Hadron physics experiments at LEPS and LEPS2

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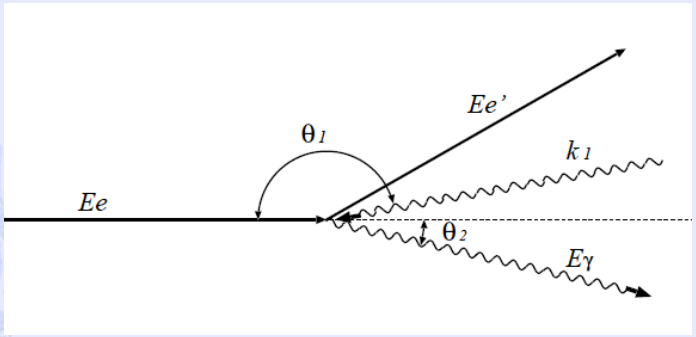
This meeting is a 'Nuclear Structure' symposium but may talk is on 'Hadron Structure', moreover I will mainly present about a new facility at SPring-8.

- From LEPS to LEPS2

  recent result on Θ^+
- Overview of the LEPS2 facility
- First beam observation at LEPS2
- Present status and prospect

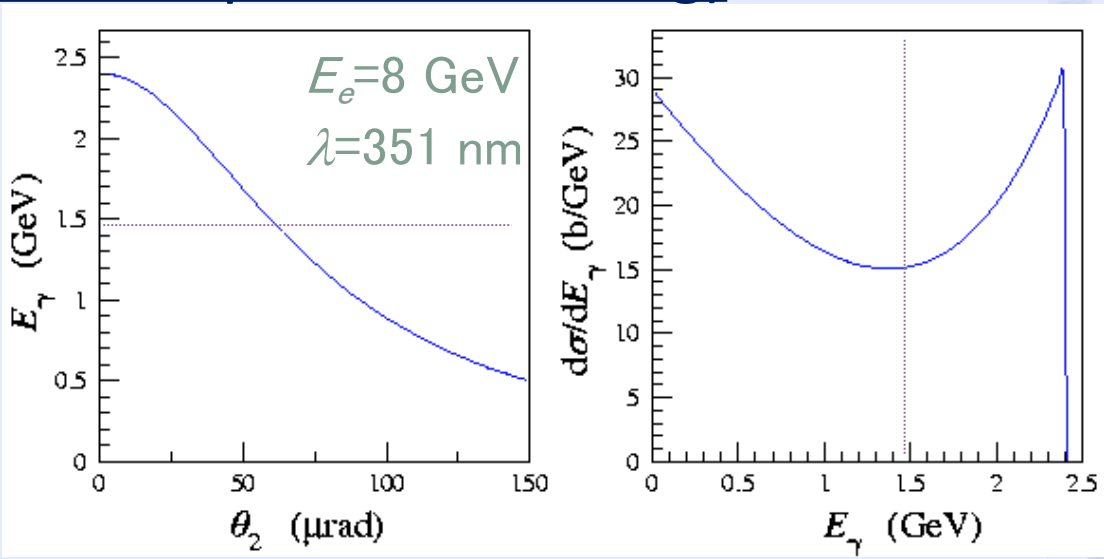
Characteristics of Laser-Electron Photon

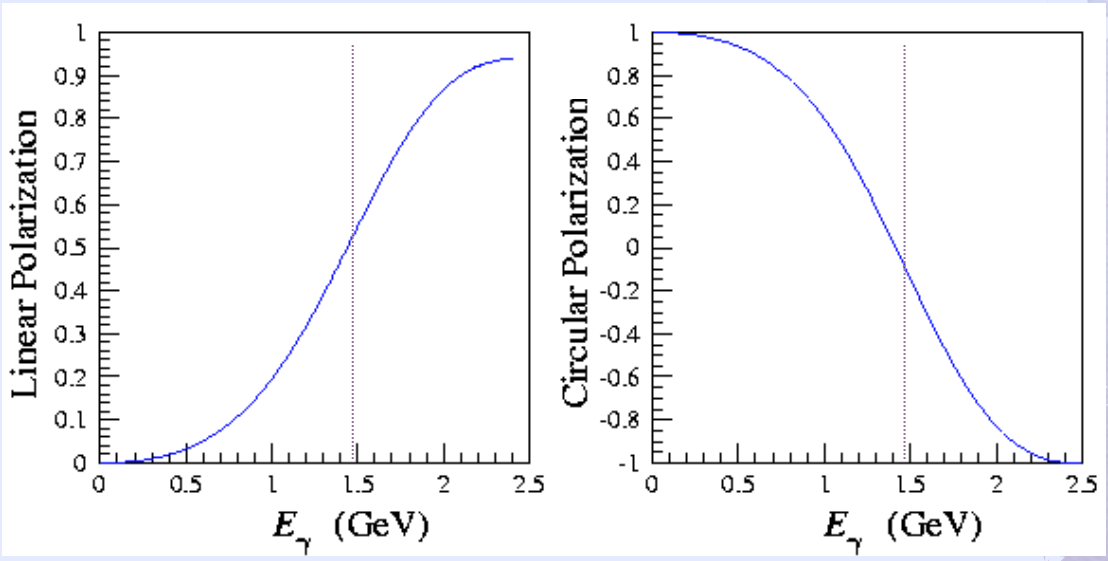
(laser Backward-Compton Scattering)



- rather flat energy distribution with small spreading

  (Unlike the Bremsstrahlung, where low energy photons are dominated, ~1/E_γ)
- high linear- or circular-polarization
- photon energy can be tagged by recoil electron





Electron Storage Ring with GeV laser-Compton γ-ray facility

LEGS@NSLS/BNL

1987 – 2006

E_e =2.8 GeV
→ E_γ< 0.5 GeV

GRAAL@ESRF 1996 – 2008

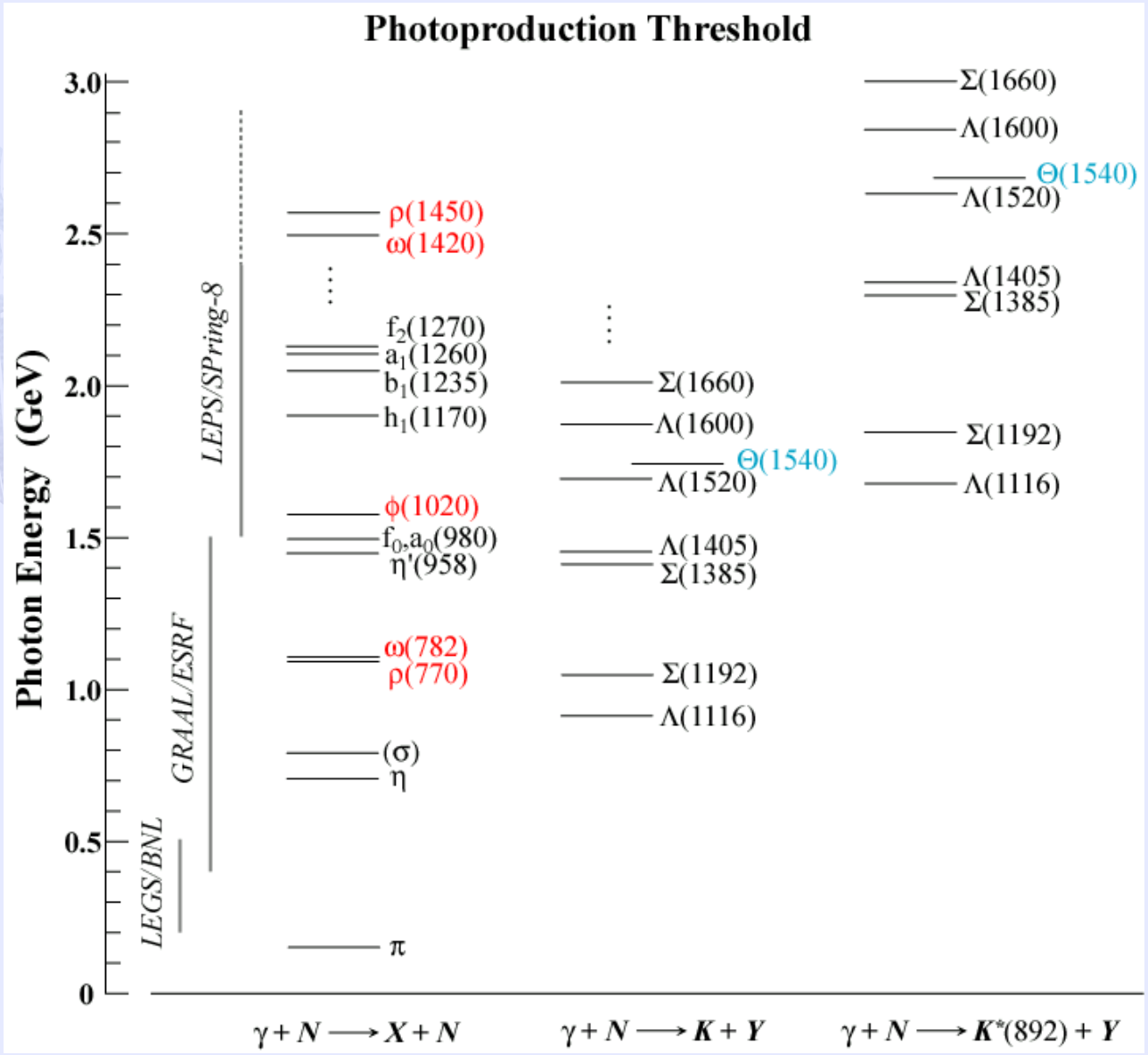
E_e = 6 GeV → E_γ < 1.5 GeV

LEPS@SPring–8 1999 –

E_e = 8 GeV → E_γ < 2.4 GeV

Polarized HD target developed at ORSAY → RCNP

What can be produced ?

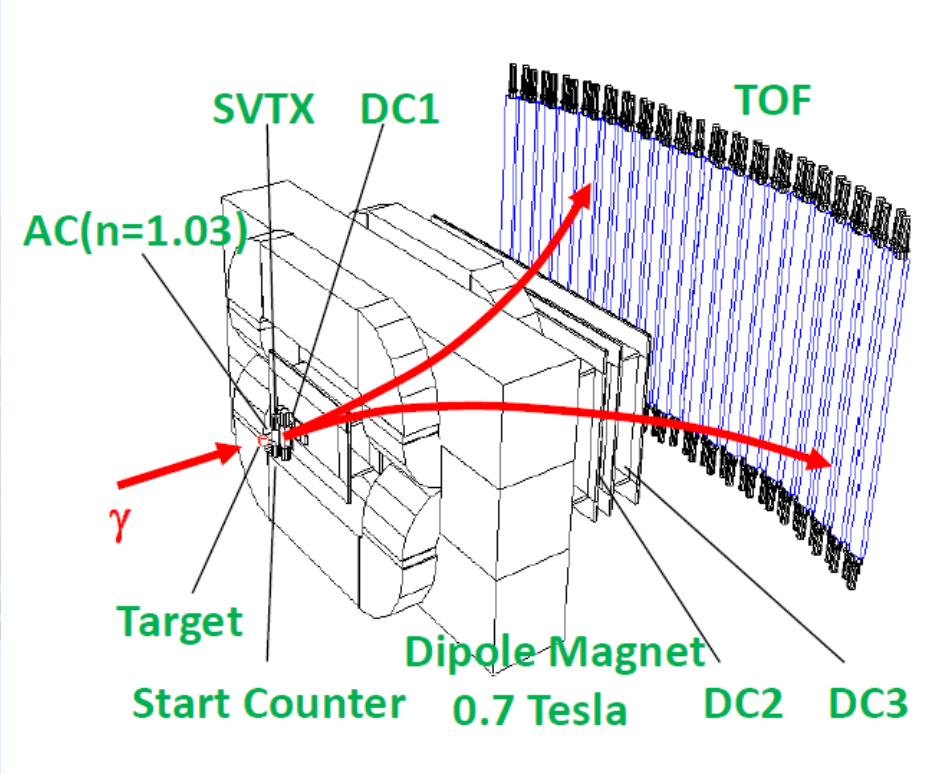


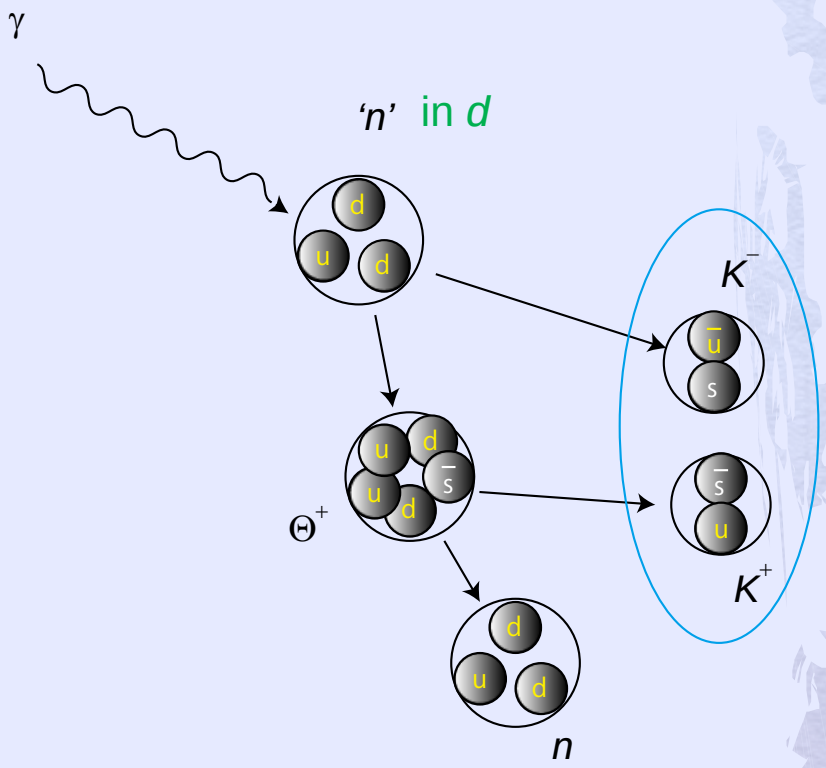
Above the threshold of $\phi(ss^{bar})$ meson and hyperon resonances

Key words :

1. **Forward angle measurement including 0 deg**
2. **Polarization observables**
3. **Strange quark**

LEPS Experiment (e.g., Θ^+)





Forward Spectrometer

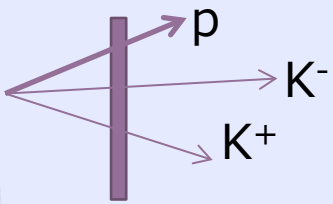
- TOF : RF signal – TOF wall, Δt = ~150 ps
- Momentum : Δp ~ 6 MeV/c for 1 GeV/c K
- Acceptance : Hori ±20° × Vert ±10°

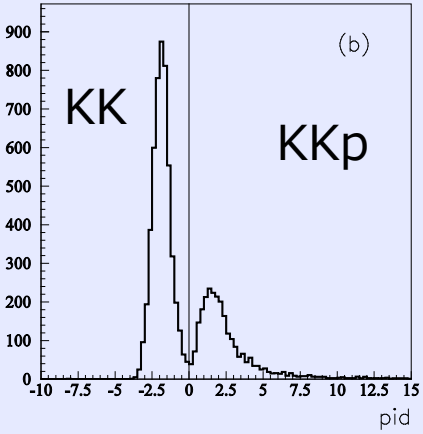
Key points in analysis

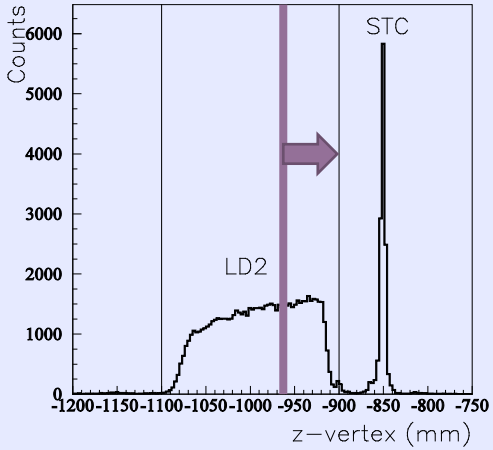
- ϕ rejection
- Fermi motion correction
  → MMSA (Minimum Momentum Spectator Approximation)
  PRC79(2009)025210
- Subtraction of events from 'proton' target

Θ^+ Analysis : two methods to reduce proton BG

1. dE/dx-based exclusive analysis





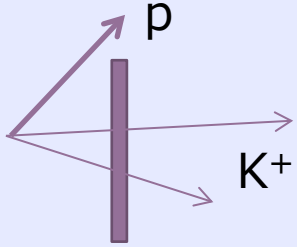


Proton detection by using dE/dx in the start counter

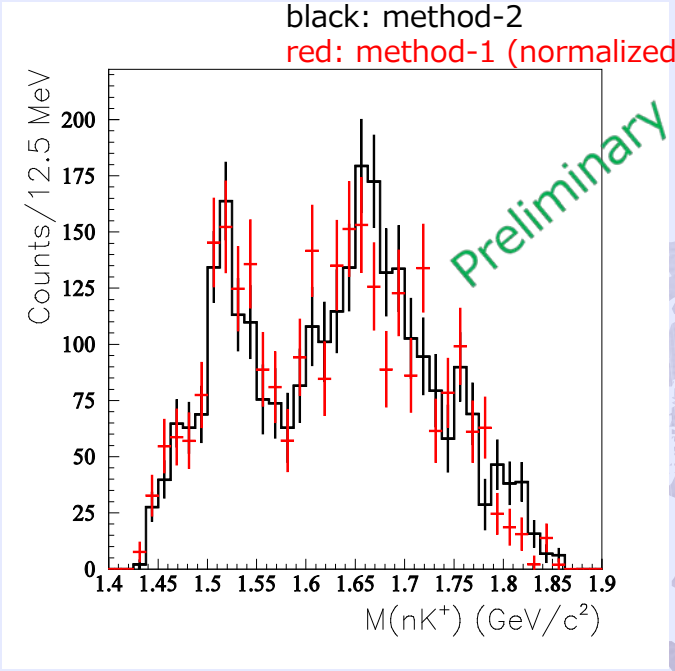
Proton rejection efficiency becomes 60%→90% by selecting downstream of target

2. MC-based exclusive analysis

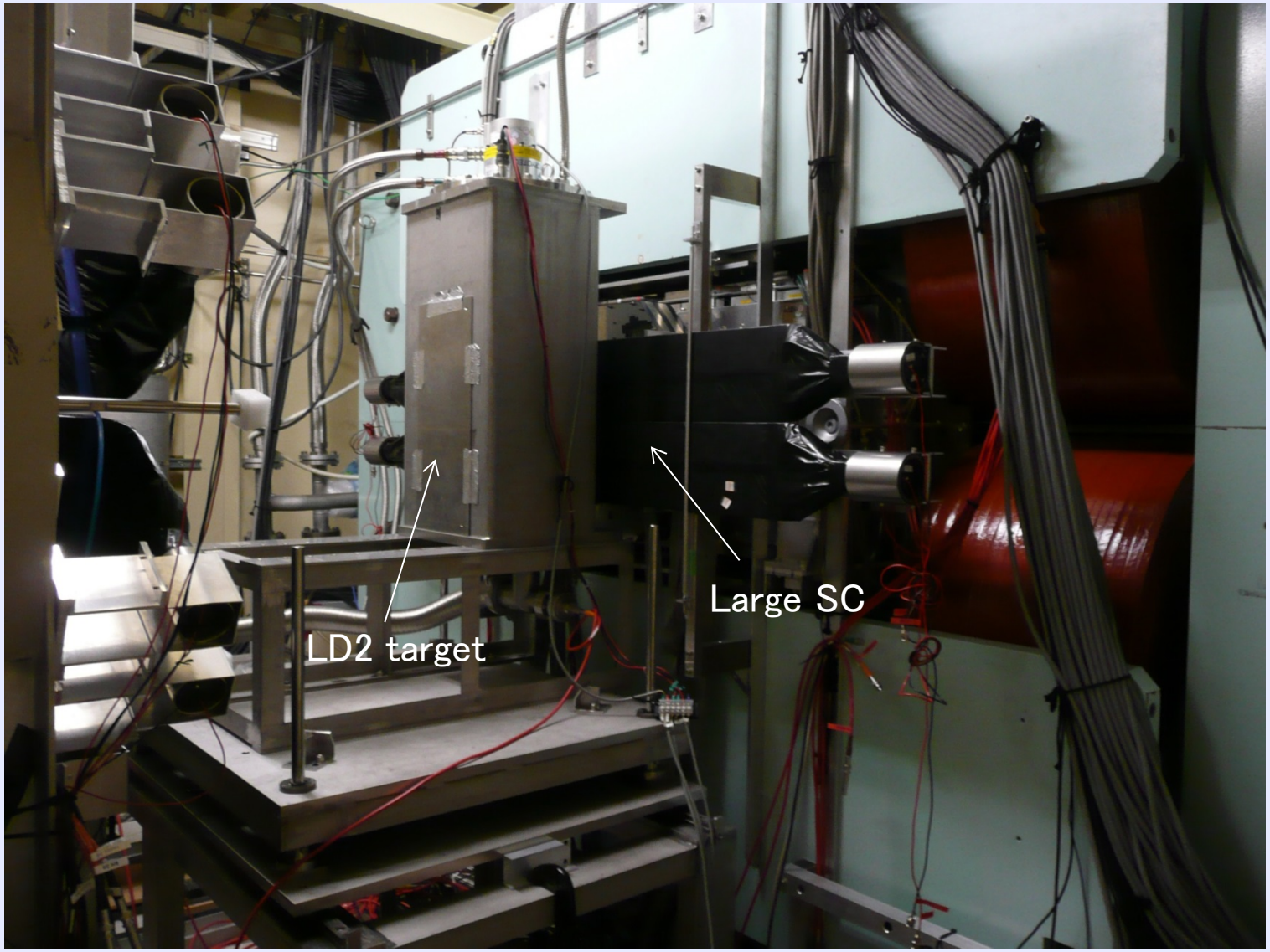
- **Proton contribution is estimated by fitting realistic MC distributions to proton-tagged spectra.**
- **The estimated proton contributions are subtracted from full data sample (without z-vertex and proton tagging cut).**



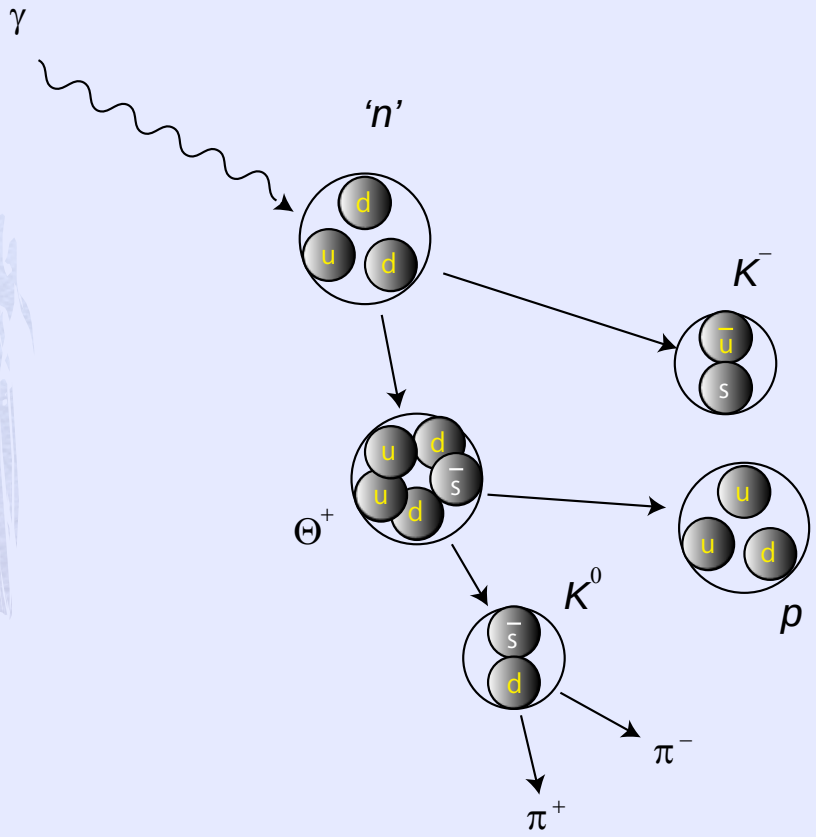
"leaked" proton BG



Now performing a new experiment with large SC

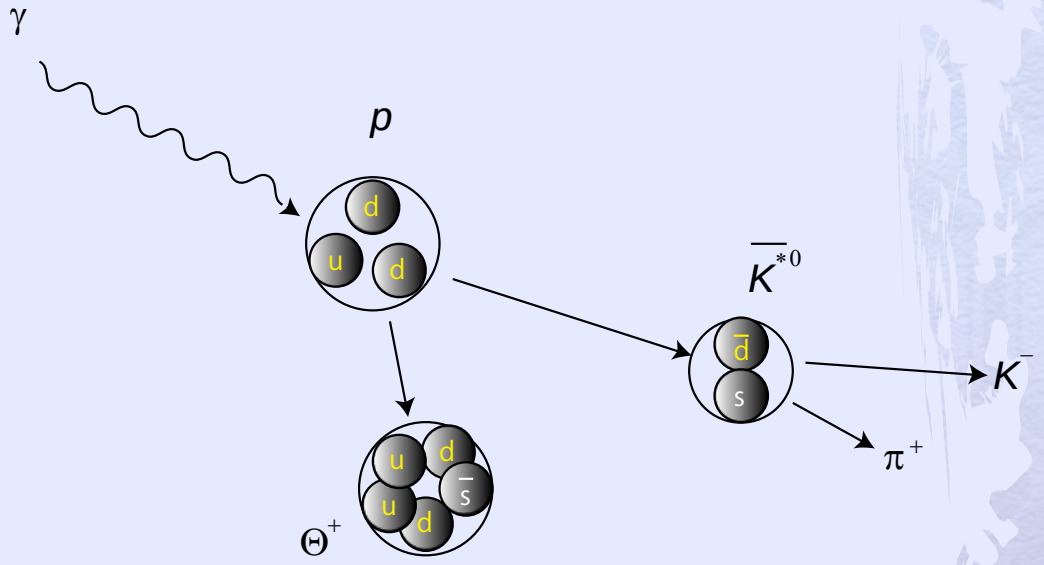


Other modes (no Fermi motion corr.)



$$\gamma +' n' \rightarrow K^- + \Theta^+$$
$$\rightarrow p + K^0$$
$$\rightarrow \pi^+ + \pi^-$$

pK_s invariant mass



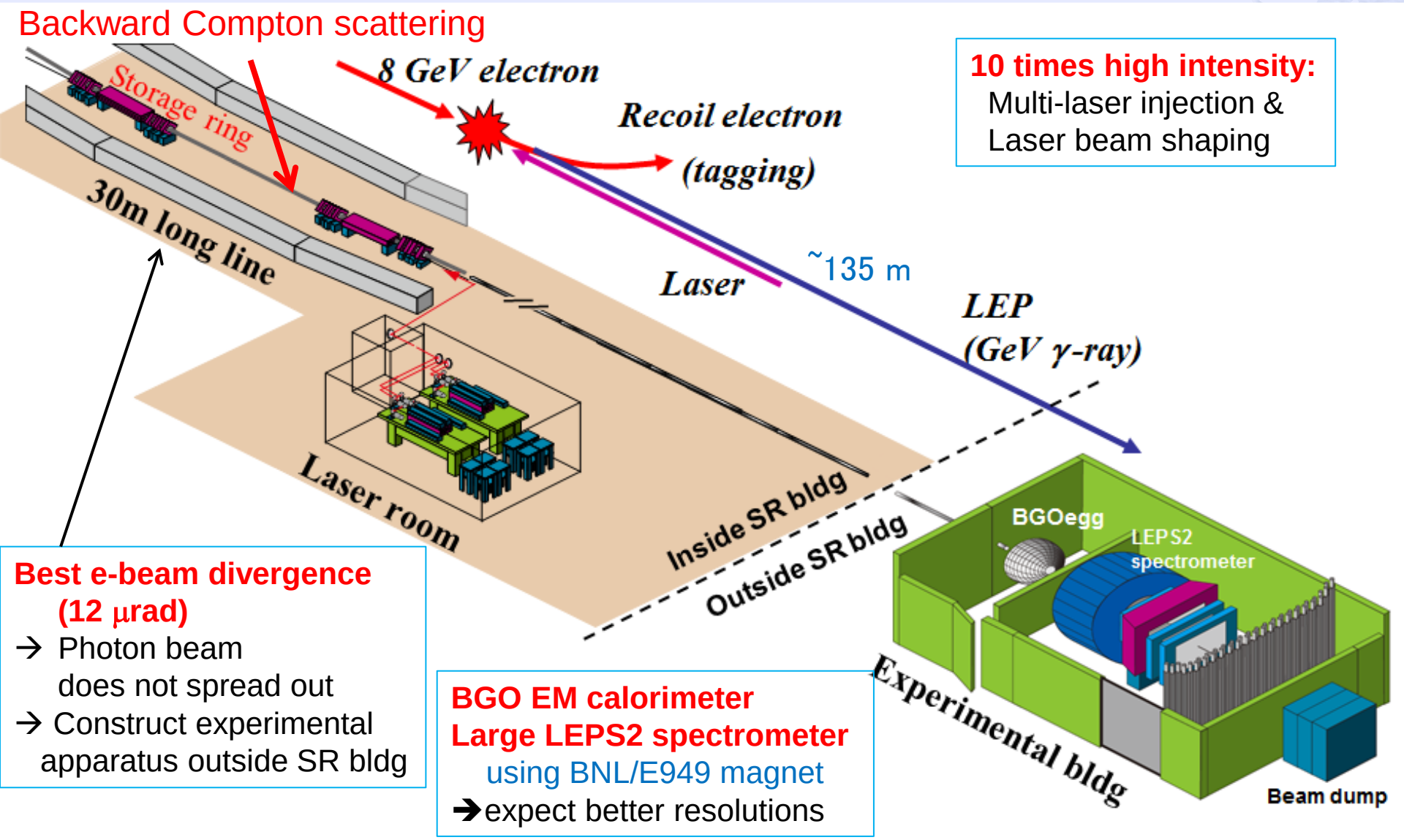
$$\gamma + p \rightarrow \overline{K^{*0}} + \Theta^+$$
$$\rightarrow \pi^+ + K^-$$

(t-channel K-exchange is possible)

$\overline{K^*}$ missing mass

Both modes need a large acceptance and better resolution detector

Outline of the LEPS2 facility



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

Best e-beam divergence
(12 μrad)
→ Photon beam
does not spread out
→ Construct experimental
apparatus outside SR bldg

BGO EM calorimeter
Large LEPS2 spectrometer
using BNL/E949 magnet
➔expect better resolutions

How to get the high Intensity Photon Beam

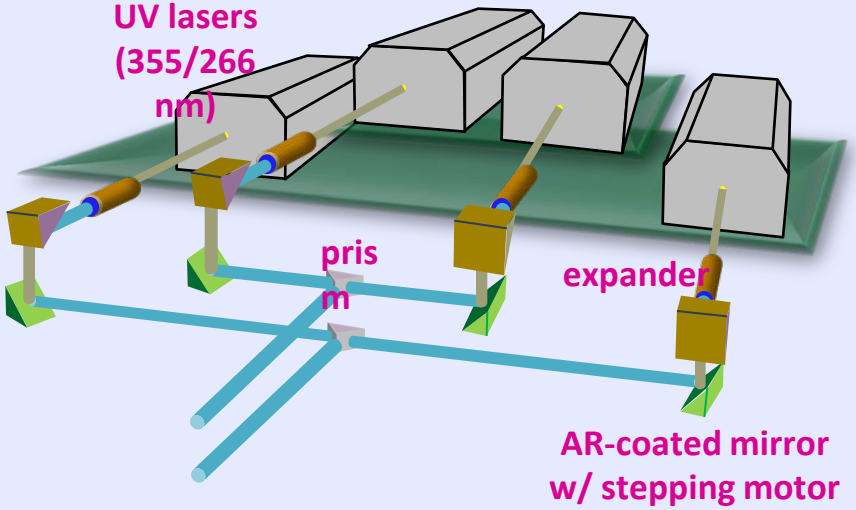
We are aiming to produce one-order higher intensity photon beam :

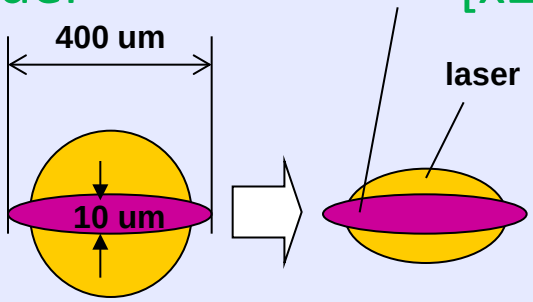
LEP intensity $\geq 10^7$ cps for E_γ<2.4 GeV beam (355 nm)

$\geq 10^6$ cps for E_γ<2.9 GeV beam (266 nm)

- Simultaneous injection of 4-lasers [x2]
- Higher output power and lower power consumption CW lasers.

  355 nm (for 2.4 GeV) 8 W→16 W, 266 nm (for 2.9 GeV) 1 W→2 W [x2]
- Laser beam shaping with cylindrical expander [x2]





- Electron beam is horizontally wide.

  ⇒ BCS efficiency will be increased by elliptical laser beam.

Need large aperture of the laser injection → reconstruct some BL chambers in SR-ring

Construction of LEPS2 Facility

- LEPS2 proposal was submitted to SPring-8 (2010.3) and approved (2010.6).
- Experimental building was constructed by the support of Riken-Nishina center (2011.3).
- Transportation, and installation of the E949 magnet was completed (2011.11).
- New BL vacuum chambers were installed (2012.8~9, 2012.12).
- Laser injection system has been prepared (2012.10~2012.12)
- First LEP beam was produced. (2013.1.27)

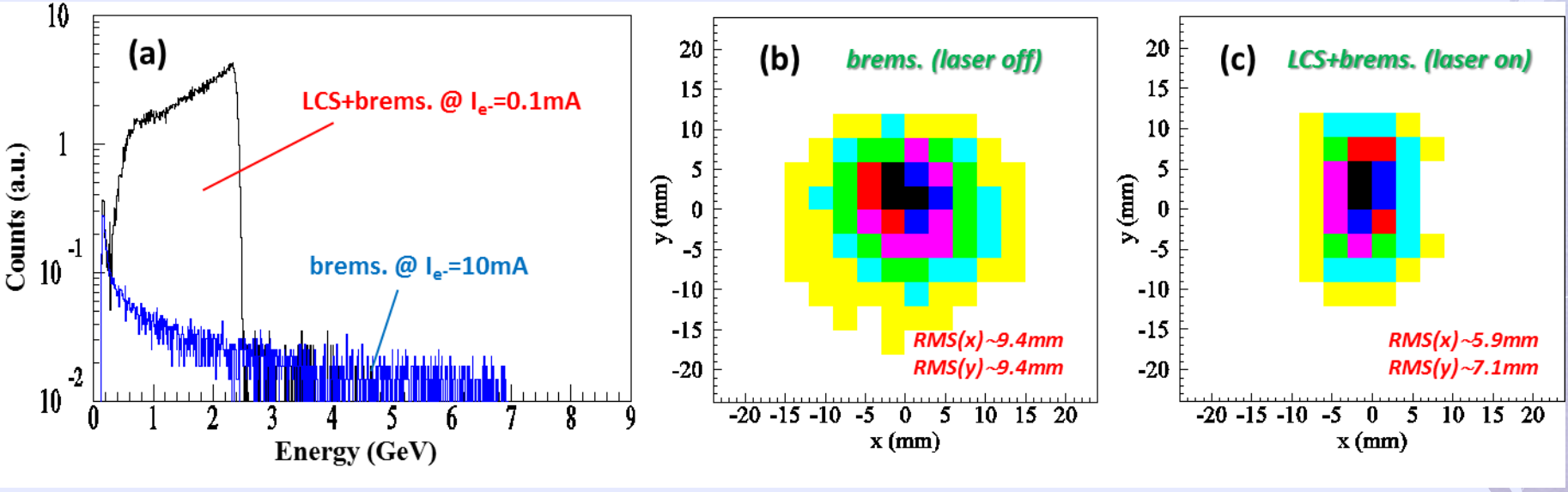
(A Ceremony to celebrate the completion of LEPS2 was held on 2013.2.21.)

1st observation of LEPS2 Laser Compton Scattering beam

- Energy spectrum was measured using a large BGO crystal on the beam axis during the low circulation current.
- Beam position and shape were measured with BPM.

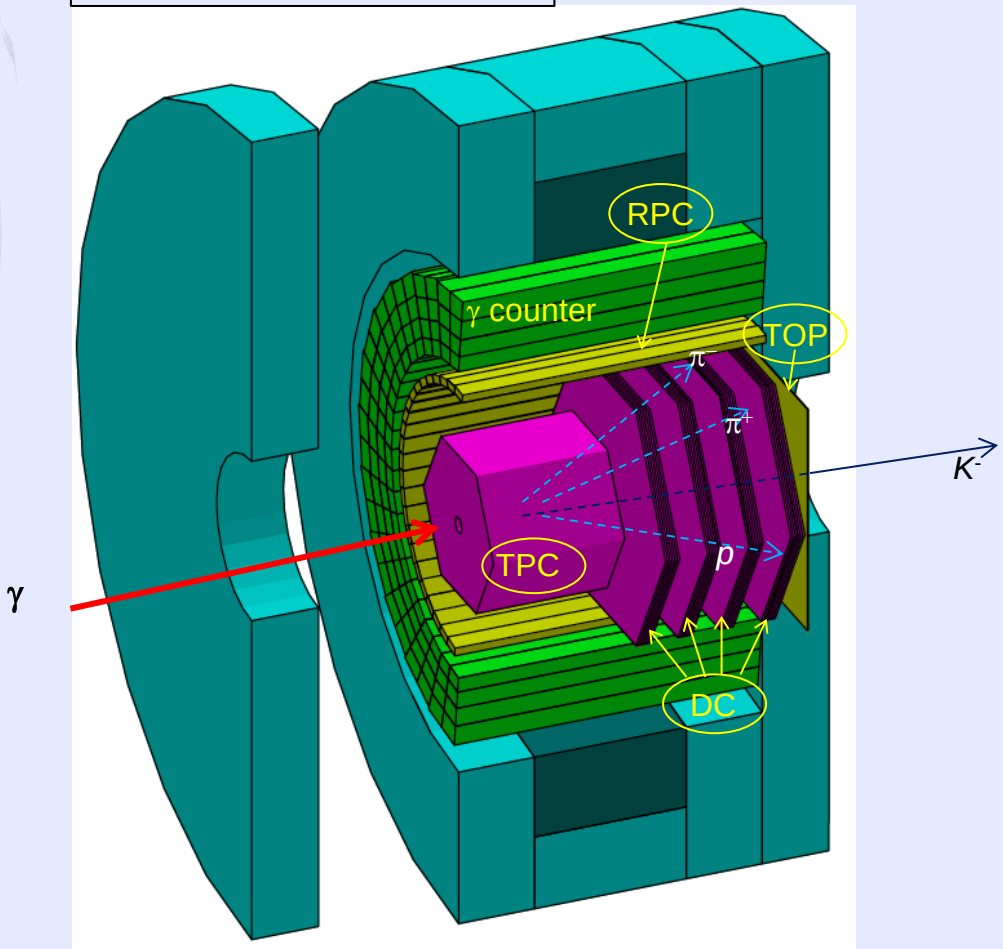
Large BGO crystal
・8 cm[ϕ] x 30 cm[L]
with 3 inch PMT

Beam Profile Monitor (BPM)
・3-mm square SciFi
X: 16 ch Y: 16 ch
・in front of BPM
+ Al converter（0.5 mm）
+ trigger scinti（1 mm）



LEPS2 Charged Spectrometer

E949 Solenoid Magnet
- size: Φ5m × 3.5m
- weight: 400 t
- Field: 1.0 T



Strangeness tagging

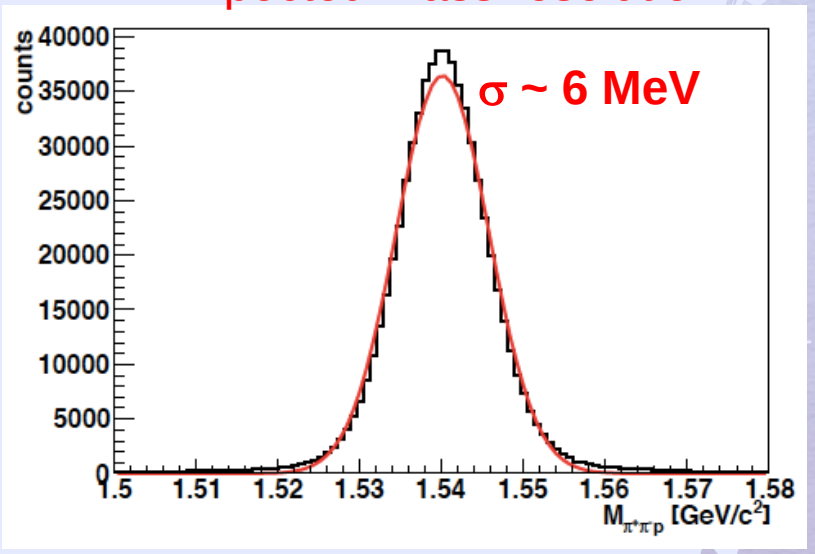
$$\gamma + n \rightarrow K^- + \Theta^+$$

$$\rightarrow p\ K^0$$

$$\rightarrow \pi^+ \pi^-$$

Invariant Mass measurement

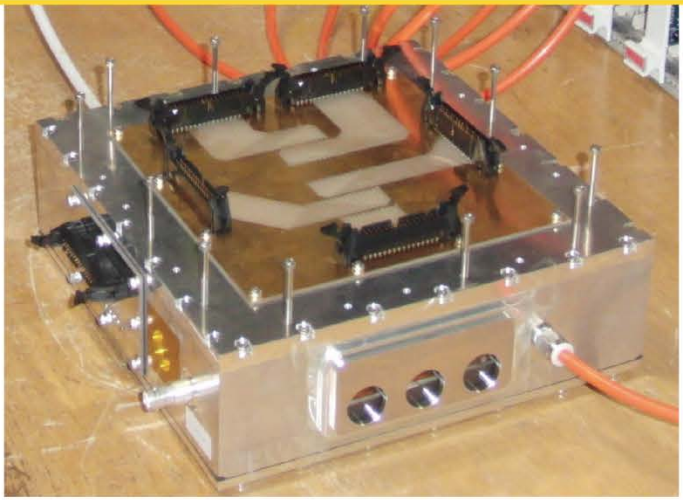
Expected mass resolution

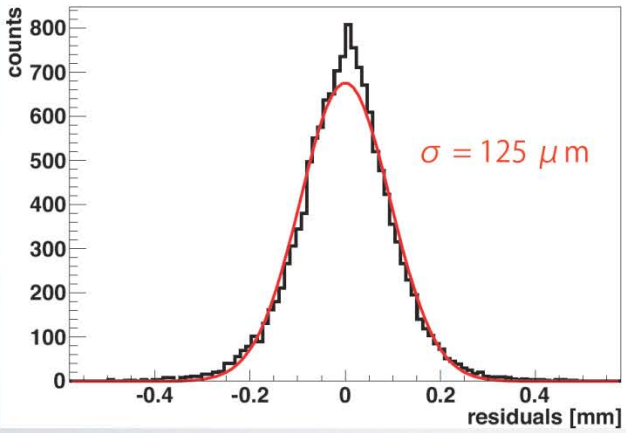


TPC(Time Projection Chamber)

prototype 1

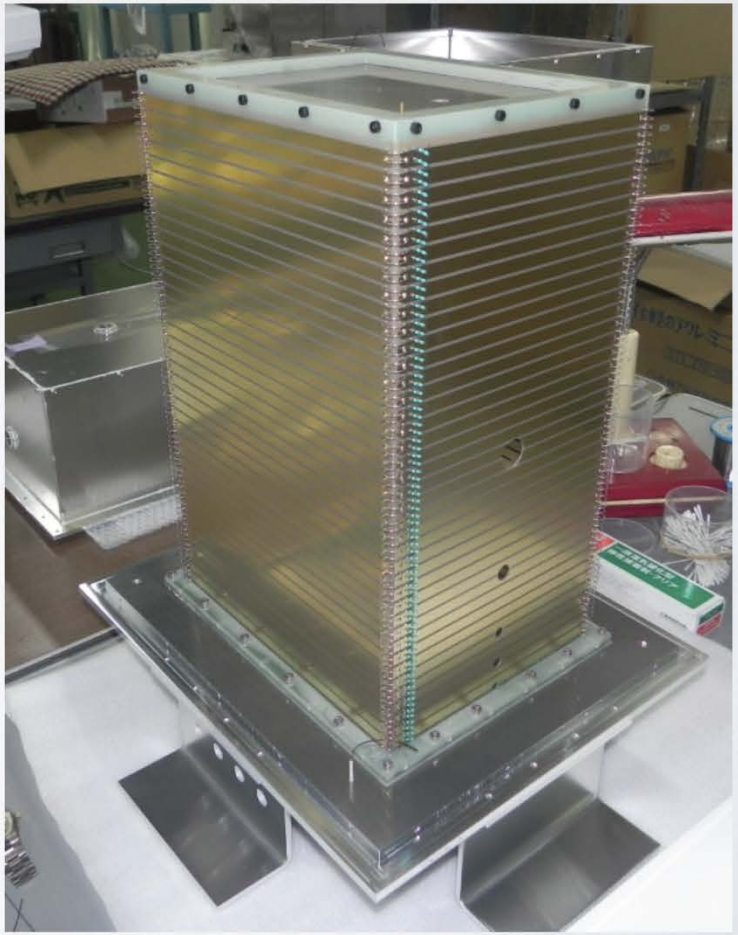
Volume (50 mm × 50 mm × 20 mm)





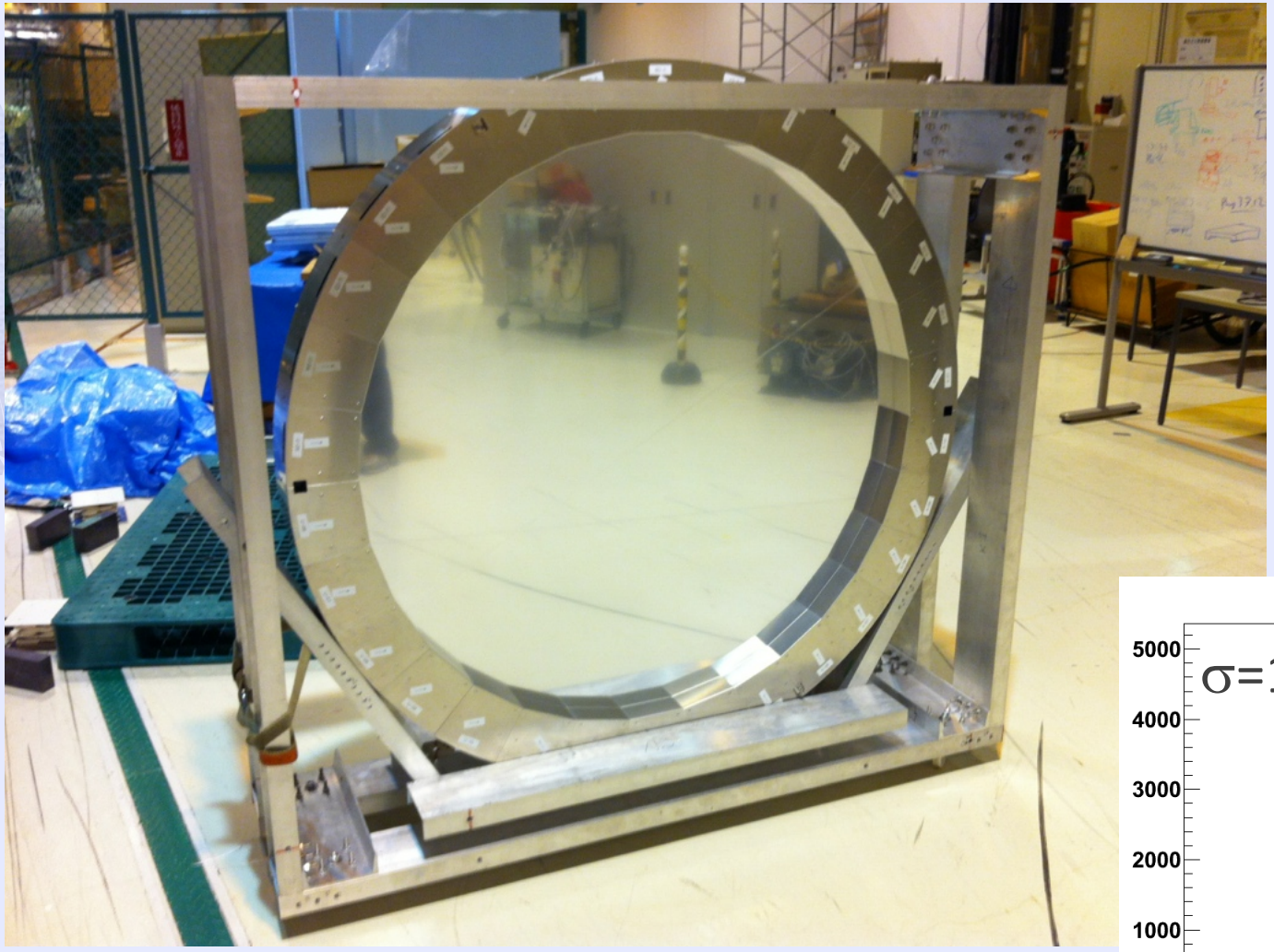
prototype 2

Volume (118 mm × 250 mm × 412.6 mm)



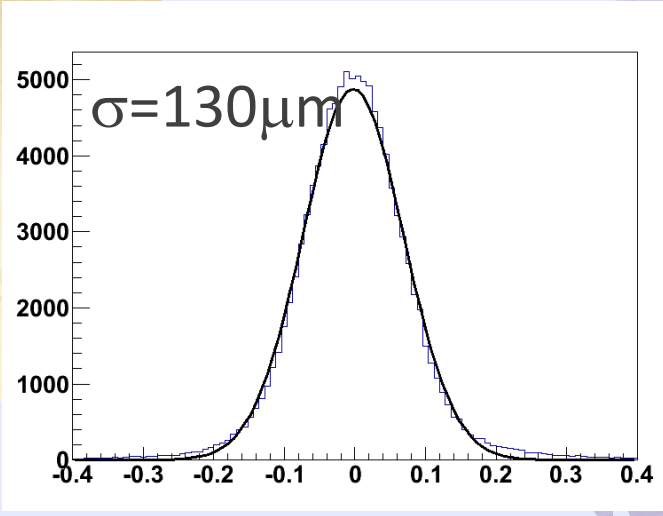
To reduce multiple scattering effect → use Ne-based gas

Drift Camber

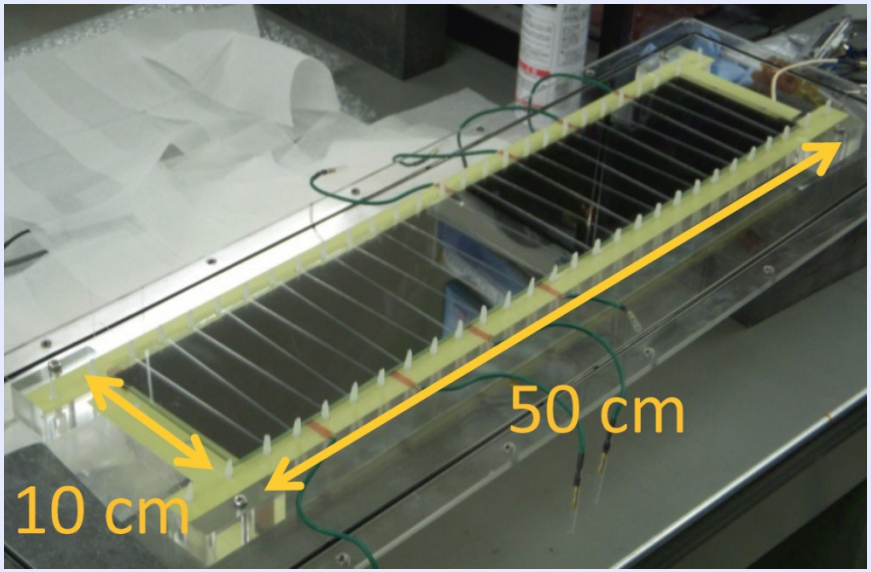


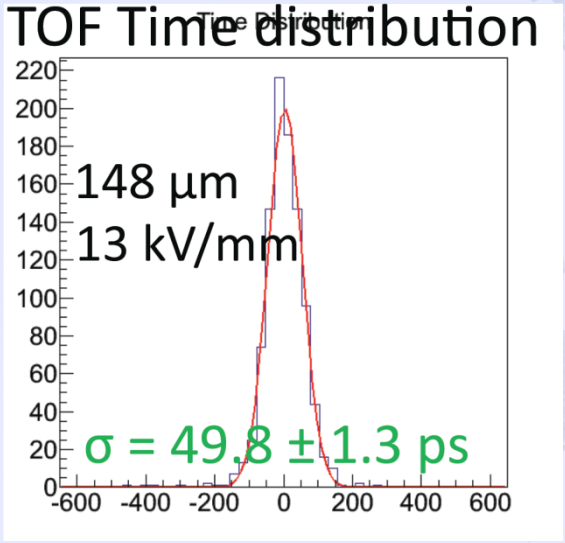
XX'UU'VV' 6 planes
Size: ϕ1600
effective area: ϕ1300
anode-cathode: 8 mm

1st DC has been Constructed and tested using beam.

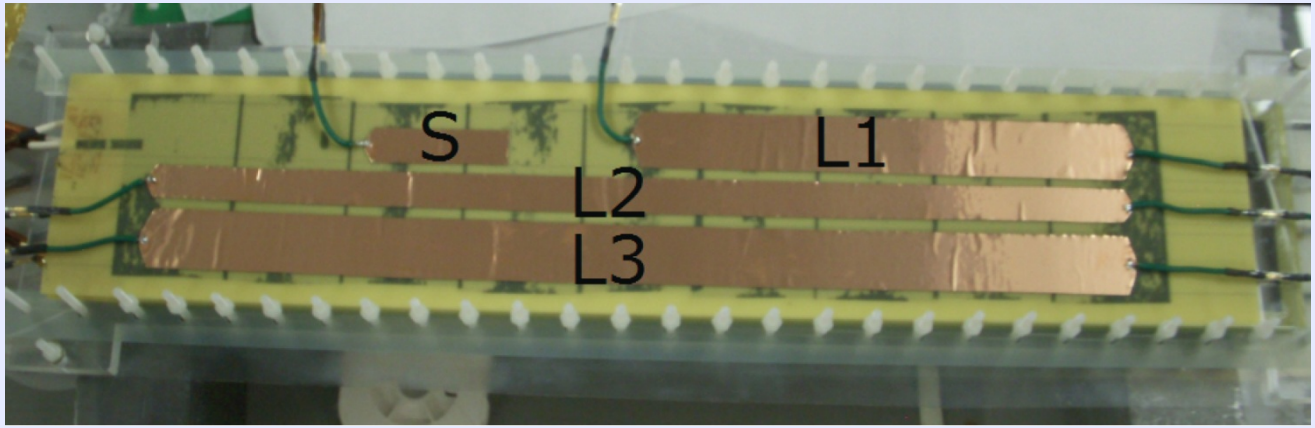


RPC(Resistive Plate Chamber) Prototype





readout strip



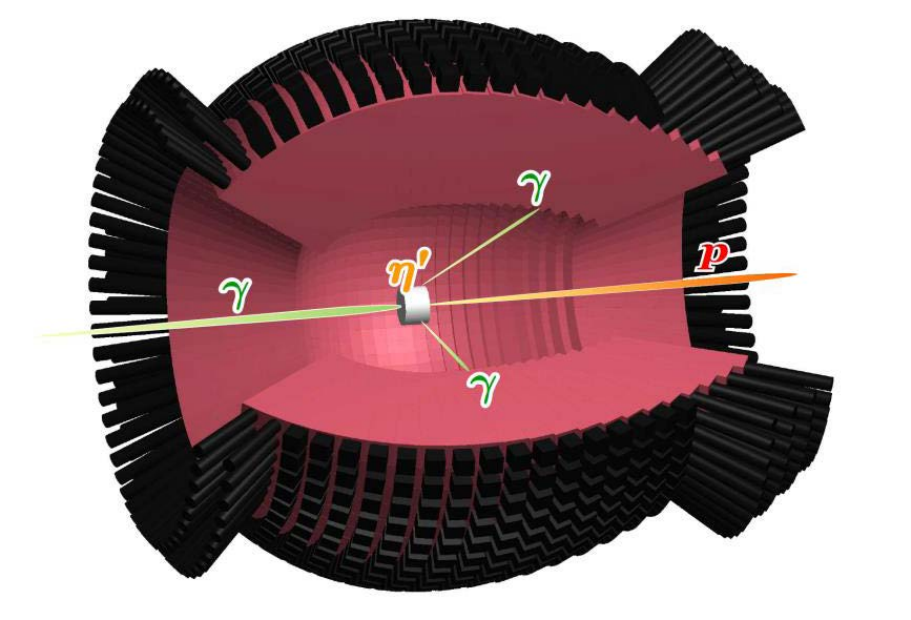
$C_2H_2F_2$:SF_6:iso-C_4H1_0=90:5:5

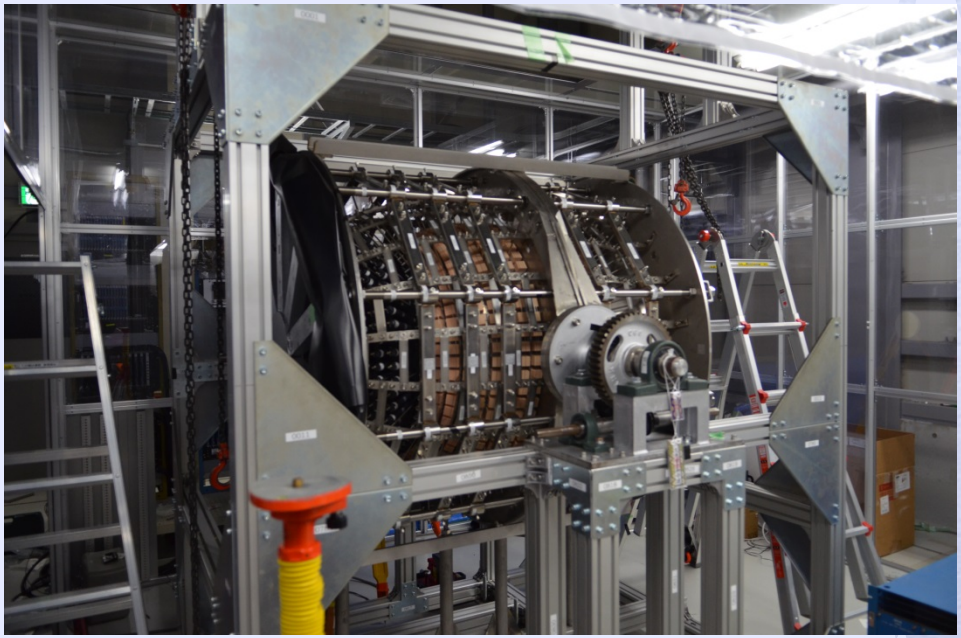
gap: 260 μm x 10

σ=60 ps

eff.=99%

BGOegg : constructed @ ELPH, Tohoku U.



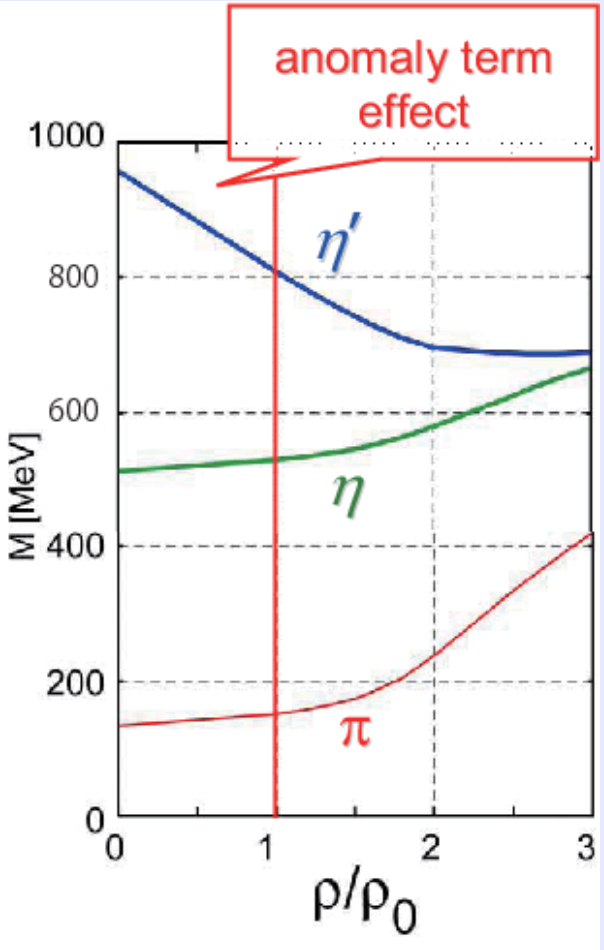


Large acceptance photon detector (BGOegg)

- 1320 BGO crystals
- Covering 24° ~144° polar angle with the angular resolution of ~1 deg
- 1.3% energy resolution for 1 GeV
- It was moved to SPring-8 in Dec. 2012. Commissioning run will start from this autumn.
- First objective is *the search for η' mesic nuclei, etc.*

Search for η' bound nuclei

(1st experiment with BGOegg)

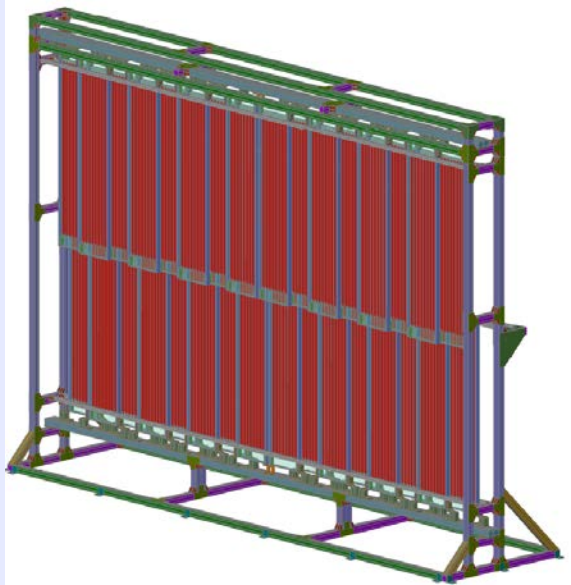


Nagahiro e al.,
PRC74,045203(2006)

- A large mass shift of η' in the nuclear density was theoretically predicted, due to the partial restoration of chiral symmetry and $U_A(1)$ anomaly effect.
  → This makes η' bound state possible.
- We will search for such bound states by the ${}_ZA(\gamma, p)_{z-1}A^{\eta'}$ reaction.
  → Add forward proton TOF detector

Forward RPC-TOF wall

Δt ~ 50ps
Flight length 12 m



Summary

- LEPS@SPring-8 has been in operation since 2000 for the study of the hadron structures (Θ^+,$\Lambda(1405)$,…) and hadron interactions (ϕN, KNN,…) using highly polarized GeV photon beam.
- For the Θ^+ status at LEPS:

  -- in the exclusive analysis with subtraction of proton events, the peak structure is enhanced. Now data is taken using a large start counter.

- Construction of the LEPS2 beamline has been completed.

  → one order higher intensity & large acceptance detectors

  The 1st photon beam has been successfully obtained at LEPS2 in early 2013.
- We plan to start BGOegg experiments from this autumn with a forward DC and TOF counters. → search for η'-bound nuclei
- Developments and constructions of detectors for the LEPS2 charged spectrometer are in progress.

Thank you !