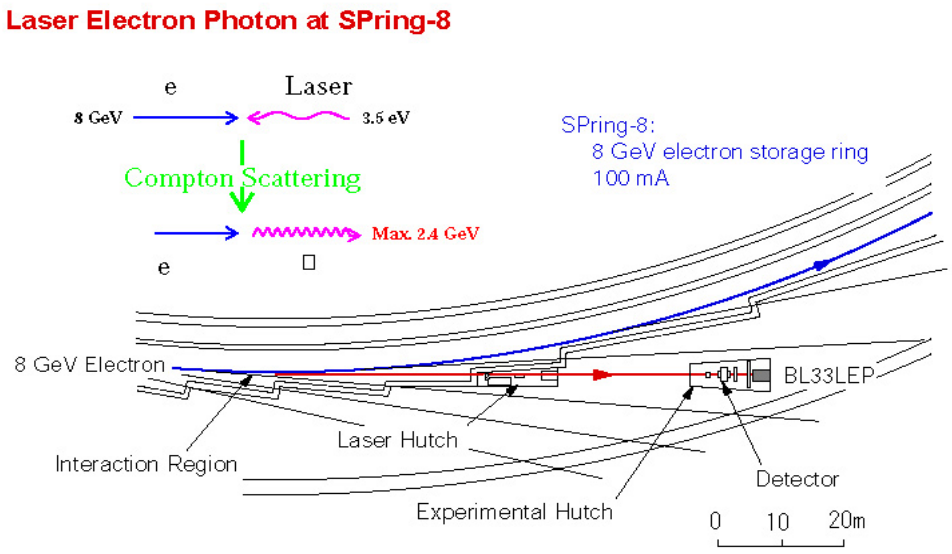
Recent status and plans at SPring-8 LEPS2 facility

M. Miyabe
ELPH Tohoku University
LEPS and LEPS2 collaborations

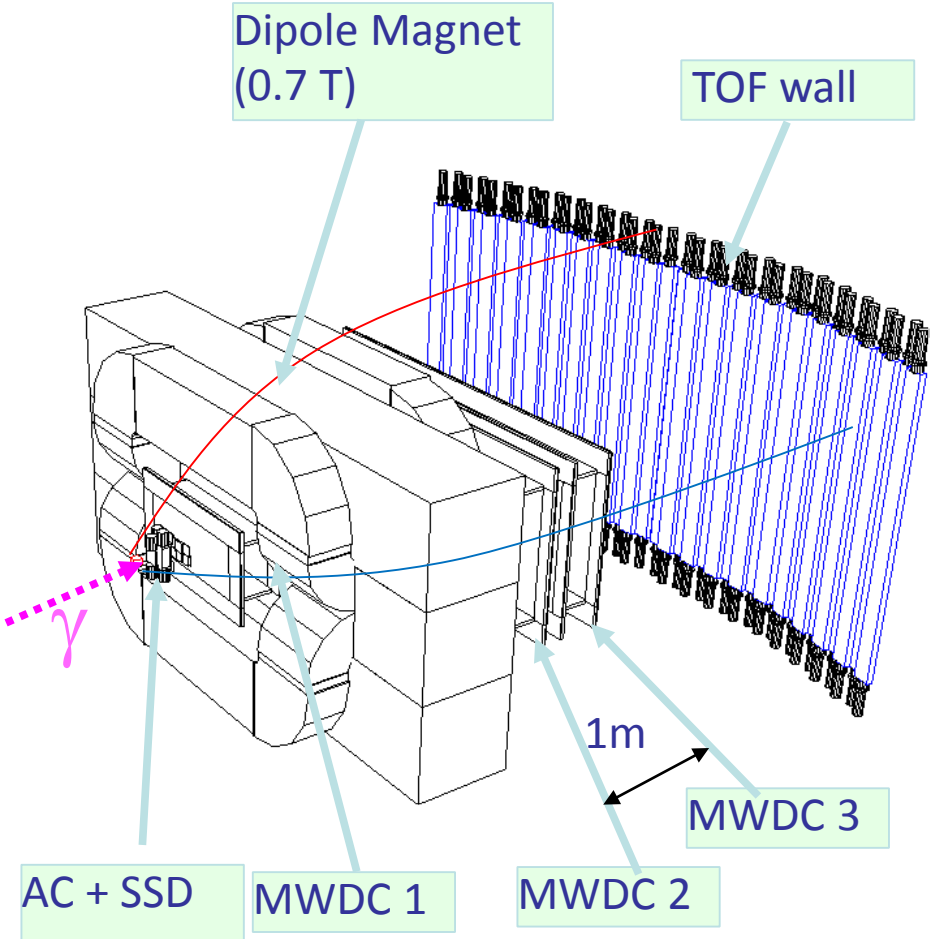
Contents

- SPring-8/LEPS2 overview
  - LEPS2 and BGOEGG experiment is just now starting.
- Physics motivations at LEPS2 and BGOEGG
  - η' mesic nuclei, baryon resonance, etc
- Experimental setup for LEPS2 and BGOEGG
- Summary

SPring-8/LEPS



- Eγ~2.4GeV
- Polarization ~95%
- ~ 1 Mcps

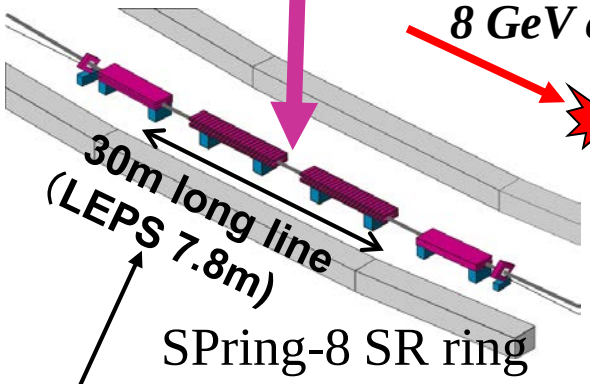


LEPS spectrometer

- Detect charged particle at Forward angle
- θ~20 deg

LEP2 Project at SPring-8

Backward Compton Scattering



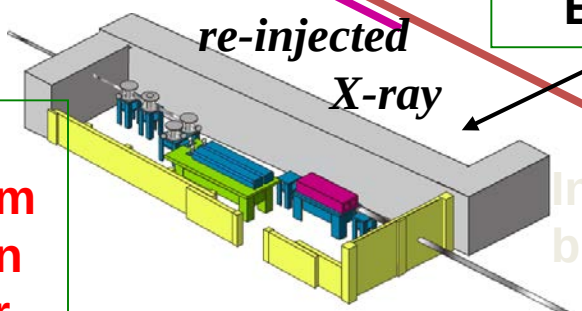
8 GeV electron

Recoil electron (Tagging)

High intensity:
Multi (ex. 4) laser injection w/ large aperture beam-line & Laser beam shaping
~10 ^{7} photons/s (LEPS ~10 ^{6})
High energy: Re-injection of X-ray from undulator
Eγ < 7.5GeV (LEPS < 3GeV)

Laser or re-injected X-ray

GeV γ-ray



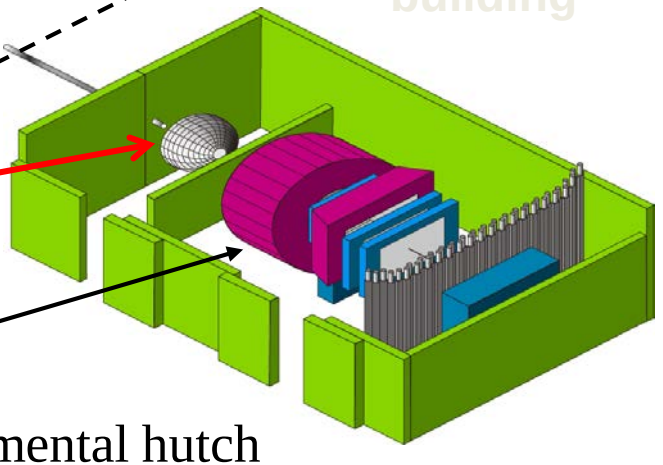
Laser hutch

Inside building

Outside building

Better divergence beam
⇒collimated photon beam
⇒better tagger resolution
Different focus points for multi CW laser injection

Large acceptance EM calorimeter BGOEGG.



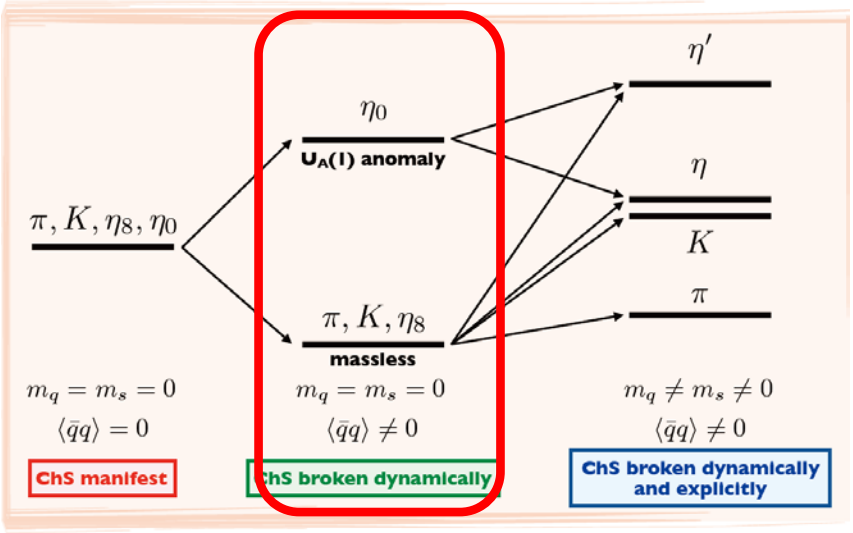
Large 4π spectrometer based on BNL-E949 detector system.

Experimental hutch

PHYSICS MOTIVATION

η'(958) and $U_A(1)$ anomaly

- The experimental mass of η' is more than 2 times larger expected value.
  - $U_A(1)$ anomaly effect.
- Origin of large η' mass
  - Chiral symmetry breaking
  - $U_A(1)$ anomaly



Daisuke Jido, Hideko Nagahiro, and Satoru Hirenzaki, Phys. Rev. C 85 (2012) 032201(R).

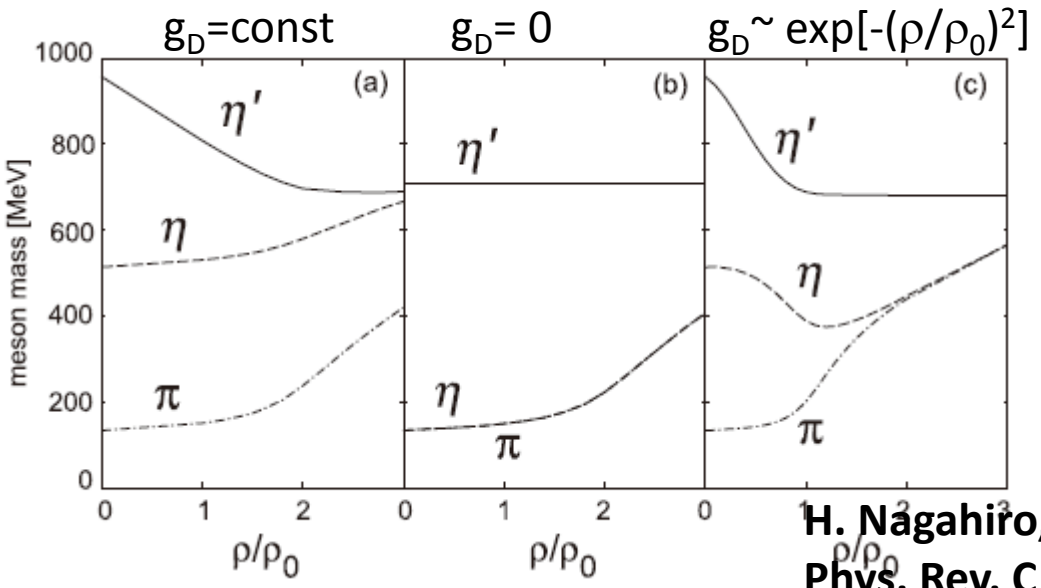
Poor experimental information for $U_A(1)$ anomaly effect

Mass reduction of η'(958)

- **Prediction from NJL model**

$$\mathcal{L} = \bar{q}(i\,\partial\!\!\!/ - m)q + \frac{g_s}{2}\sum_{a=0}^{8}\left[(\bar{q}\lambda_a q)^2 + (i\bar{q}\lambda_a\gamma_5 q)^2\right]$$
$$+g_D\left[\det \bar{q}_i(1-\gamma_5)q_j + h.c.\right]$$

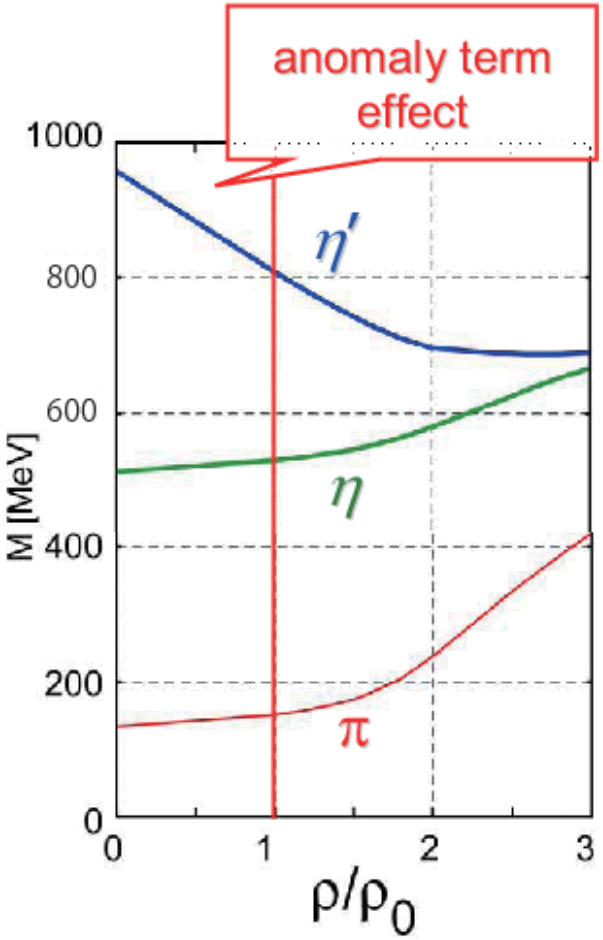
KMT interaction : $U_A(1)$ anomaly



H. Nagahiro, M Takizawa, S. Hirenzaki
Phys. Rev. C 74, 045203 (2006)

Mass modification in finite density

- Mass of η' is possibly modified under the finite density compared with mass in the vacuum
  - $\Delta m_{\eta'} \sim$ -150MeV @ρ_0
  - $\Delta m_{\eta} \sim$ + 20MeV @ρ_0



- P. Rehberg, et al. Phys. Rev. C53(1996) p410
- H. Nagahiro, M Takizawa, S. Hirenzaki Phys. Rev. C 74, 045203 (2006)

Measurement of η‘ in finite density

- Large mass reduction(150 MeV) of the η’ meson in the normal nuclear density

- existence of a bound state with a nucleus (η’-mesic nuclei)
  - H. Nagahiro, M. Takizawa, and S. Hirenzaki, Phys. Rev. C 74, 045203 (2006).

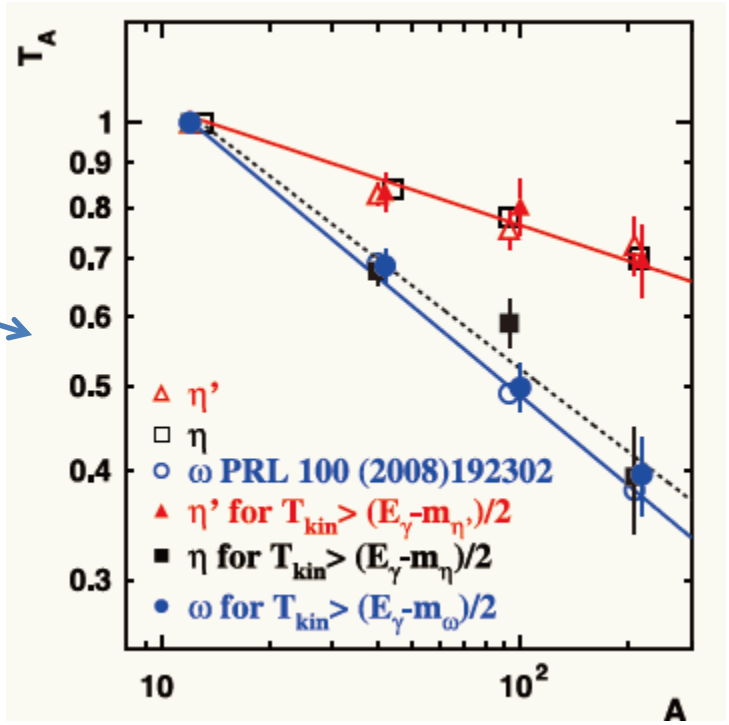
- If we observe the η’ bound state, we get the information for UA(1) anomaly effect.

η'-mesic nuclei

- Strong attractive force and small absorption
  - Attractive force
    - $U_A(1)$ anomaly effect
  - Absorption
    - $ReW_0 \sim 7.5\text{-}12.5$MeV（CB-ELSA）

    M. Nanova et al., PLB 710, 600 (2012)
- Experimental results
  - Re $a_{\eta'N}$<0.8fm
    - Phys. Lett. B474(2000)p416
  - $|a_{\eta'N}|$ <0.1fm
    - Phys. Lett. B482(2000)p356
- Optical potential with Chiral unitary model
  - ReV >> ImV (possible)

→ more detailed experiment!



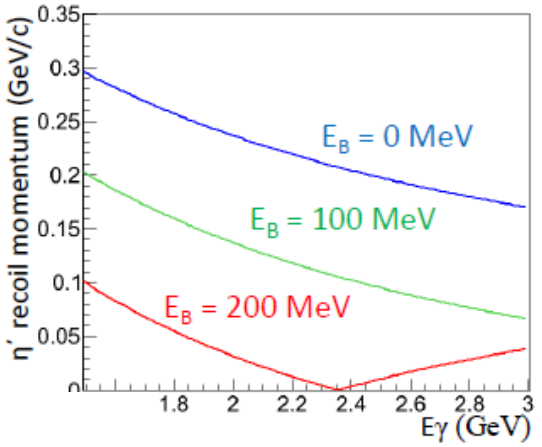
Transparency ratio

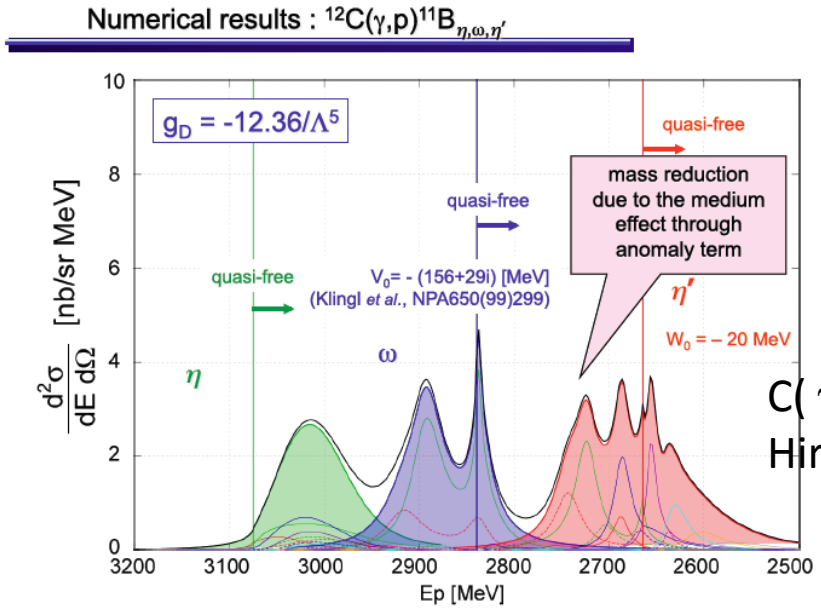
Search the η' mesic nuclei using nuclear target.

η' mesic nuclei in (γ,p) reaction

- Lower Recoil momentum of η' than hadron beam
- Experimental parameters
  - Eγ 1.6~2.9 GeV
  - Target C
  - Forward proton detection

- momentum transfer (0 degree)

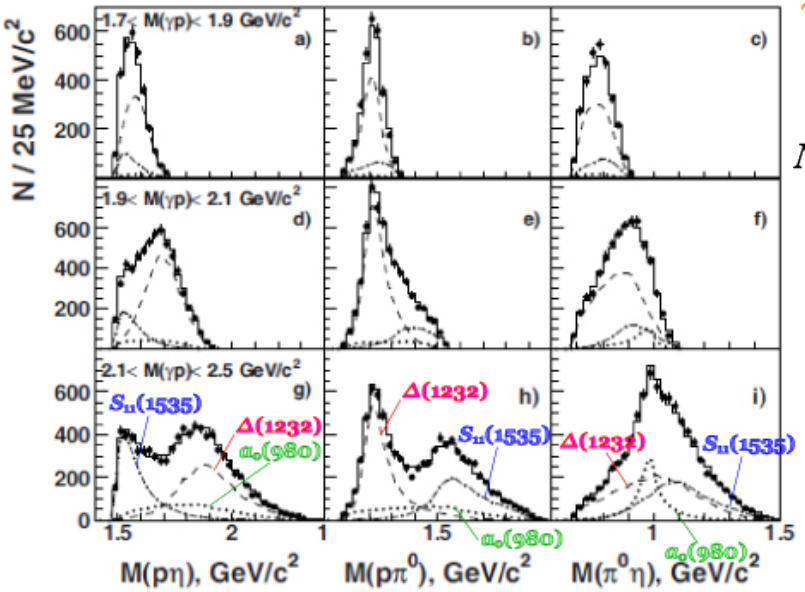




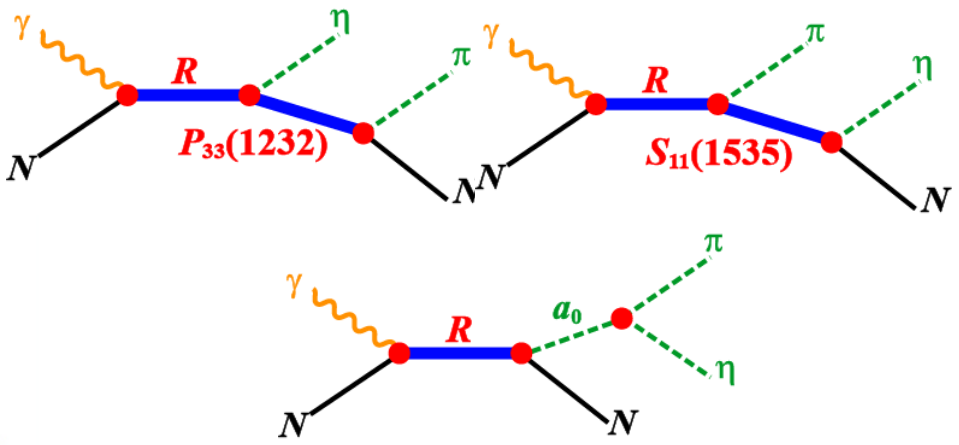
C(γ, p)X missing mass
Hirenzaki@ELPH 2011

Baryon resonance study with multi meson production

- The multi-meson photoproduction process provides important information on highly excited baryon states, which usually have a large branching ratio to multi-meson decay channels.



invariant mass in $\gamma p \rightarrow \pi^0 \eta$ p reaction
Eur. Phys. J. A38(2008) p173



Highly exited baryon state contribution
P33(1920), D33(1930)

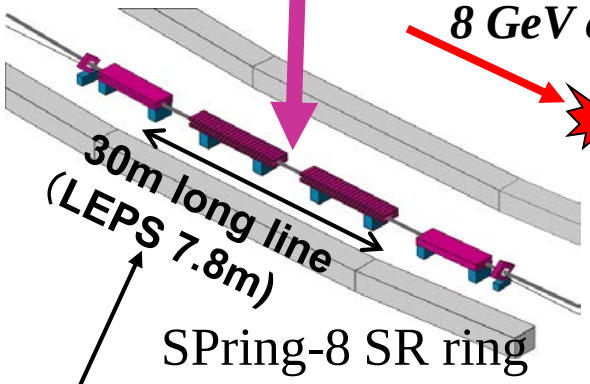
More detaild study with BGO EGG @LEPS2

LEPS2 FACILITY


LEPS2 Laser-Room
LEPS Experimental Hutch
LEPS2 Experimental Building
SPring-8
8GeV e⁻ 100mA
457 m
Booster Synchrotron
XFEL SACLA
Linac: 1 GeV
New SUBARU

LEP2 Project at SPring-8

Backward Compton Scattering



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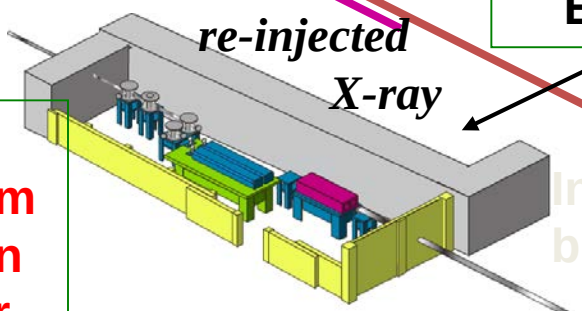

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Outside building

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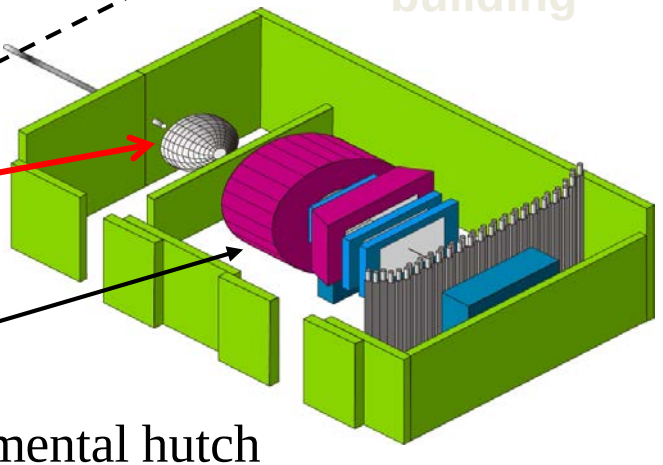
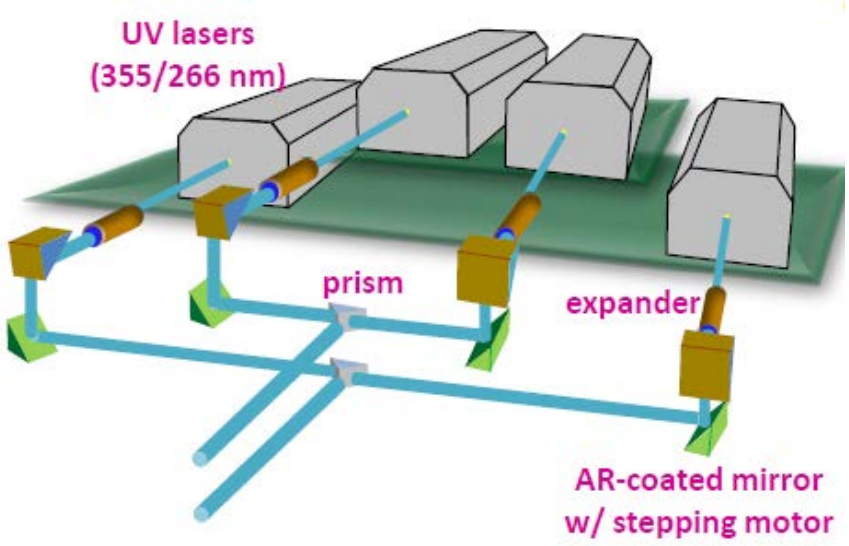


Large 4π spectrometer based on BNL-E949 detector system.

Experimental hutch

LEPS2 laser system

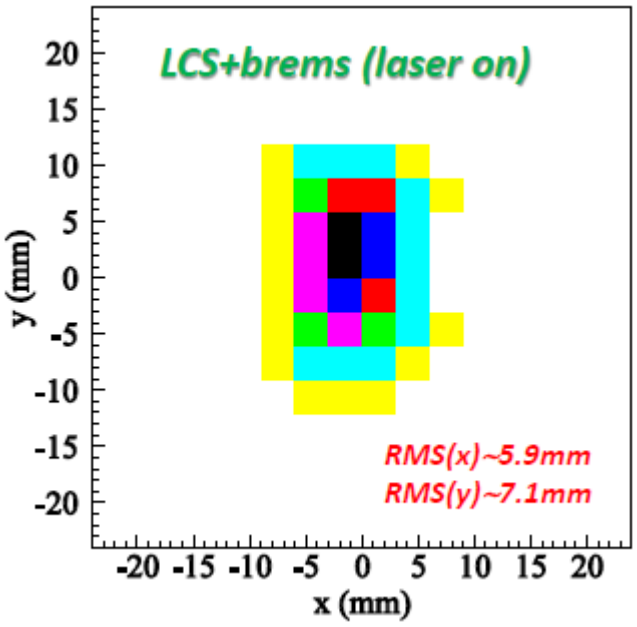


Multi laser injection system

- simultaneous 4-laser injection
- Increase the laser power
  - 8 W -> 16 W or 24W
- Smaller beam size
  - Lower e^- divergence

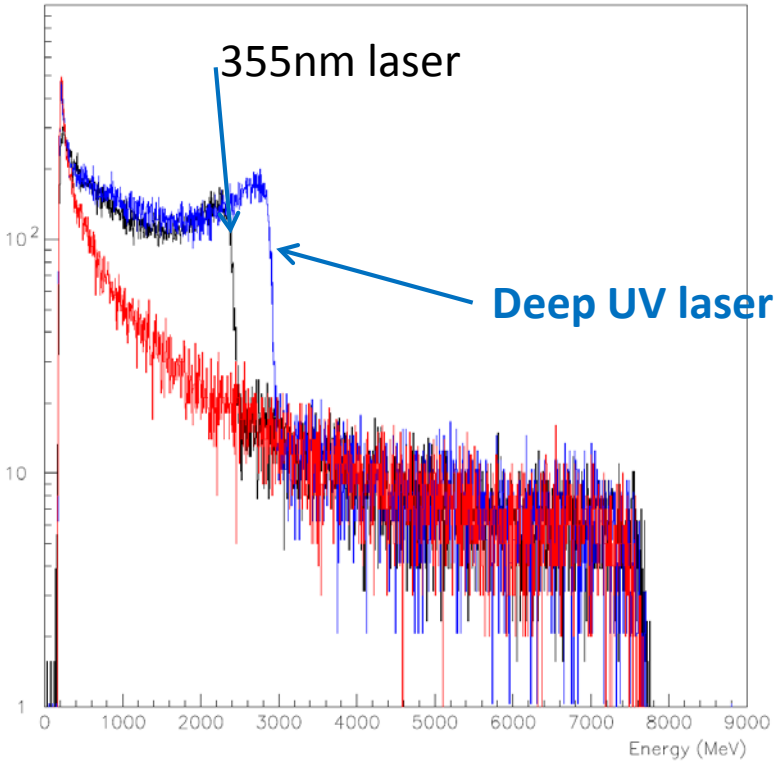
    $<\sigma_{x'}>$=58 μm -> 14 μm

First beam observation at LEPS2



beam profile is well collimated

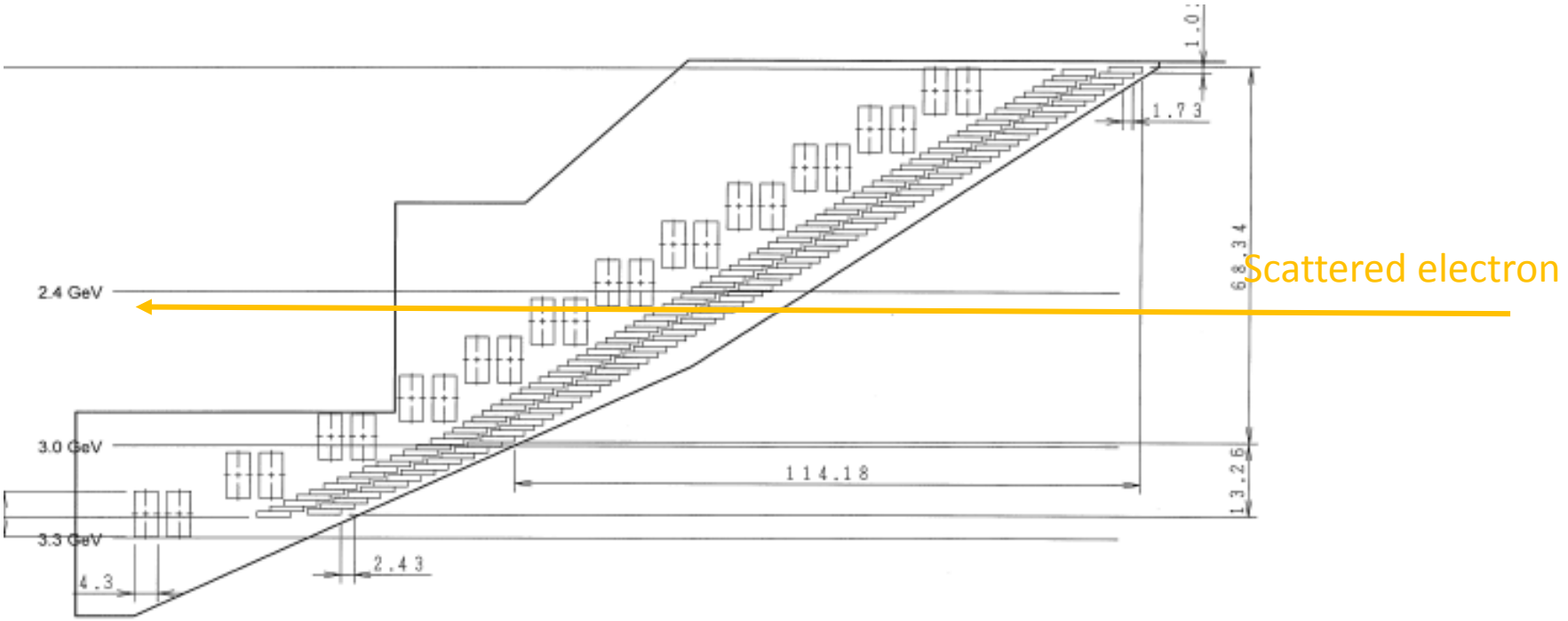
consistent with the expectation



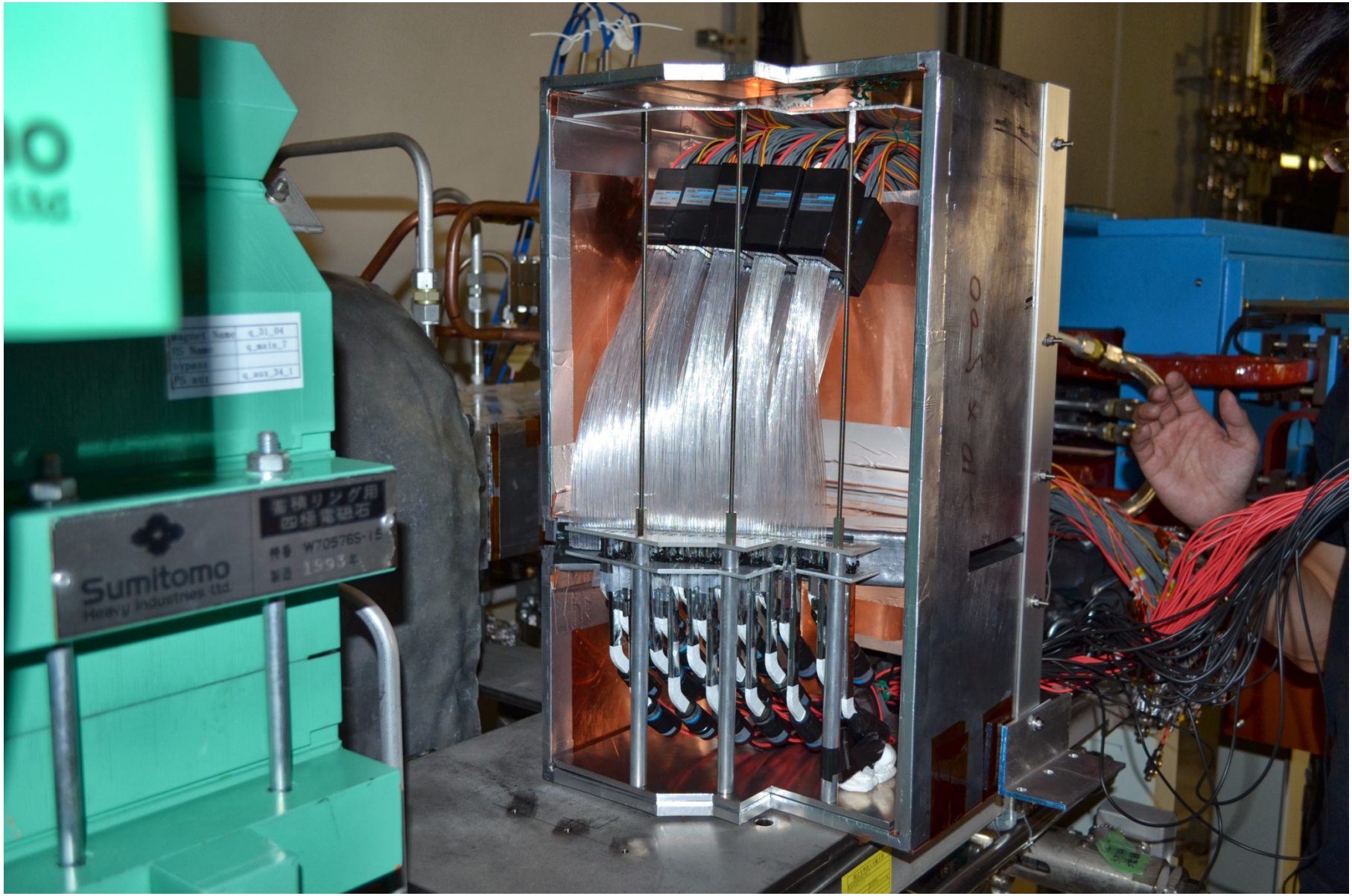
Energy spectrum with
large BGO crystal (ϕ 8 cm x L 30cm)

Photon beam intensity ~ **7 MHz** (for 0<Eγ<2.4 GeV)
@ 3-(355nm) laser

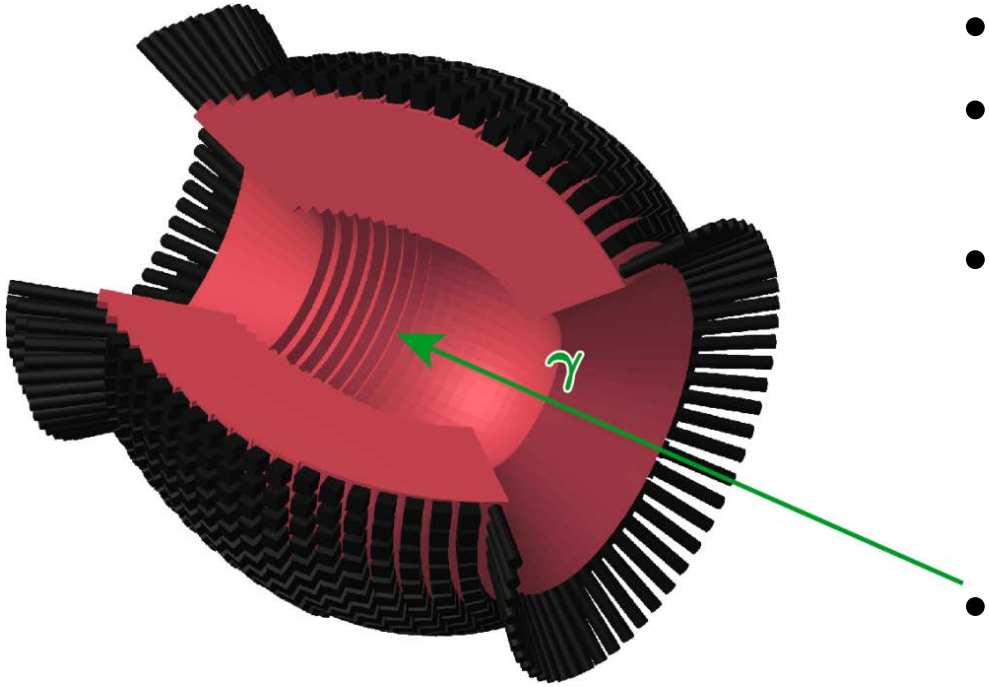
LEPS2 tagging system



PL counter: 4mm-thick x 8mm-wide x 10-mm high
SciFi : 1mm x 6mm thick

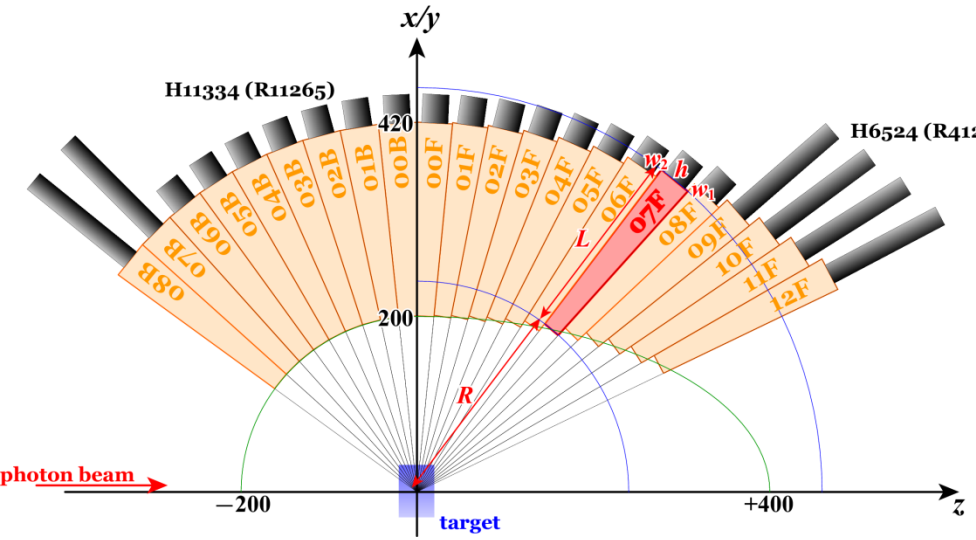

Sumitomo
Heavy Industries Ltd.
W70576S-15
1993

Large acceptance EM caloriemeter BGO EGG



- Egg like shape
- Total volume 264L
- Total weight 1.9t (crystal only)
- Two type photomultipliers
  - H11334 (metal package type)
  - H6524 (head on type)
- Very few dead-region
  - Without housing material
  - Only with 3M-Vikuity ESR film reflector.

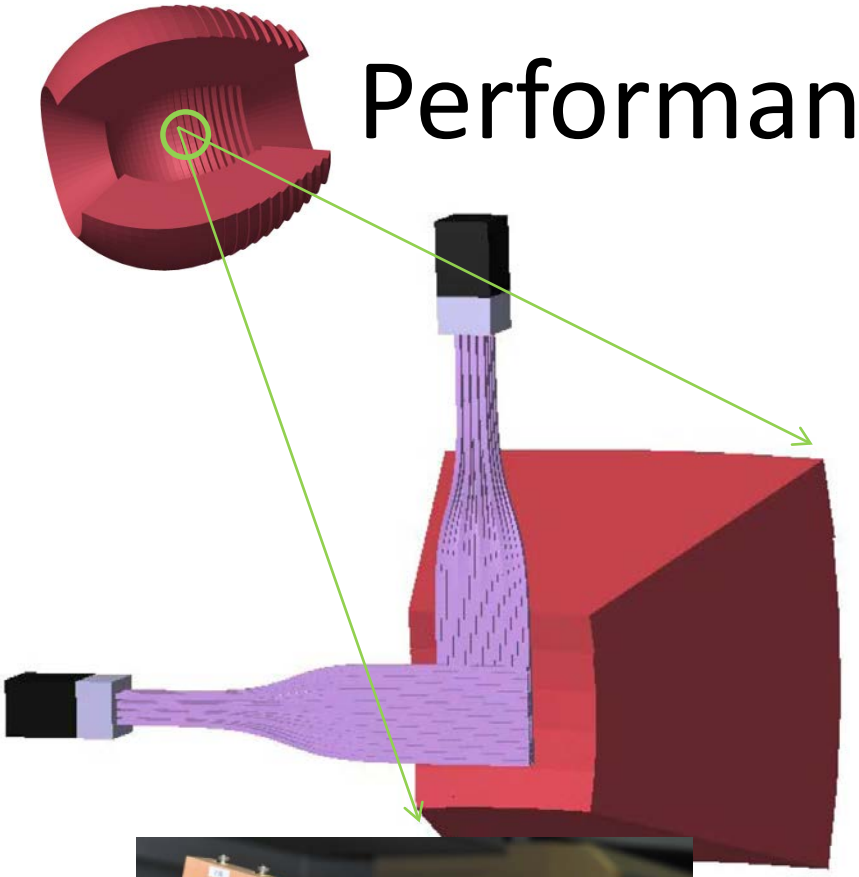
Overview of BGOEGG

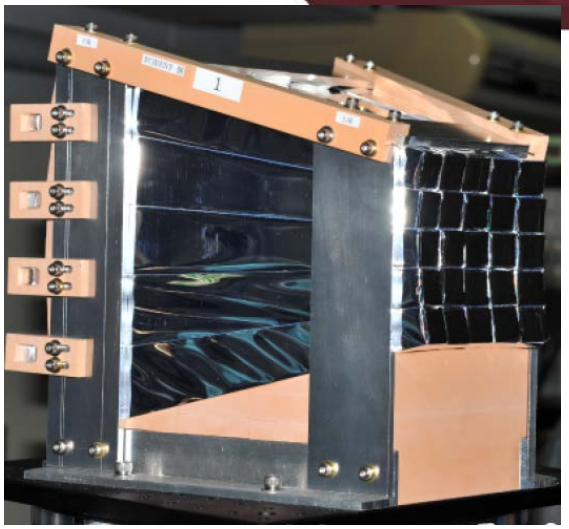


Cross section view of BGOEGG

- Forward (24° -90°)
  - 13 layers (153L)
- Backward (90° -144°)
  - 9 layers (112L)
- 1320 BGO Crystal with 220mm($20X_0$) length
- Each crystal is pyramidal shape with isosceles trapezoid face.
- 60 BGO crystals per layer

Performance of BGOEGG

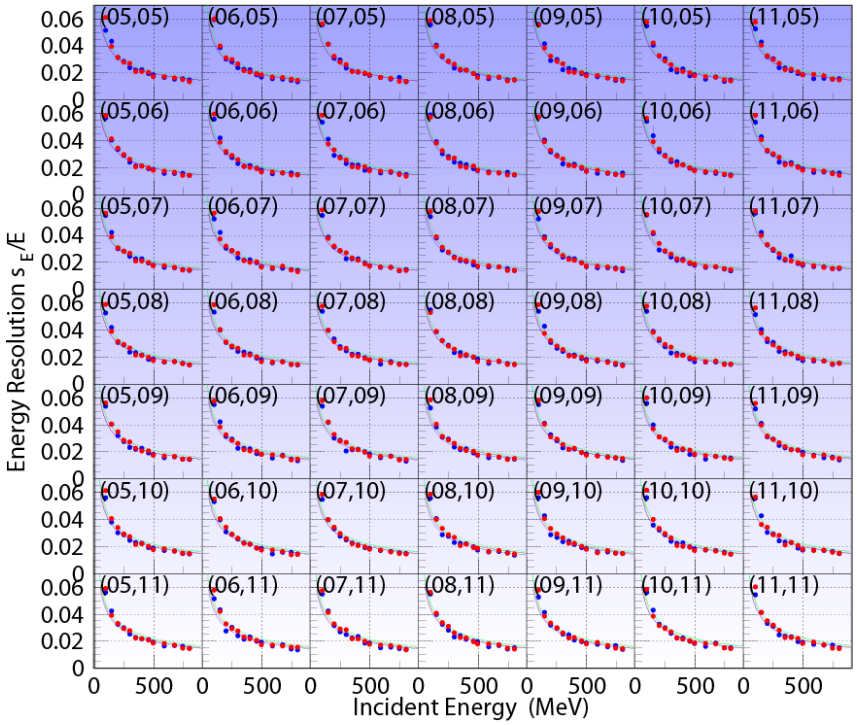




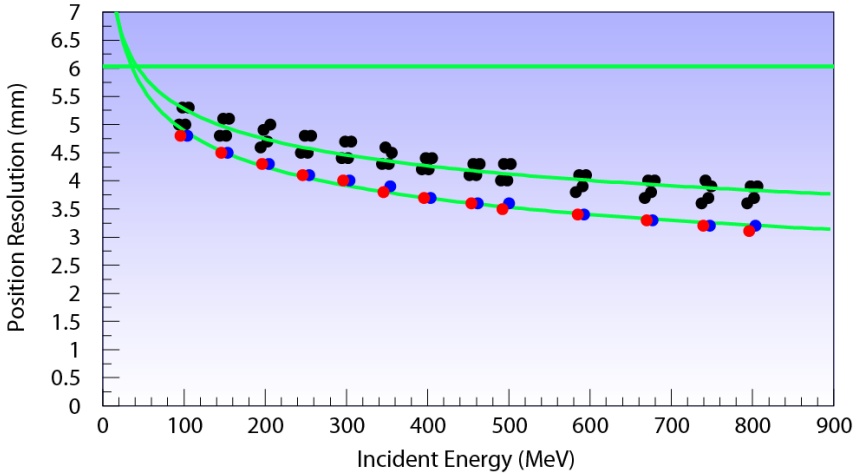
- We test the 5x5 proto-type BGO detector at ELPH
- Positron beam (100-800MeV)
  - Energy resolution
  - Position resolution
- Reflector
  - ESR film
- PMT H11334
- Gate width is 2μs
  - LeCroy2249w
- SciFi phodoscope (3mm fiber, 16x16) position detector

Performance of BGO EGG

Energy resolution

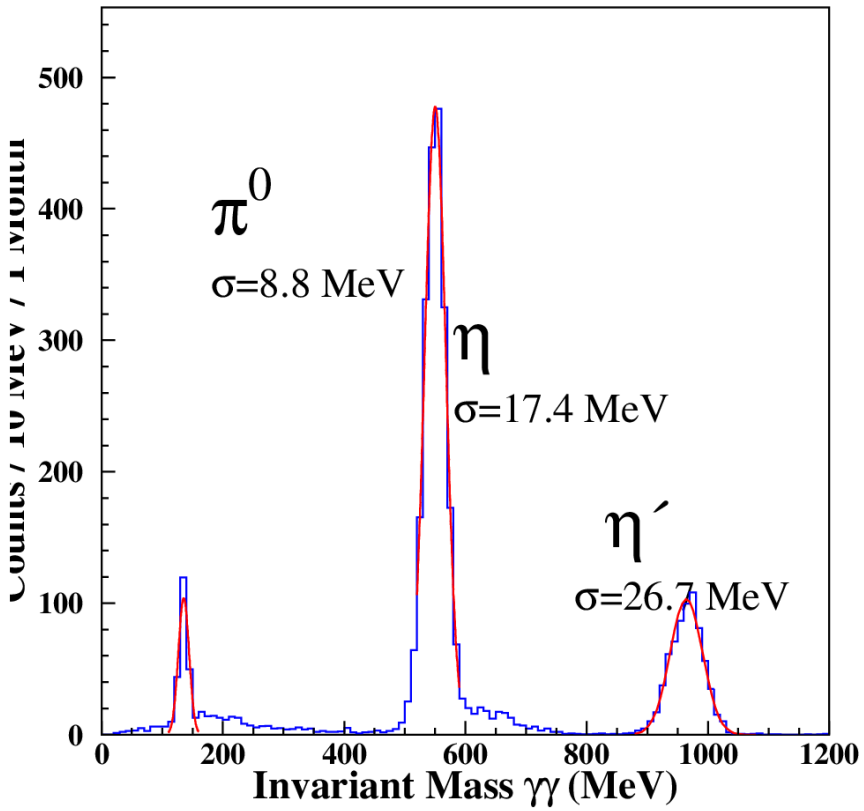


1.3% energy resolution @ 1GeV



3.1 mm for centeral modules
3.7 mm for peripheral modules
@1GeV

Simulation result of BGO EGG



＊BGO EGGで γγ の2クラスターのみ検出

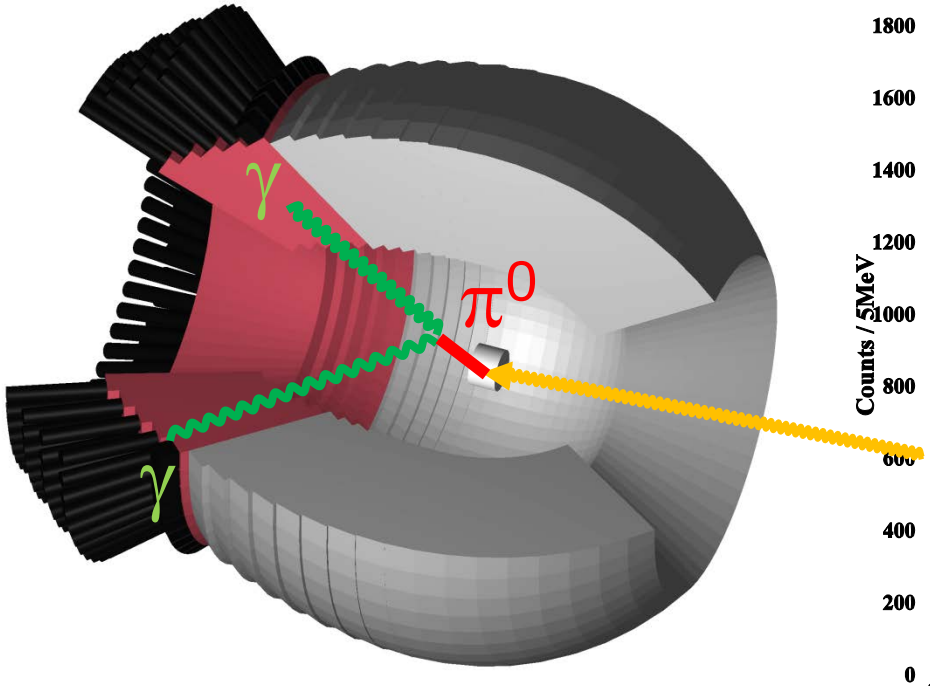
- Geant4 simulation
  - 44.3% η’ → $\pi^+\pi^-\eta$
  - 29.5% η’ → ργ
  - 20.9% η’ → $\pi^0\pi^0\eta \rightarrow 6\gamma$
  - 2.1% η’ → γγ

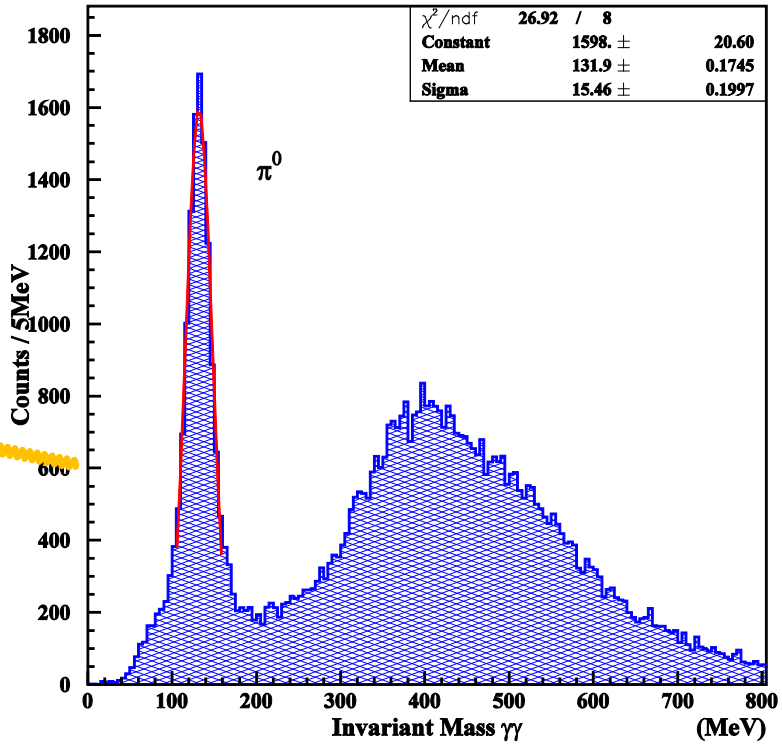
  @ proton target (40mm)
- η’ mass resolution

  ~2.8 %
- 1,0000 η’ event @ LEPS2 per 1 month

BGOEGG test with LEPS2 beam

Test experiment at Jan 2013





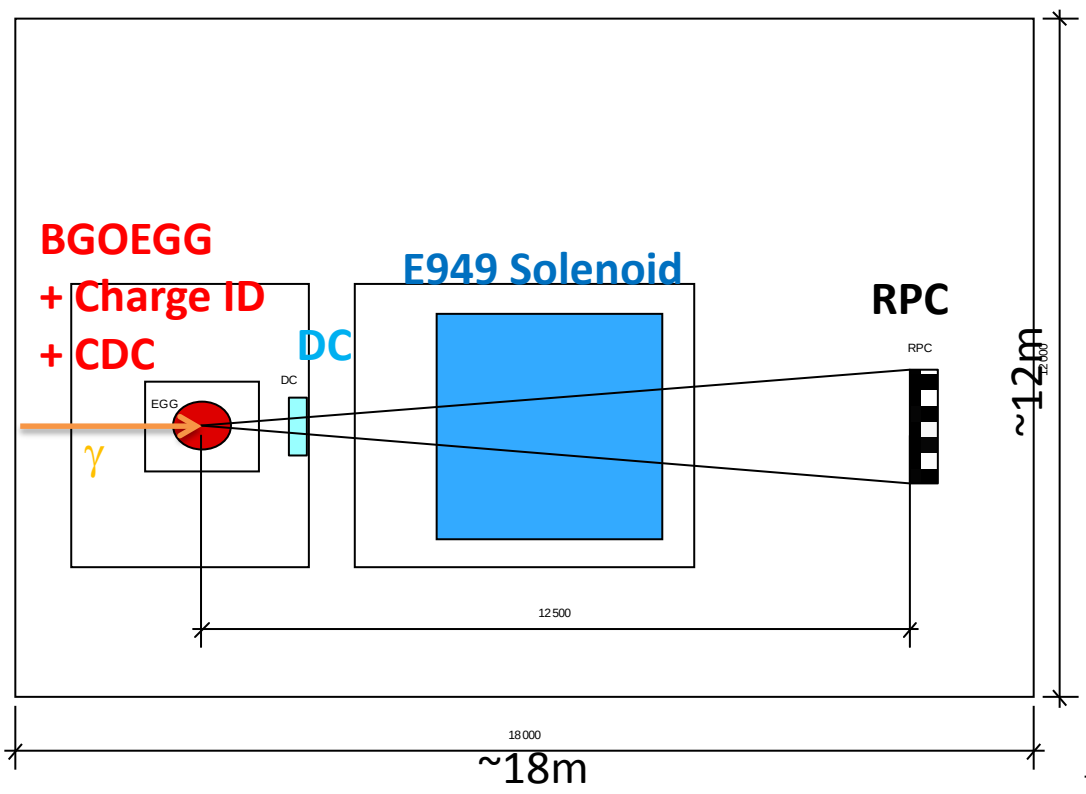
Only 300 channel is activated
(forward 5 layer)

γγ invariant mass / 6hour

Resolution is worse because of incomplete calibration

Peripheral detectors

- Time of flight counter
  - RPC
- Charge identification detector
- Caharged particle tracker chambers
  - CDC, DC

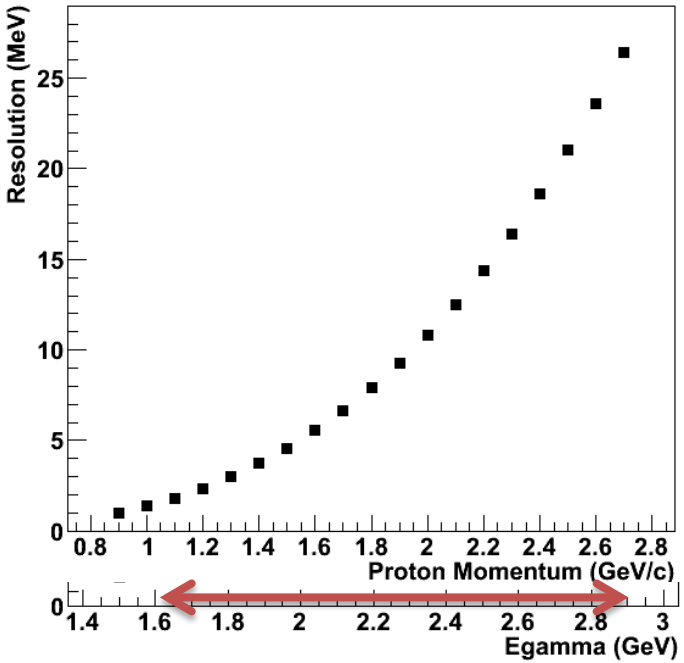


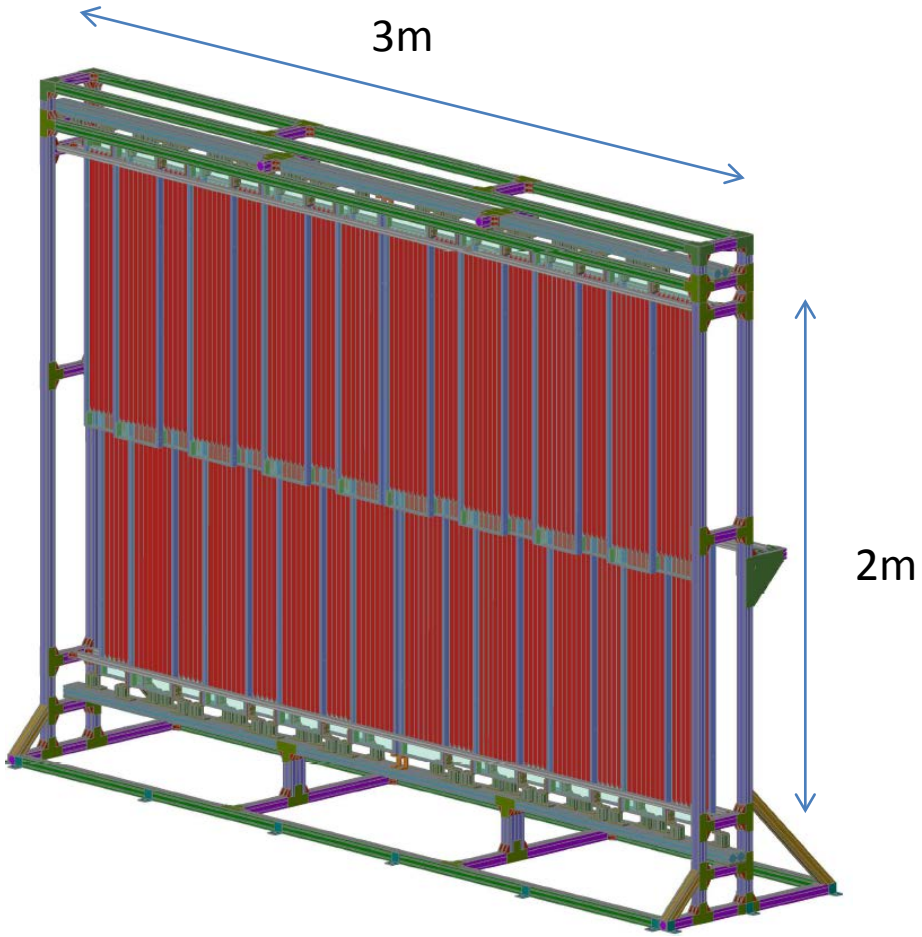
LEPS2 experiment hatch

Resistive Plate Chamber (RPC)

- Focus on mesic nuclei search
  - 12 MeV forward proton momentum resolution

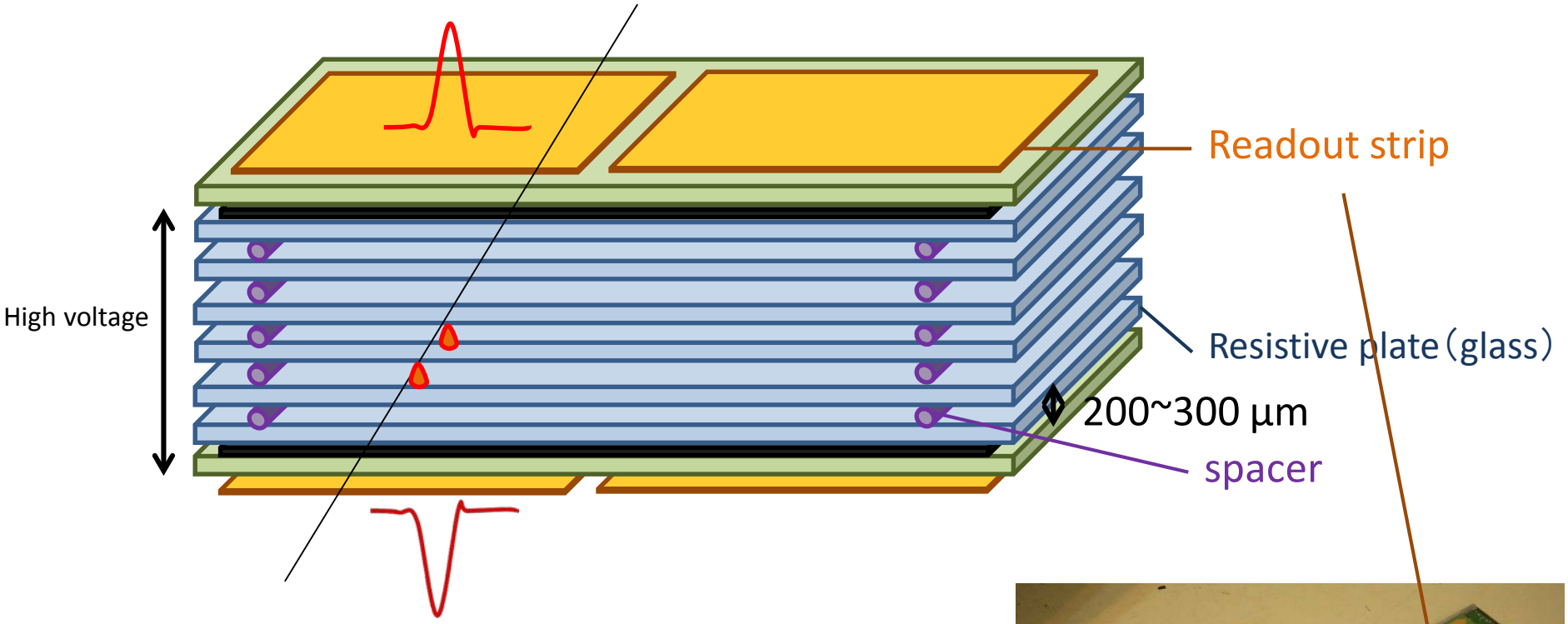
  -> 50 psec time resolution at 12 m flight length



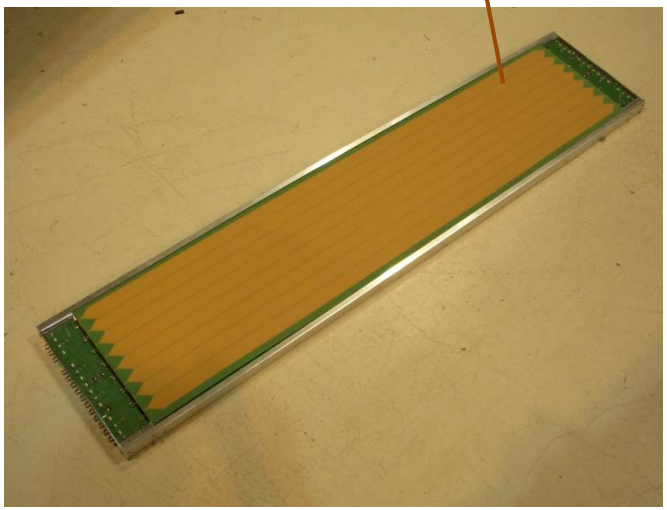


32 modules in wall

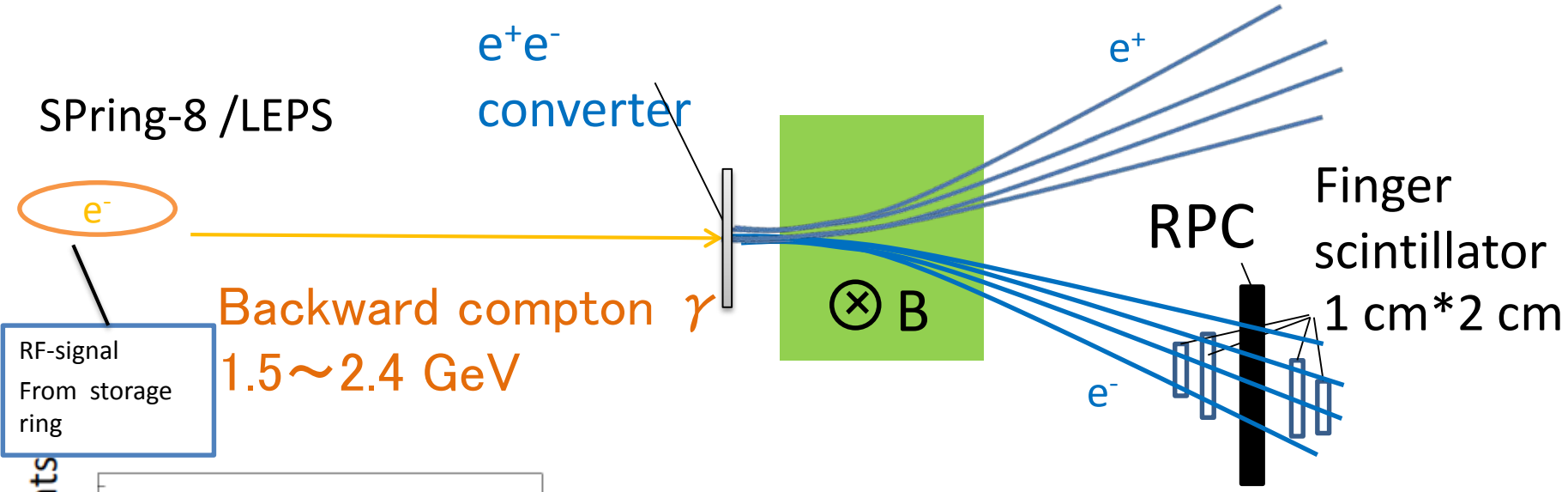
Resistive Plate Chamber (RPC)

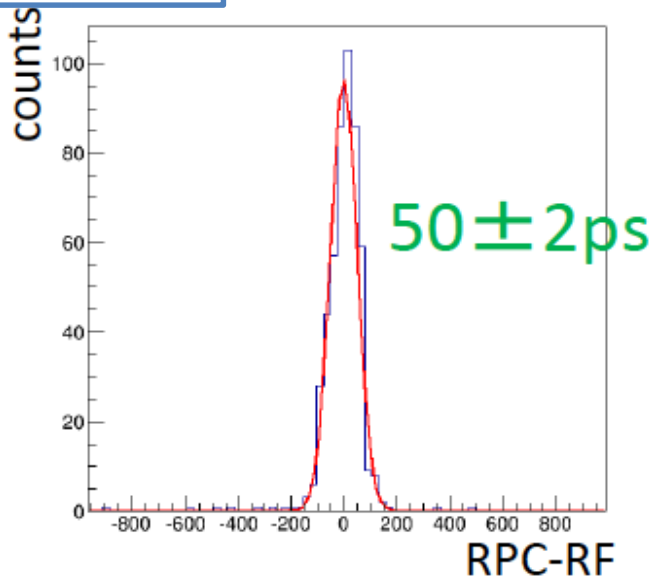


- Glass resistive plate with Freon and SF_6 gas
- Narrow gap
  →good time resolution
- Multilayer
  →high efficiency, resolution



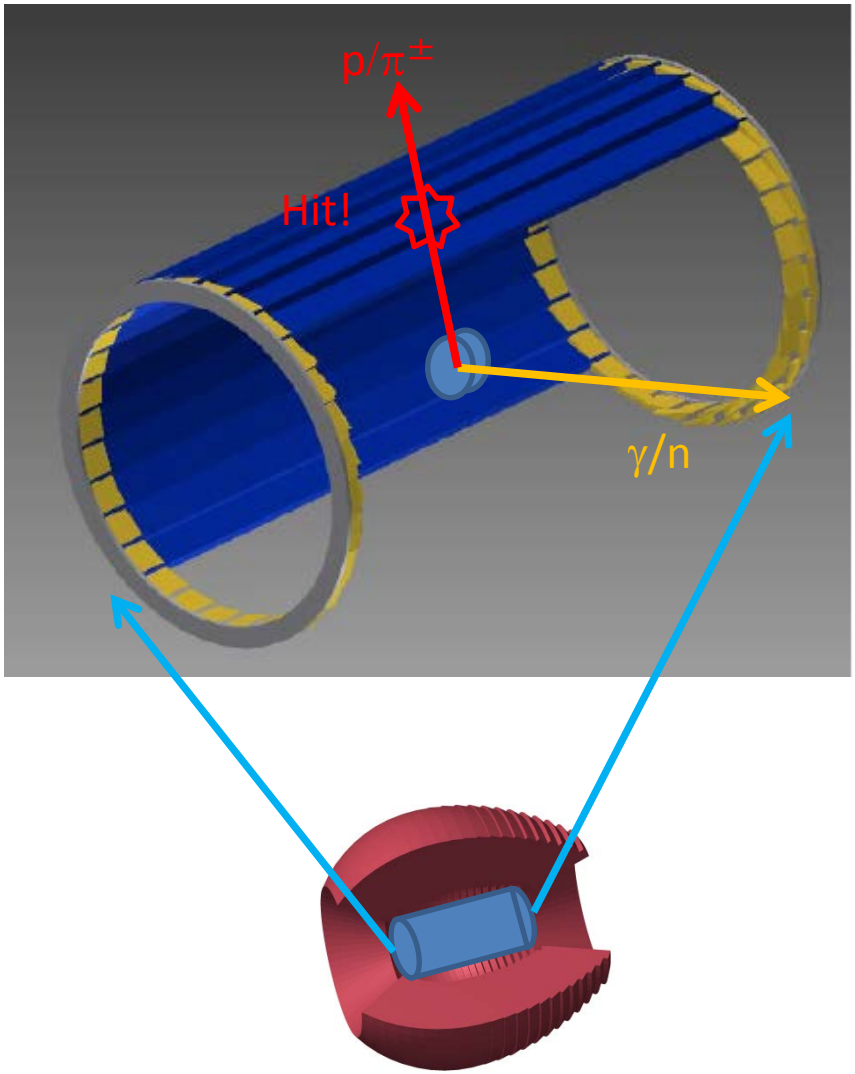
Performance of RPC





- Test experiment for RPC at SPring-8/LEPS
- Electron from converter and Dipole magnet
- Estimated resolution
  - σ ~50 ps !

Charge identification detector



- Place at inside of BGOEGG
- 30 scintillators with overlap.
- Scintillator size
  - 5 x 26 x 413

  -> covering the inner face of BGOEGG
- Multi Pixel Photon Counter (MPPC) readout
  - Effective area 3mm × 3mm
  - Pixel size 50um × 50um

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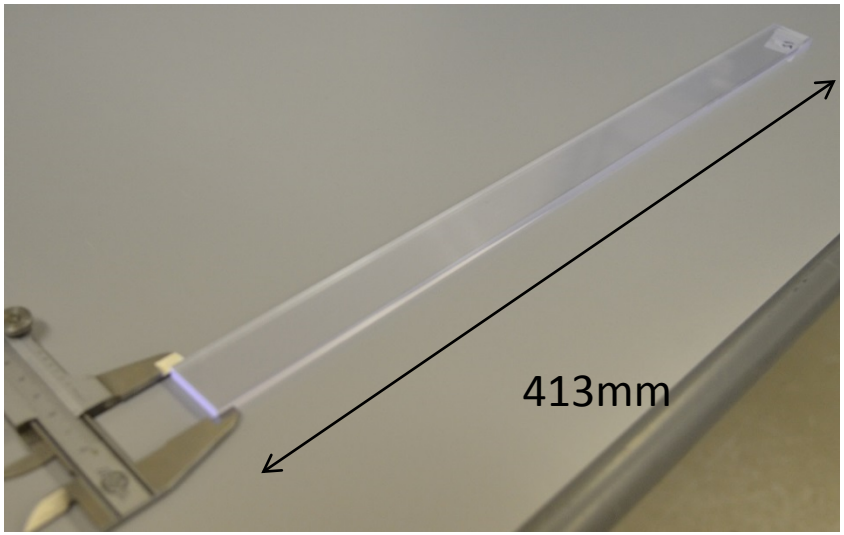
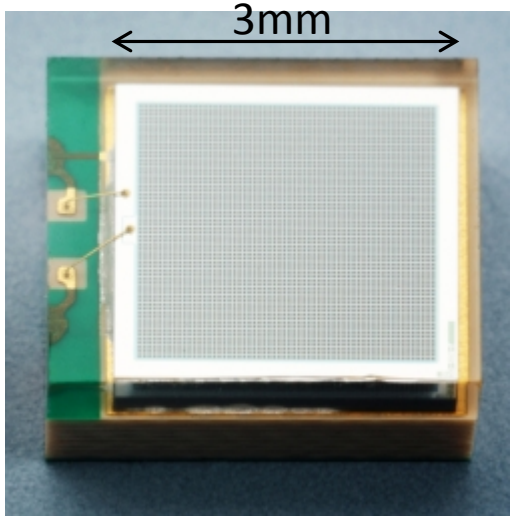


Scintillator

MPPC



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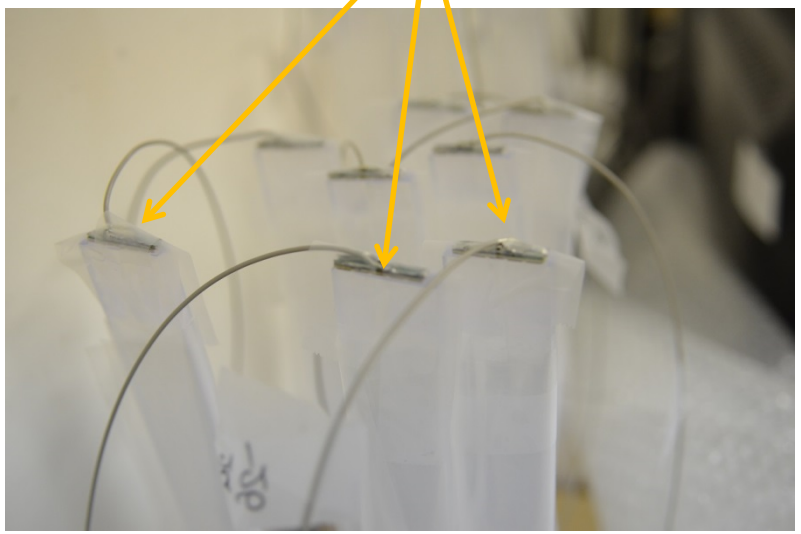
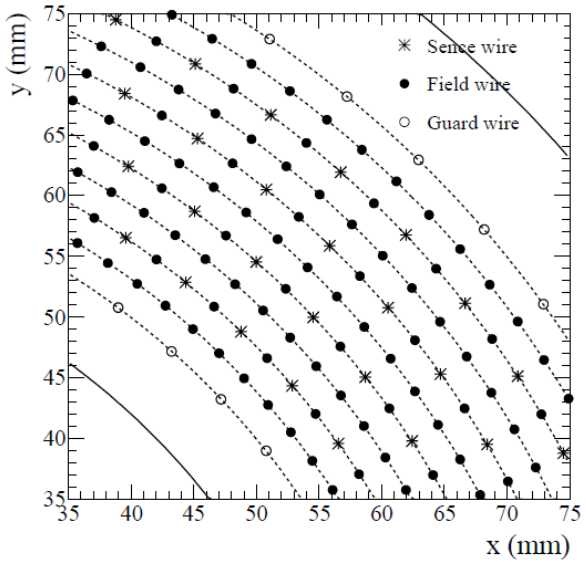
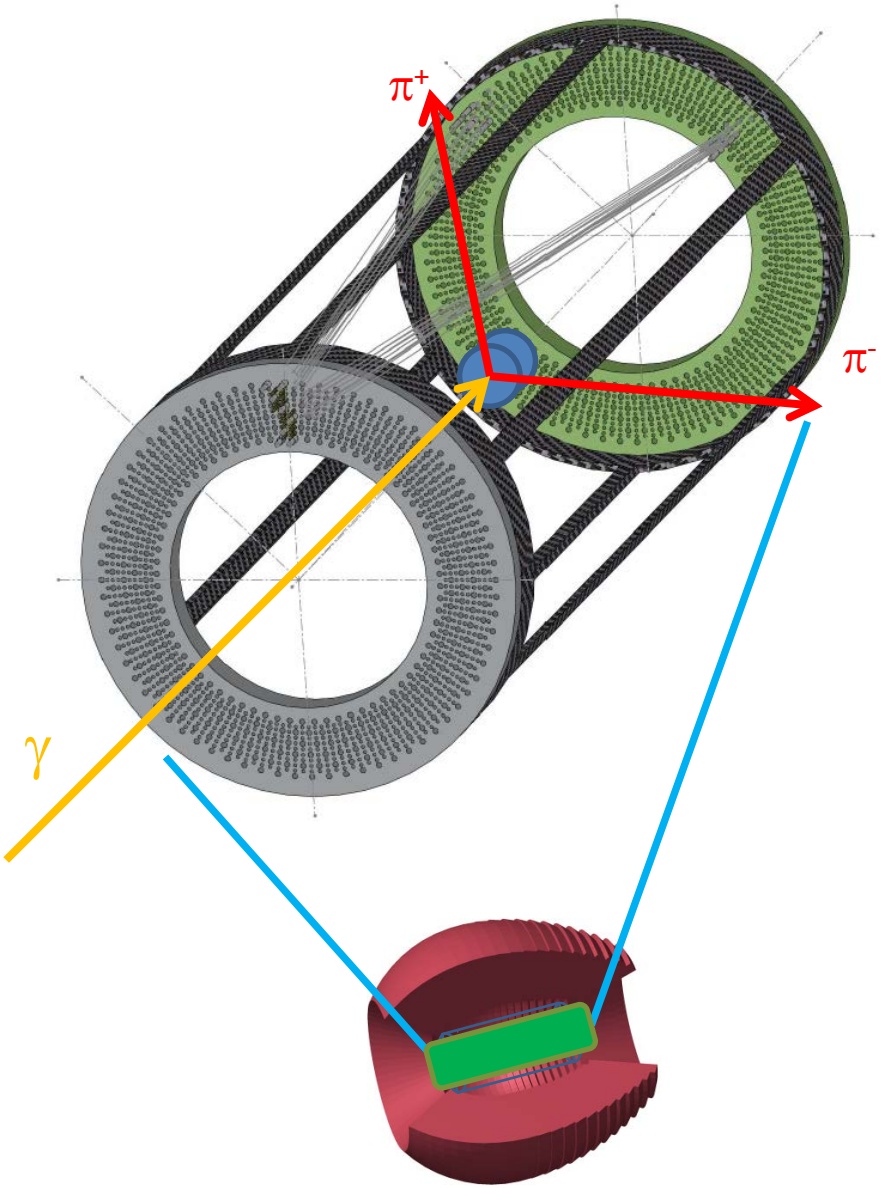


Scintillator with 5-connected MPPC

Charged particle tracker chambers

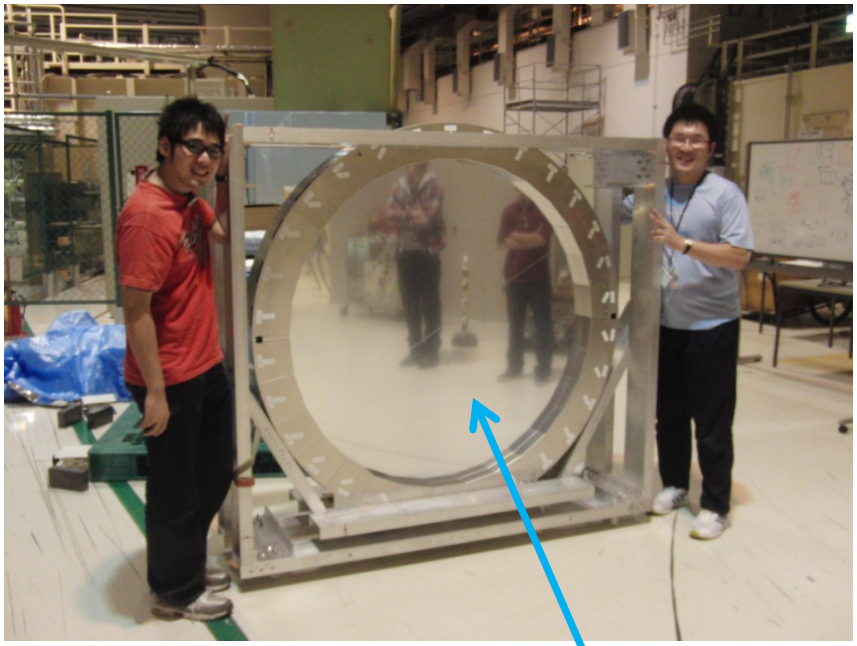
- Inner vertex chamber
- Inside of charge identification detector
- 4 layer (U, U', V, V')
- 550mm length

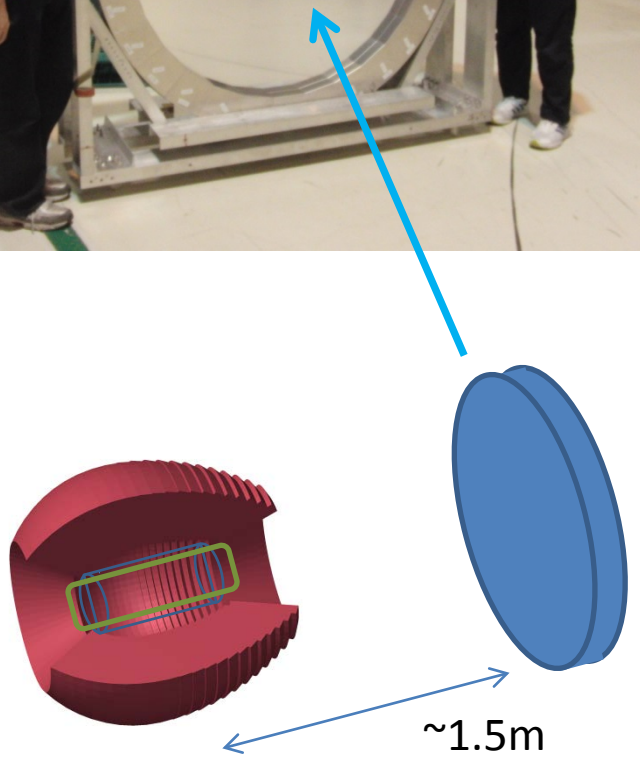




Charged particle tracker chambers

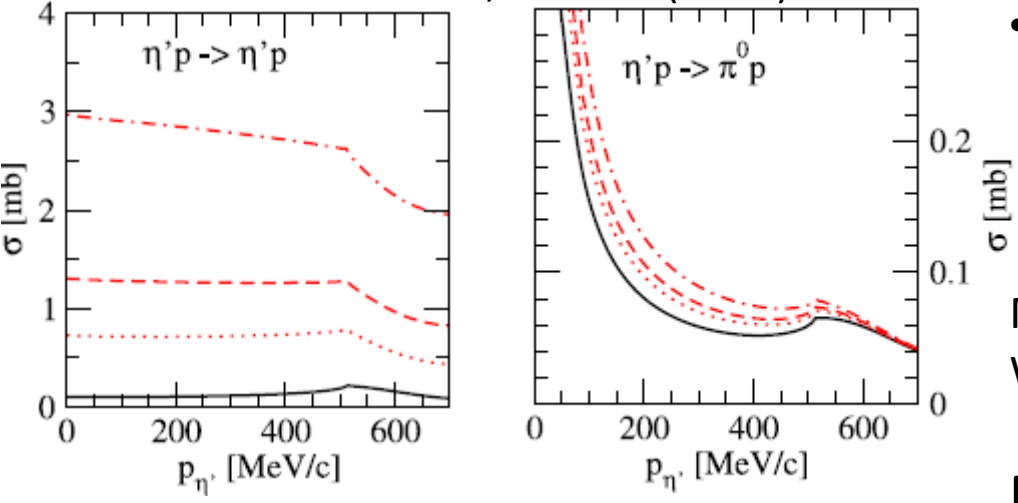
- Charged particle Positions/angles at forward angle(θ<24°)
- 6 planes (XX'UU'VV')
- 80 sense wires / plane
- effective area: ϕ1280mm
- 16 mm square cell
  - σ=130 μm

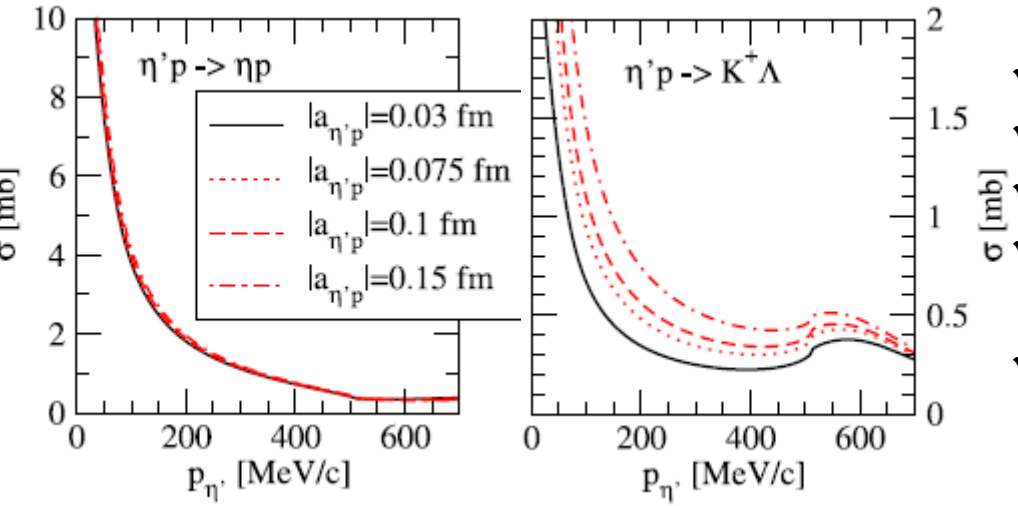




Yield estimation η' mesic nuclei by η tagging at BGOEGG

E. Oset and A. Ramos, PLB704 (2011) 334





- Dominant conversion from η'
  ~ η'p->ηp
  - η -> γγ (39.3%)
  - η -> $\pi^0\pi^0\pi^0$ -> 6γ (33%)

Multi meson production background
Will be suppressed by η tag at BGOEGG!

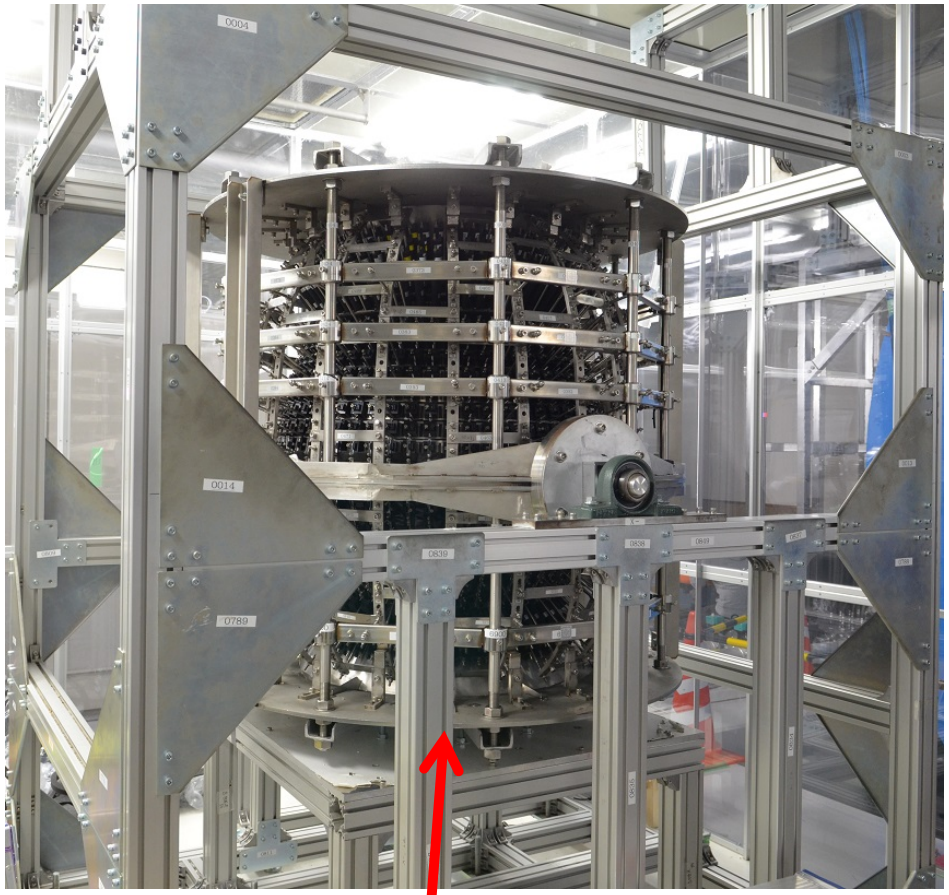
Expected yield

- ✓ $d^2\sigma/dEd\Omega$ ~2nb/sr/MeV
- ✓ Target ~ Carbon 20mm
- ✓ Beam intensity ~ 2Mcps (Tag. Eff~50%)
- ✓ Forward proton with RPC(2x4m)
  -> 70000 event / month
- ✓ With η tag at BGOEGG
  -> 2~3000 event / month
  (η'N->ηN : 50% from bound state)

Summary

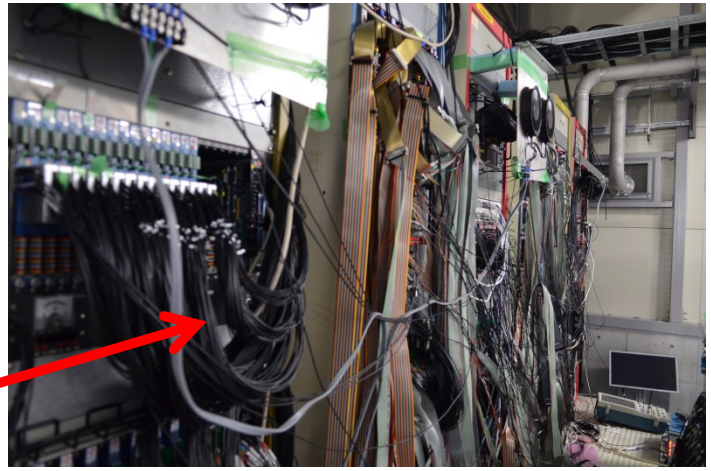
- SPring-8 LEPS2 facility just started
- LEPS2 has one order of magnitude higher intensity beam and large acceptance coverage.
  - BGOEGG, E949 based detectors.
- BGOEGG calorimeter experiments will start in this autumn.
  - η' mesic nuclei, baryon resonance, etc
- Thanks!

This week photos



BGOEGG with all PMTs

RPC support frame



DAQ system