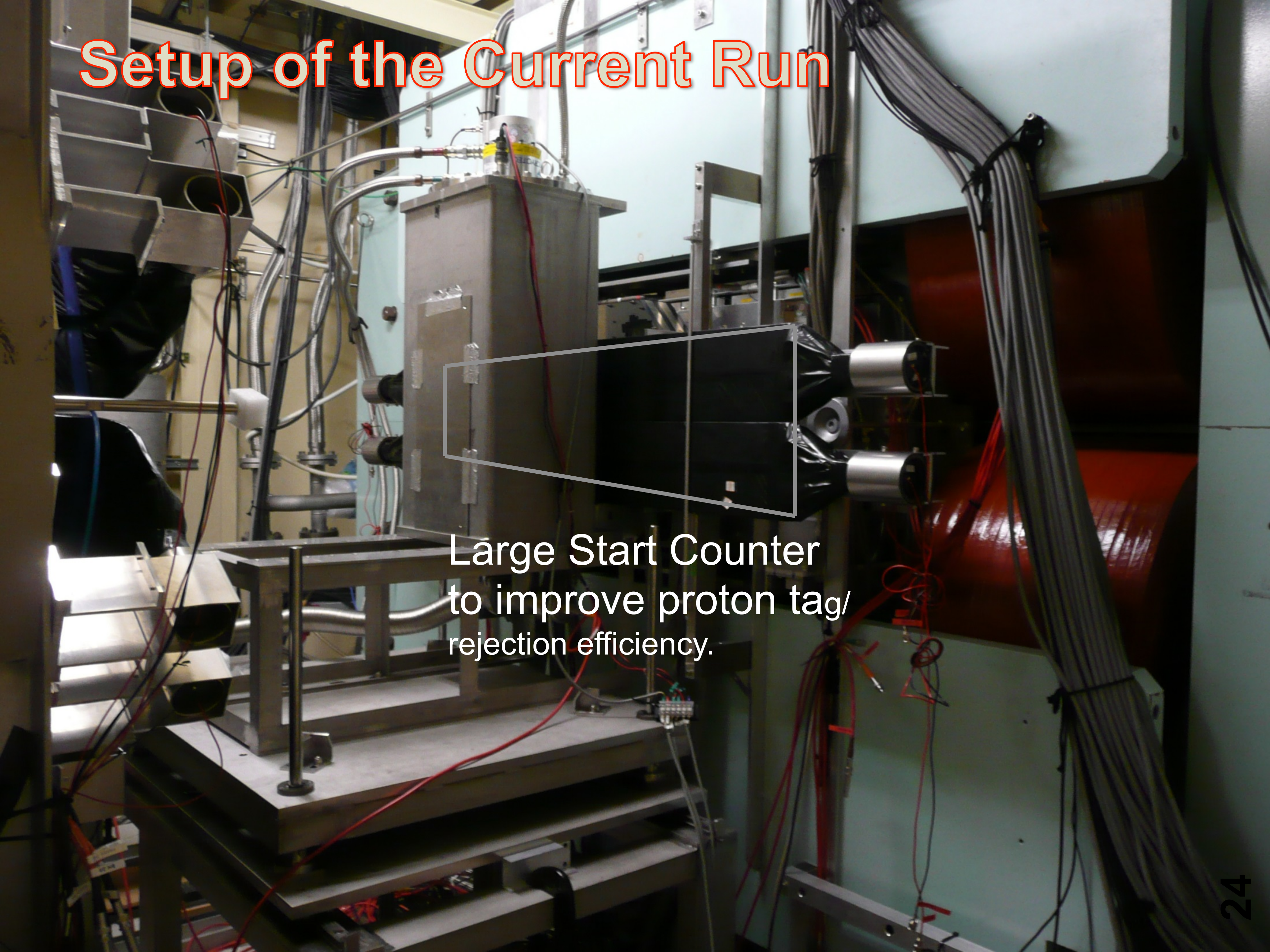
M(nK^+) with two methods

MC-based exclusive events **dE/dX-based exclusive events**

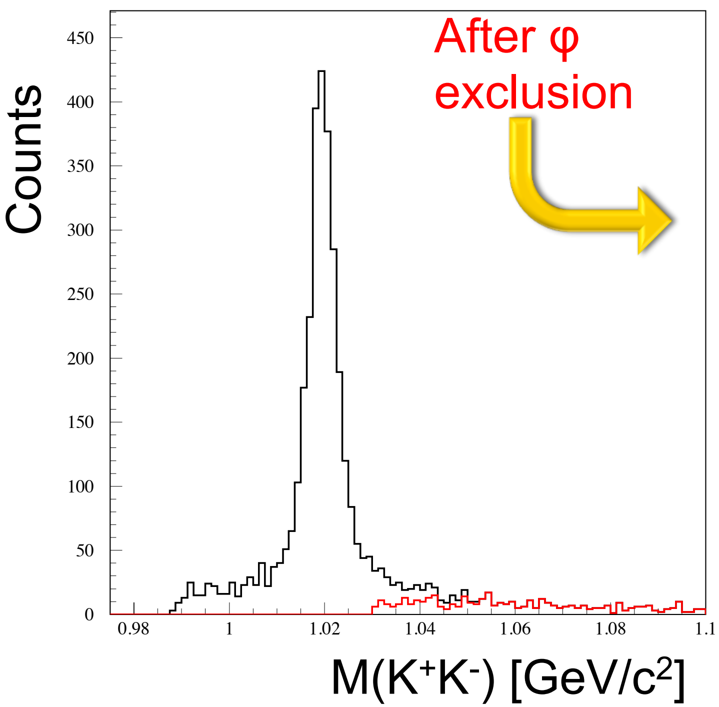


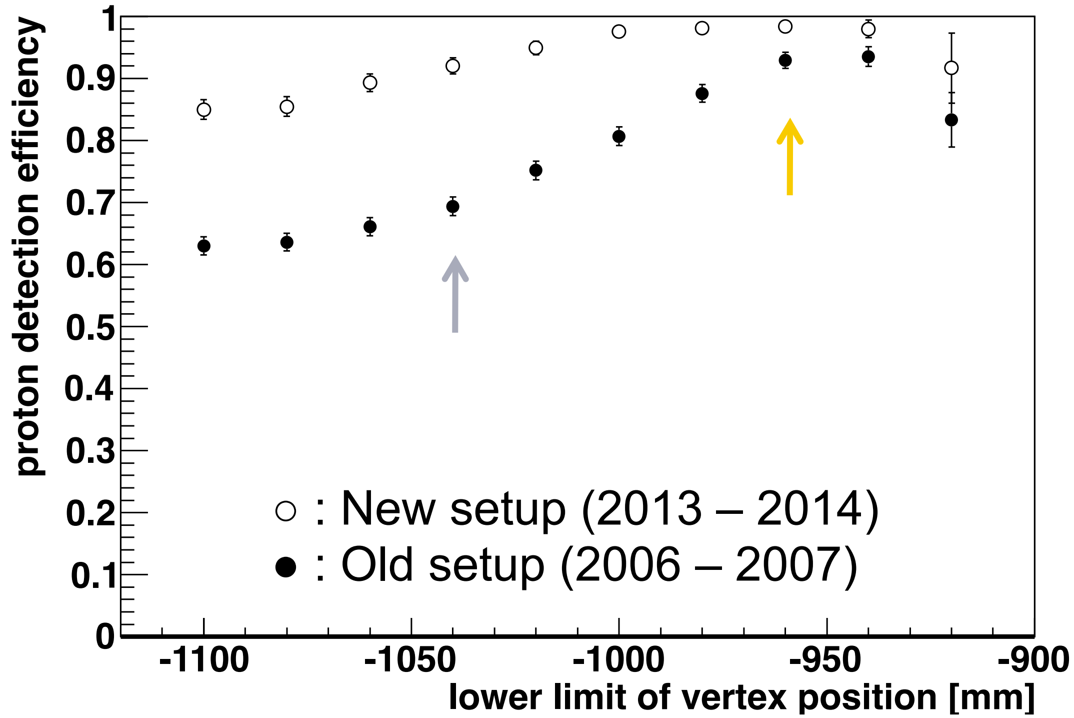
Overlay with normalization by entry

Setup of the Current Run



Proton detection efficiency

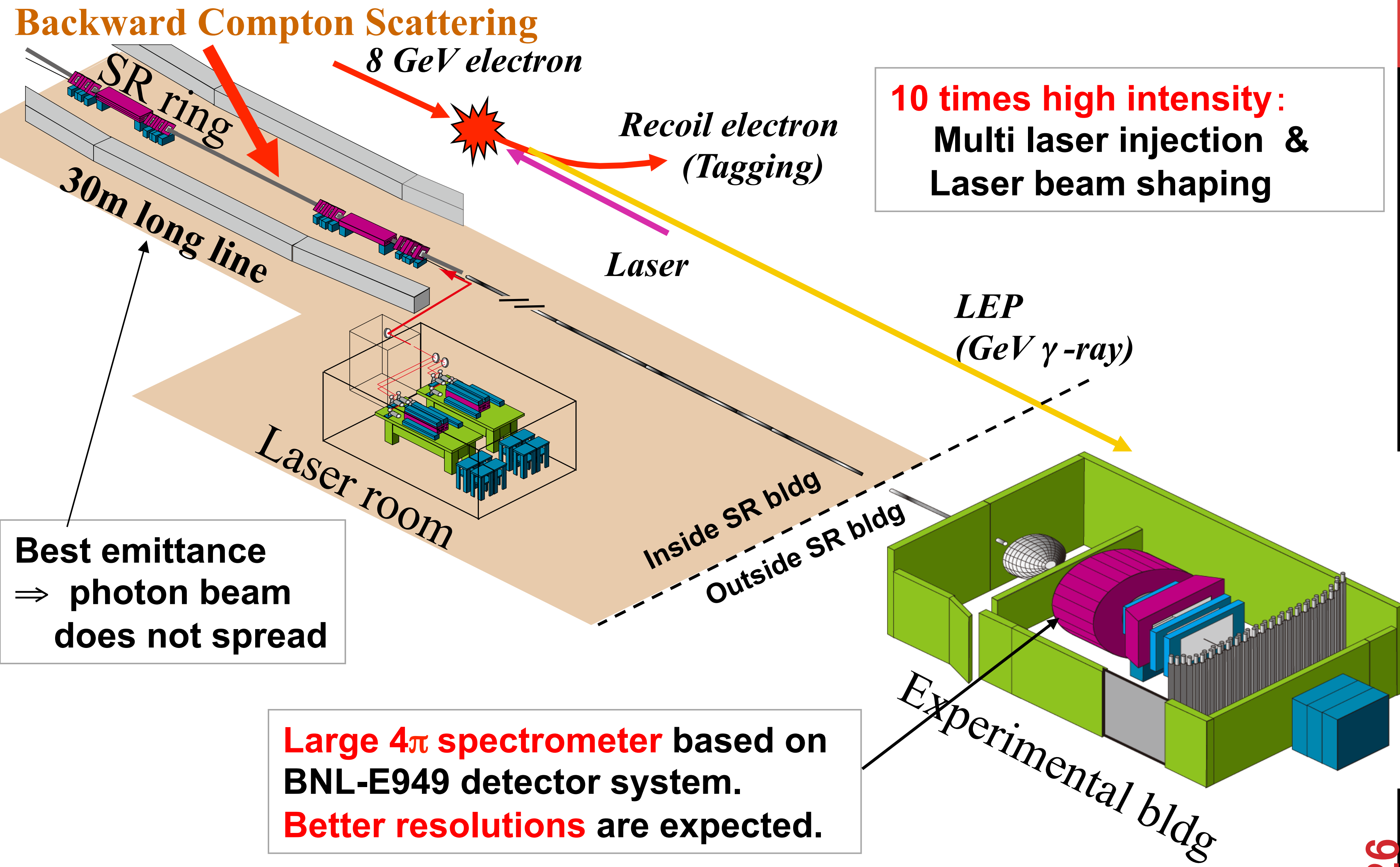




We have just finished data taking with the new setup.

Data with new setup $\simeq$ Data with old setup

LEPS2 Facility



10 times high intensity:
Multi laser injection & Laser beam shaping

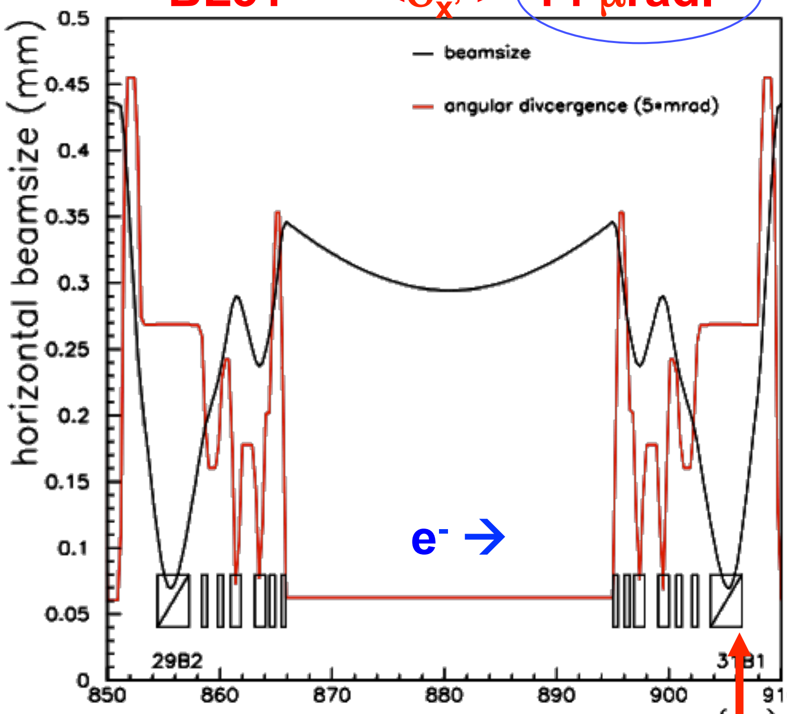
Best emittance
⇒ photon beam does not spread

Large 4π spectrometer based on BNL-E949 detector system.
Better resolutions are expected.

Divergence of LEP beam

LEPS2

BL31 **$<\sigma_{x'}>$=14 μrad.**

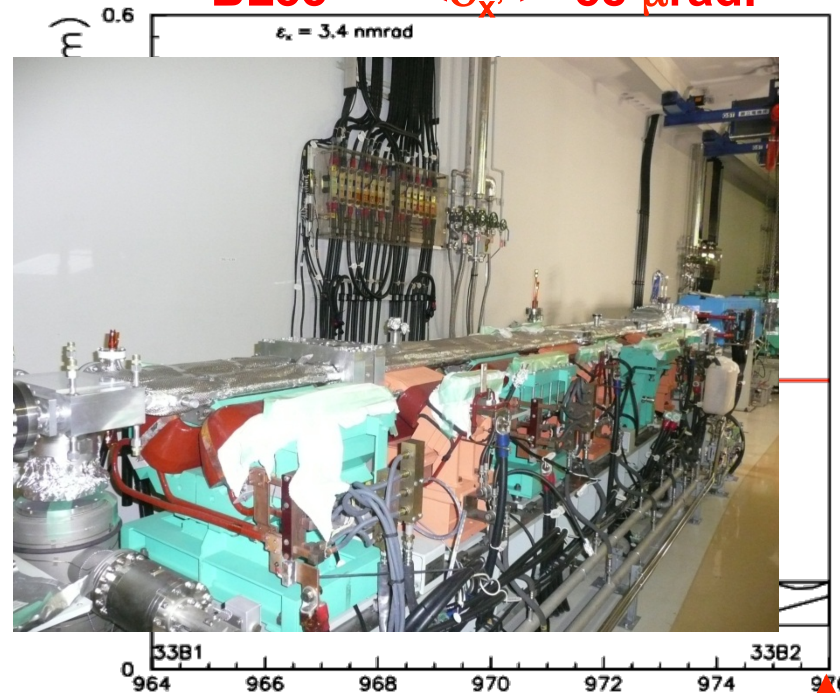


Reaction region (30m)

Tagging point

LEPS

BL33 **$<\sigma_{x'}>$=58 μrad.**



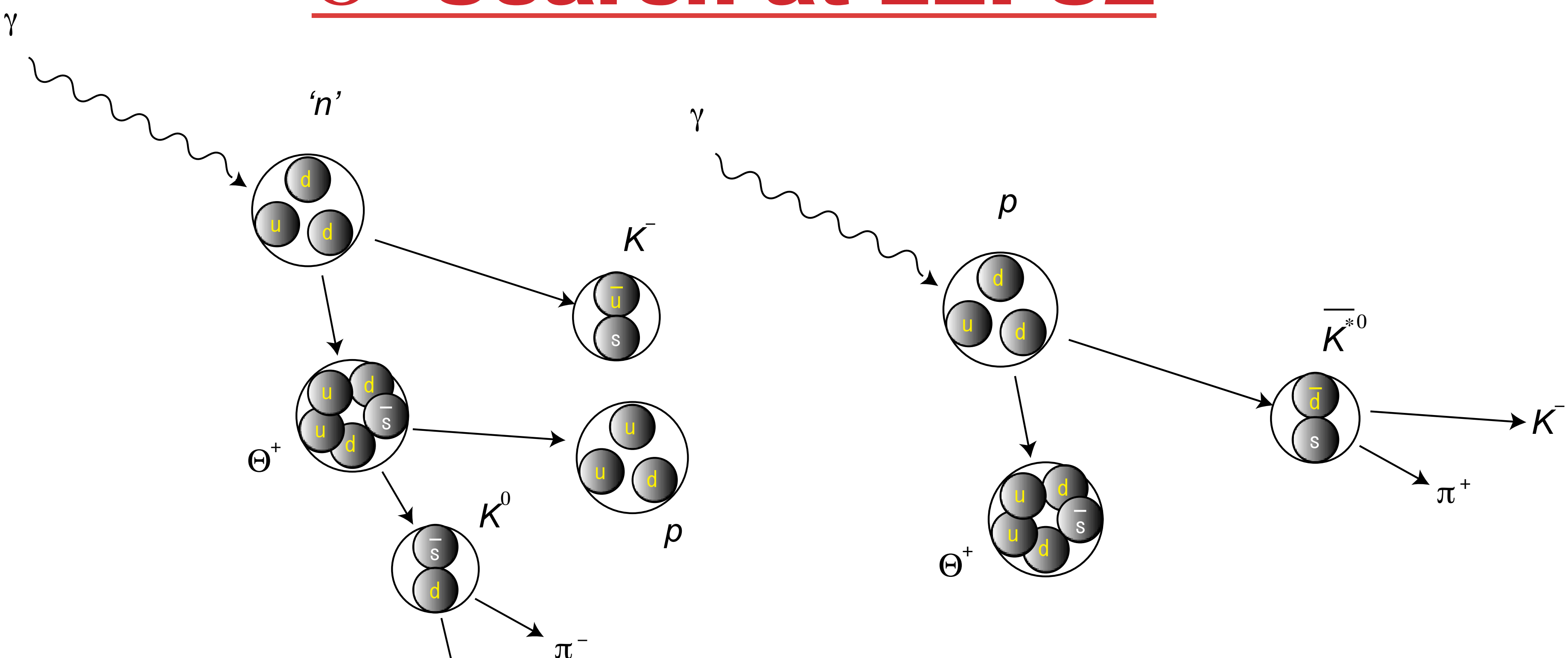
Reaction region (7.8m)

Tagging point

Better divergence → Better tagging resolution

Smaller beam size at long distance

Θ^+ Search at LEPS2



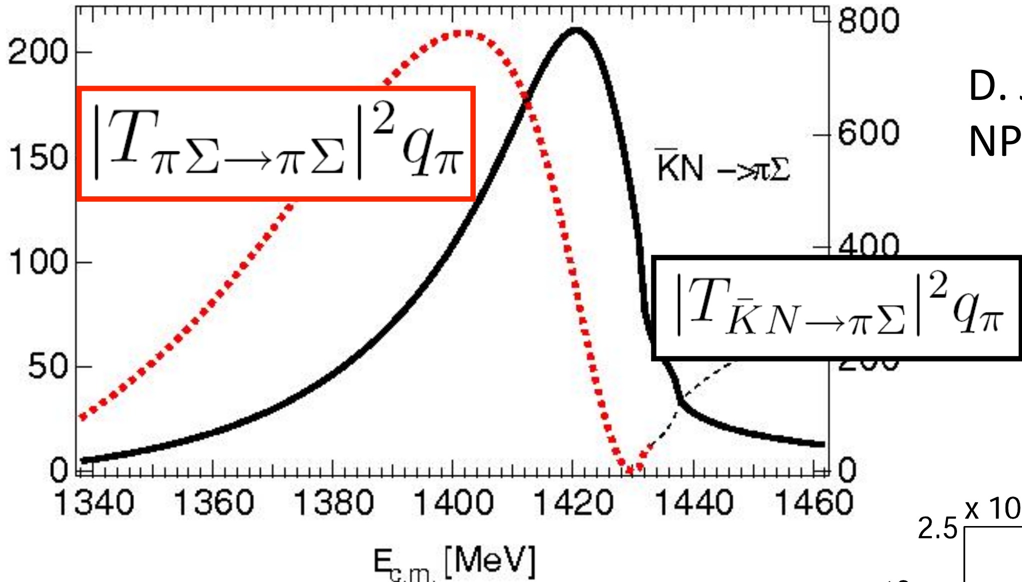
ble)

No Fermi motion correction.
No φ background.

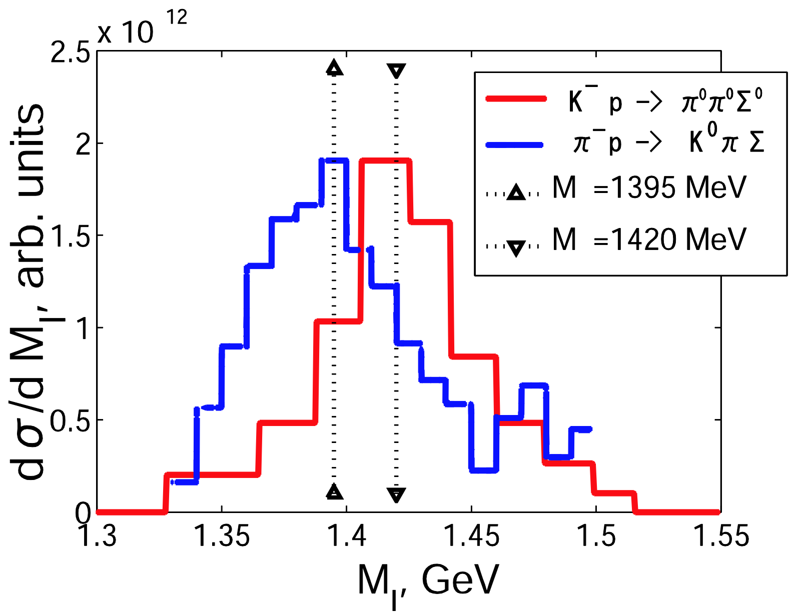
To measure angular dependence of production rate in
large angle region, up to CLAS acceptance.

A large acceptance and better resolution detector is necessary.

Two pole structure of Λ(1405)

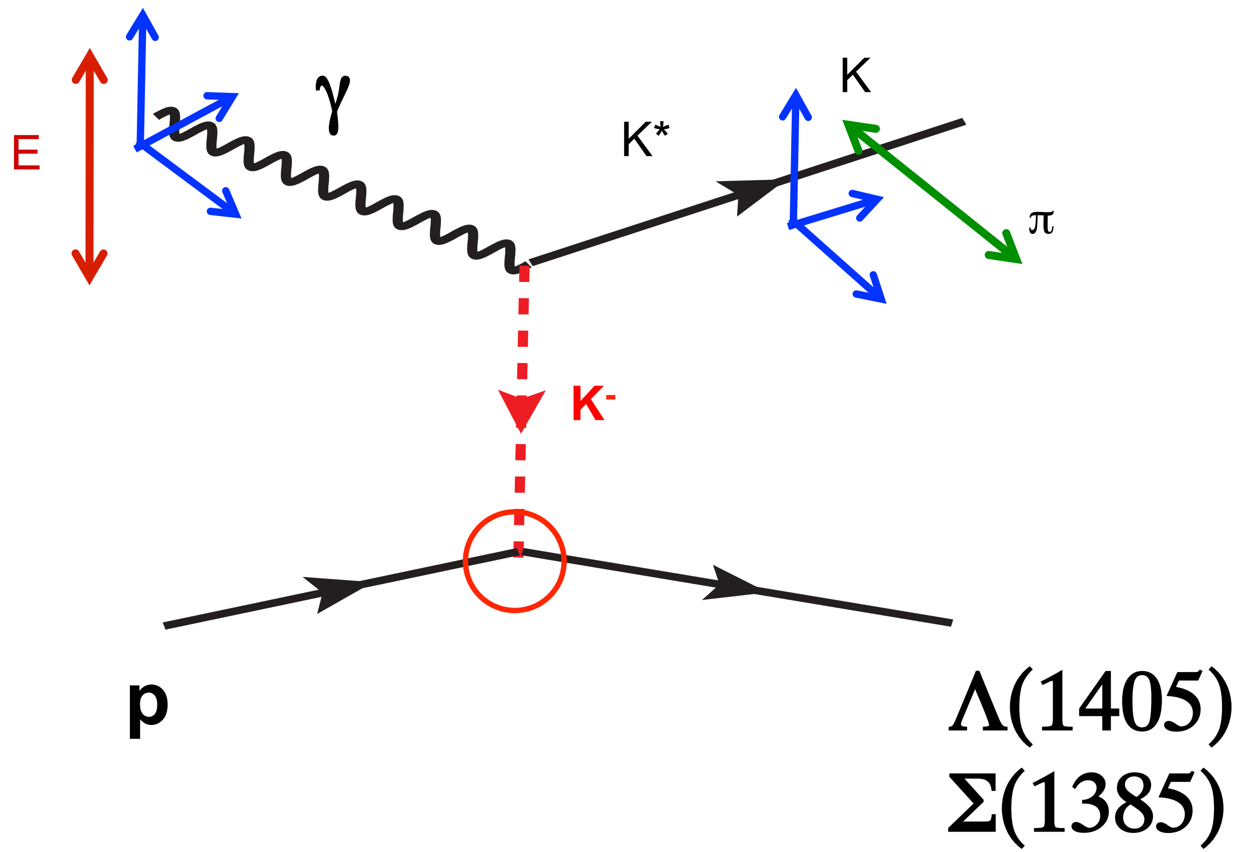


D. Jido, et al.
NPA725(2003)

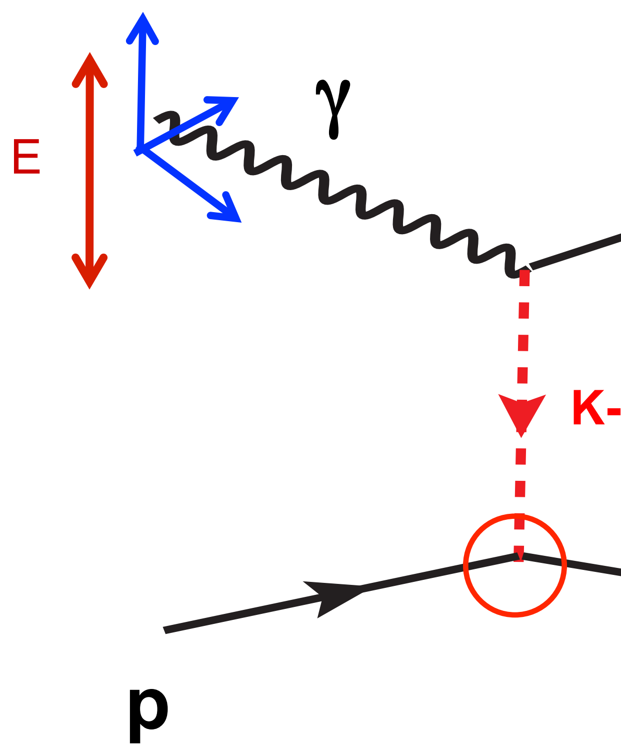


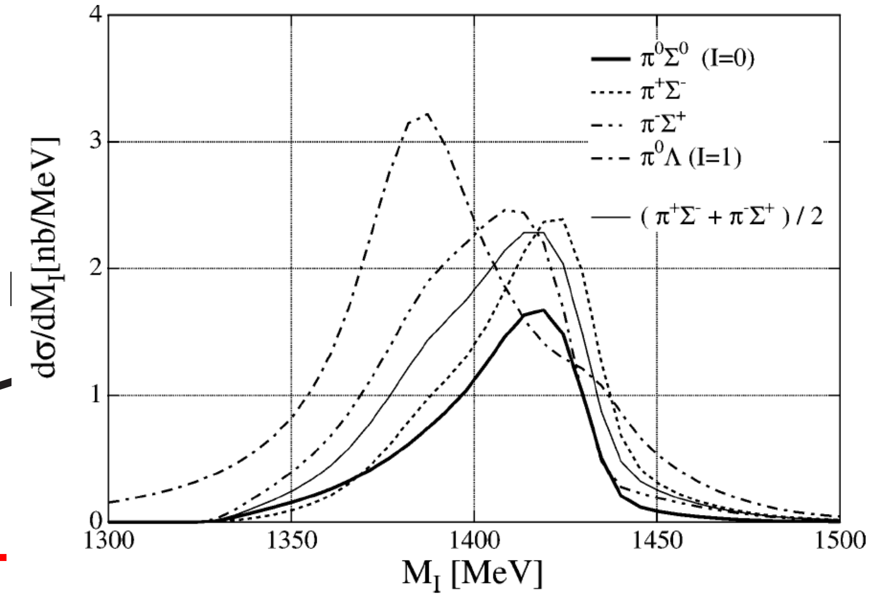
V.K. Magas, E. Oset and A. Ramos, PRL 95

K*(890) Λ(1405) photoproduction with linearly polarized photon



K*(890) Λ(1405) photoproduction with linearly polarized photon

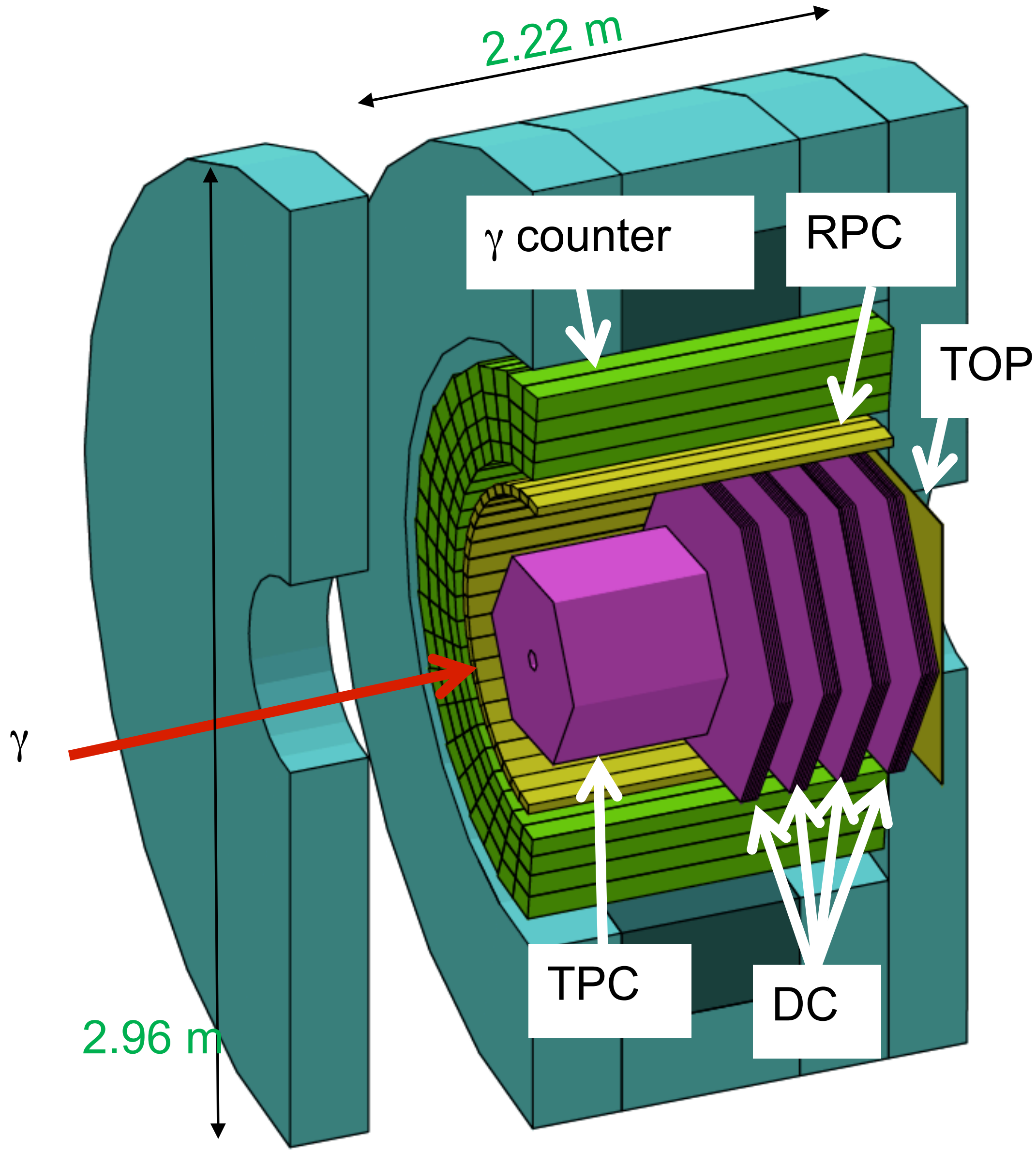


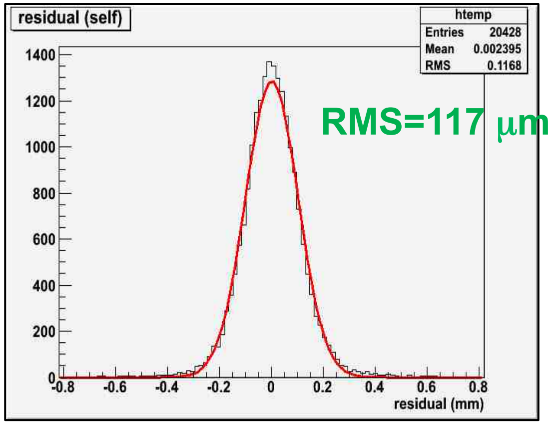


T.Hyodo et. al, PLB593

LEPS2 Detector

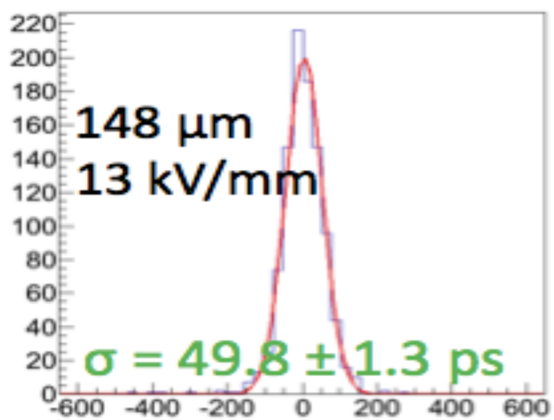
B=1 T : **$\Delta p/p \sim 1\%$** for $\theta > 7°$





TPC Prototype Residual

RPC ToF time distribution



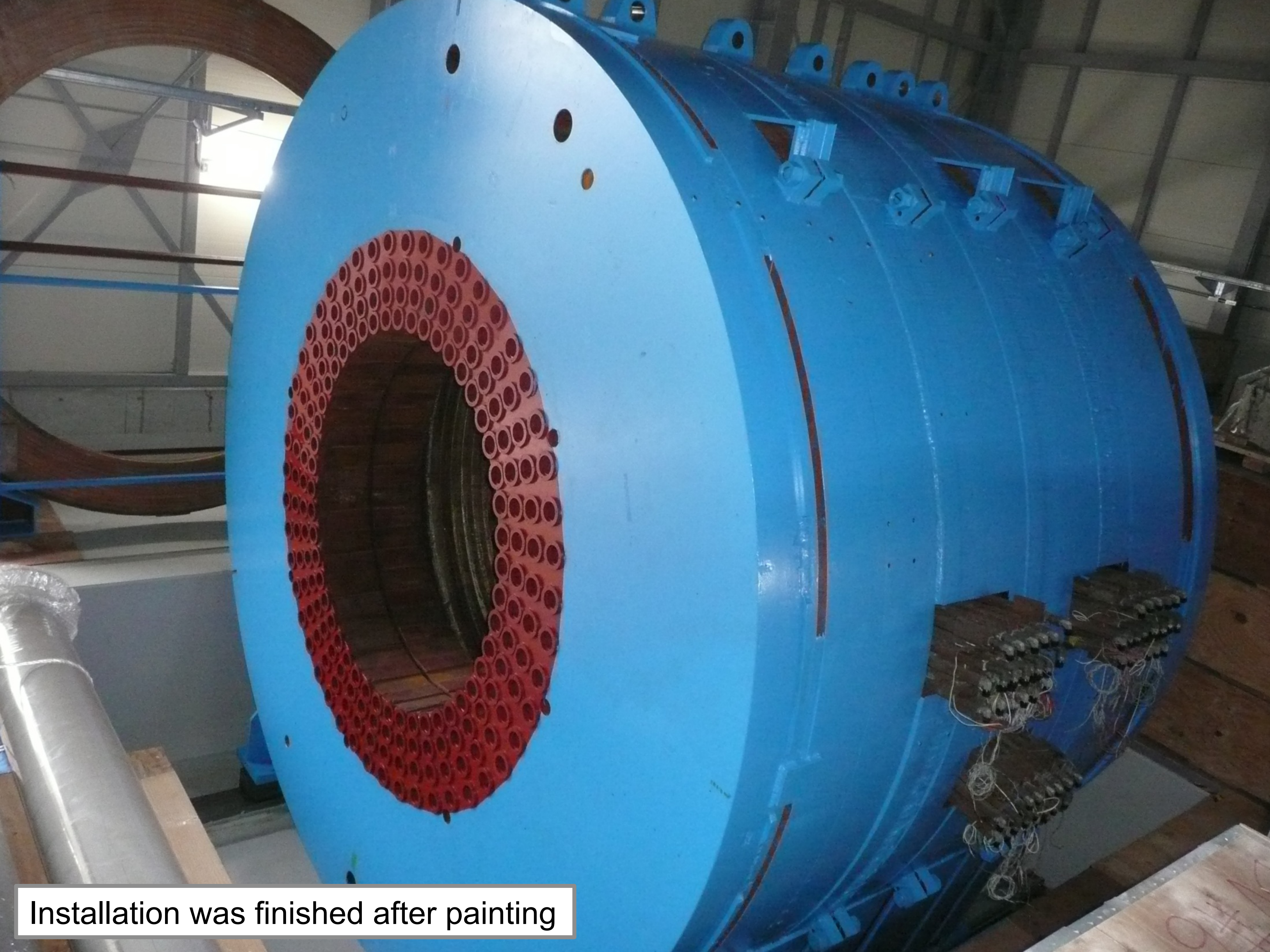
>3σ K/π separation @1.1 GeV/c^2

Transport each disk

Installation of the E949 magnet (2011.Nev-Dec)


Open the roof of LEPS2 building

Insert each disk using 360t crane



Installation was finished after painting


Exp. hall was constructed. (2010.Oct-2012Jan)


Installation of the E949 magnet (2011.Nev-Dec)

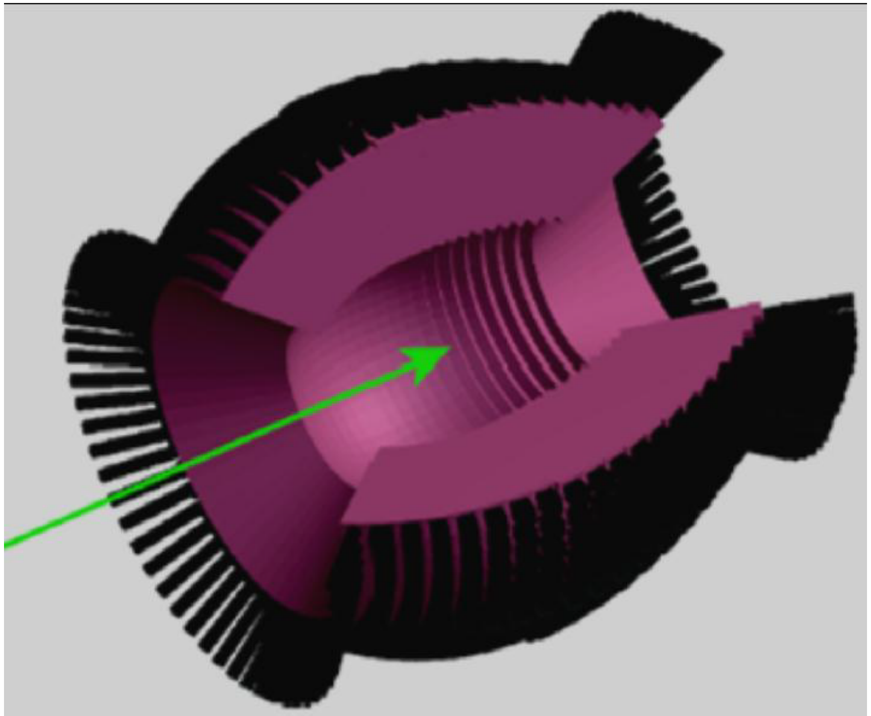

γ counters were installed. (2012.June)

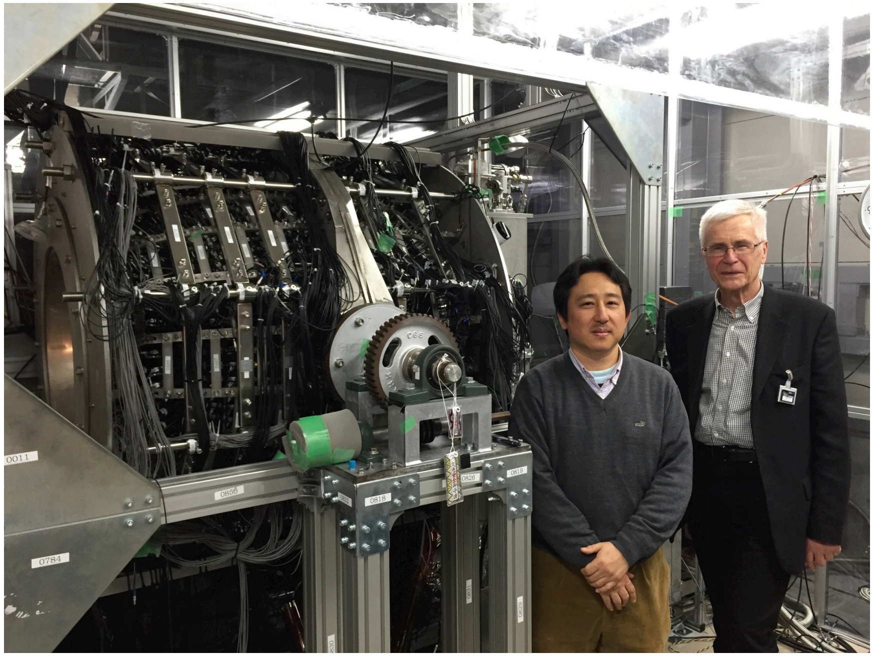

Beam pipe (2012.May)

Comparison of LEPS and LEPS2

	LEPS	LEPS2
Beam Intensity (~2.4 GeV)	$2\sim3 \times 10^6$ (2 lasers)	$<10^7$ (4 high-power lasers)
Beam Intensity (~2.9 GeV)	$2\sim3 \times 10^5$ (2 lasers)	$<10^6$ (4 high-power lasers)
Polarization	Linear/Circular	Linear/Circular
Detector Area	$42m^2$ x 3m(h)	$198m^2$ x 10m(h)
Charged Particle Acceptance	0~30 degrees	7~120 degrees
Momentum Resolution	0.5% (for 1-GeV kaon)	1~1.5% (for 1-GeV kaon)
Photon Coverage	none	30~110 degrees

BGO-Egg : constructed @ ELPH, Tohoku U.

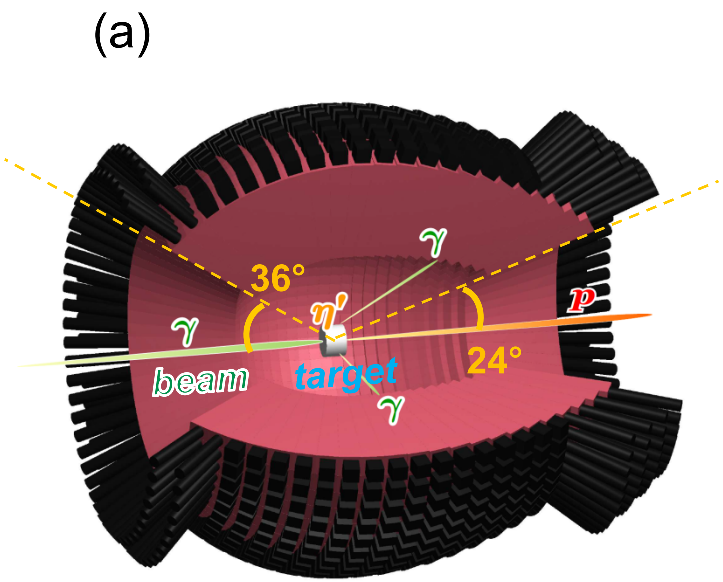


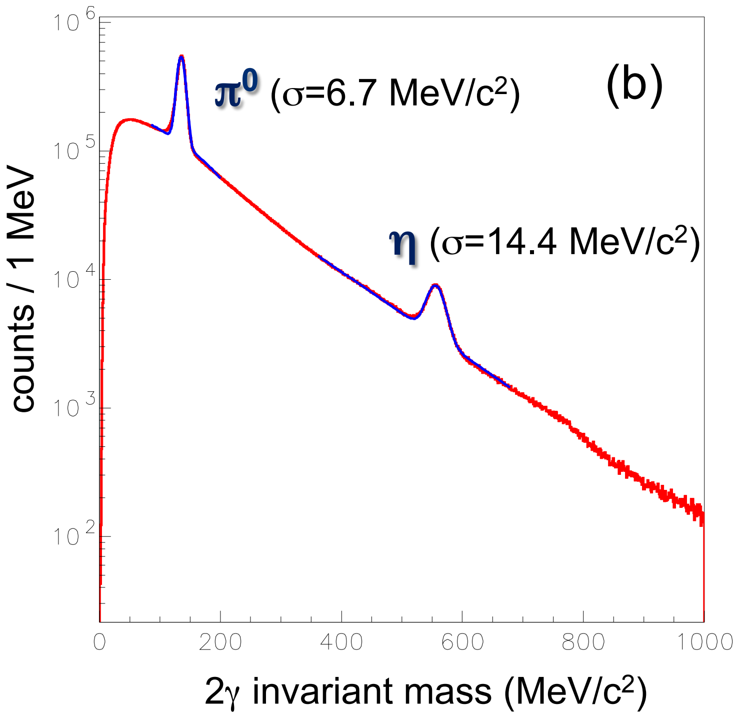


Large acceptance photon detector (BGO-Egg)

- 1320 BGO crystals
- Covering $24^{o}\sim144^{o}$ polar angle
- 1.3% energy resolution for 1 GeV

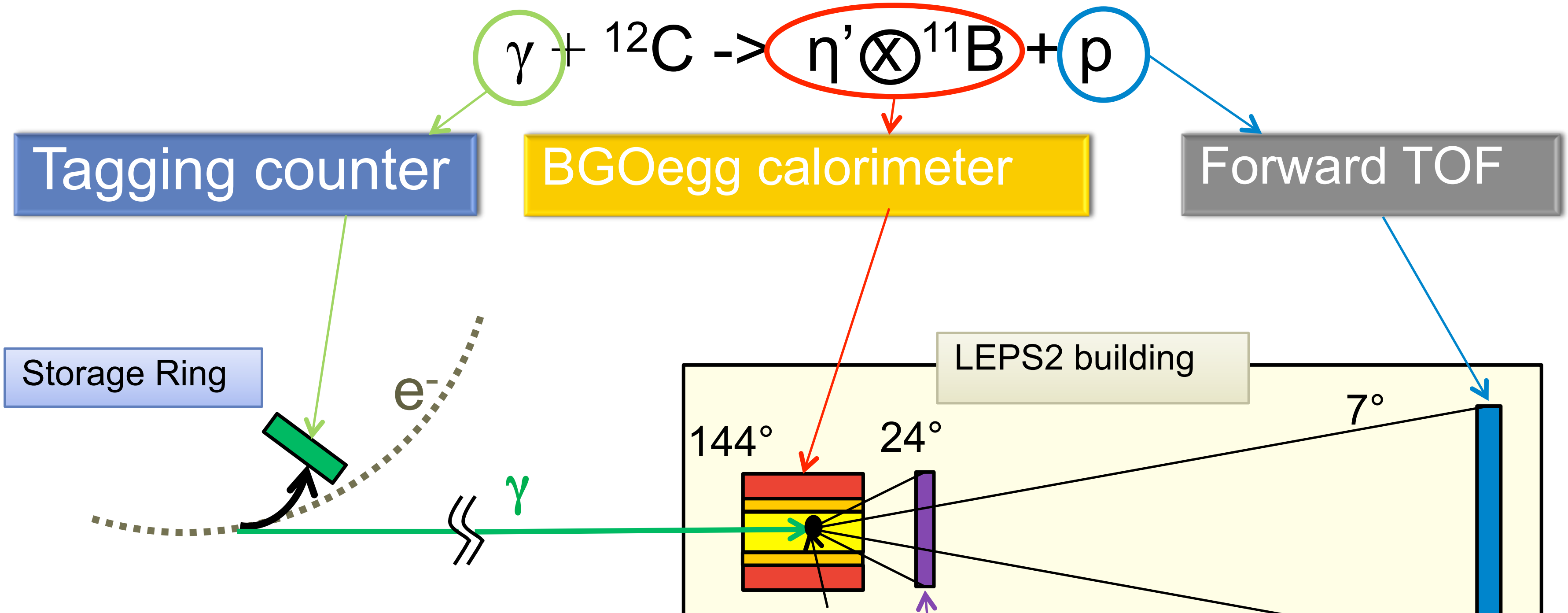
BGOegg calibration

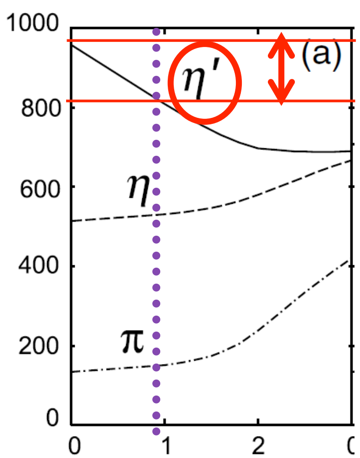




- Obtained mass resolutions are consistent with MC simulation results.
- Timing resolution was measured to be 340 ps by checking $\pi^0 \to 2\gamma$.

Experimental setup





150 MeV

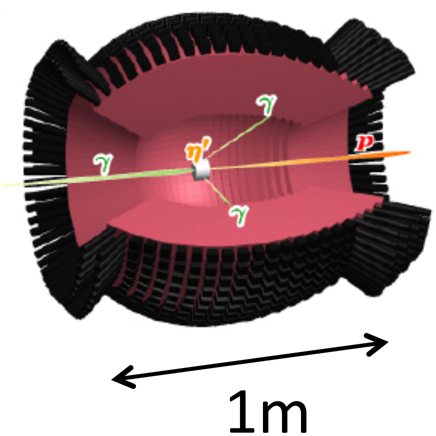
H.Nagahiro et al.
PRC74(2006)45203

Experimental method

$\gamma + {}^{12}C \rightarrow \eta' \otimes {}^{11}B + p$

Identify η' production by η tag

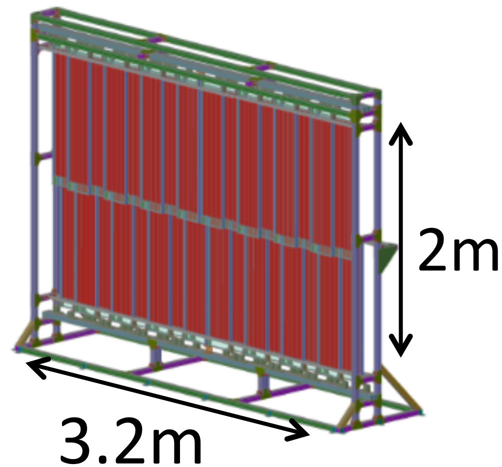
Search for a bound state



$\eta \rightarrow 2\gamma$ (39%)

$\eta \rightarrow 3\pi^0 \rightarrow 6\gamma$ (33%)

BGOegg calorimeter



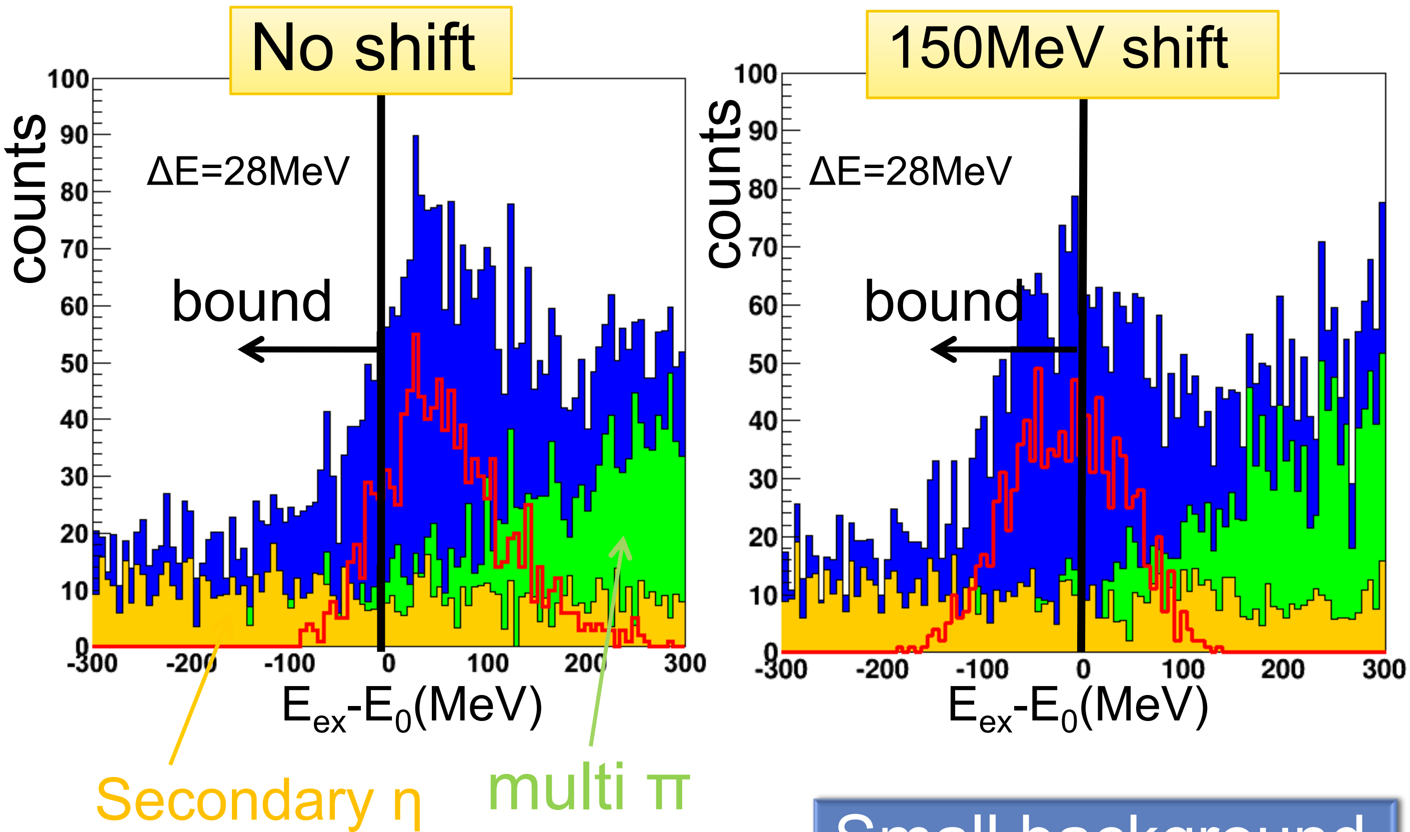
12.5m from the target

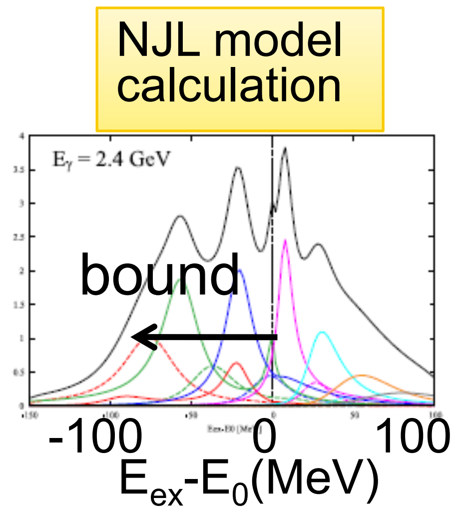
Vert : ±7°
Hori: ±4°

Forward TOF

Expected energy spectrum

2.4 GeV γ | 0° | η tag (6γ)





H. Nagahiro

Small background

See signals in bound region

Summary

- LEPS
  - Kaonic nuclei search, updates on Θ^+.
- LEPS2
  - **x10 luminosity.** ~10Mcps.
  - Two different experimental setups.
    - **Solenoid spectrometer**
    - Θ^+, $\Lambda(1405)$
    - **BGO EGG + TOF**
    - Backward meson production from proton and nuclei
- BGO EGG experiment was started last year!