Quark Nuclear Physics at LNS, Sendai

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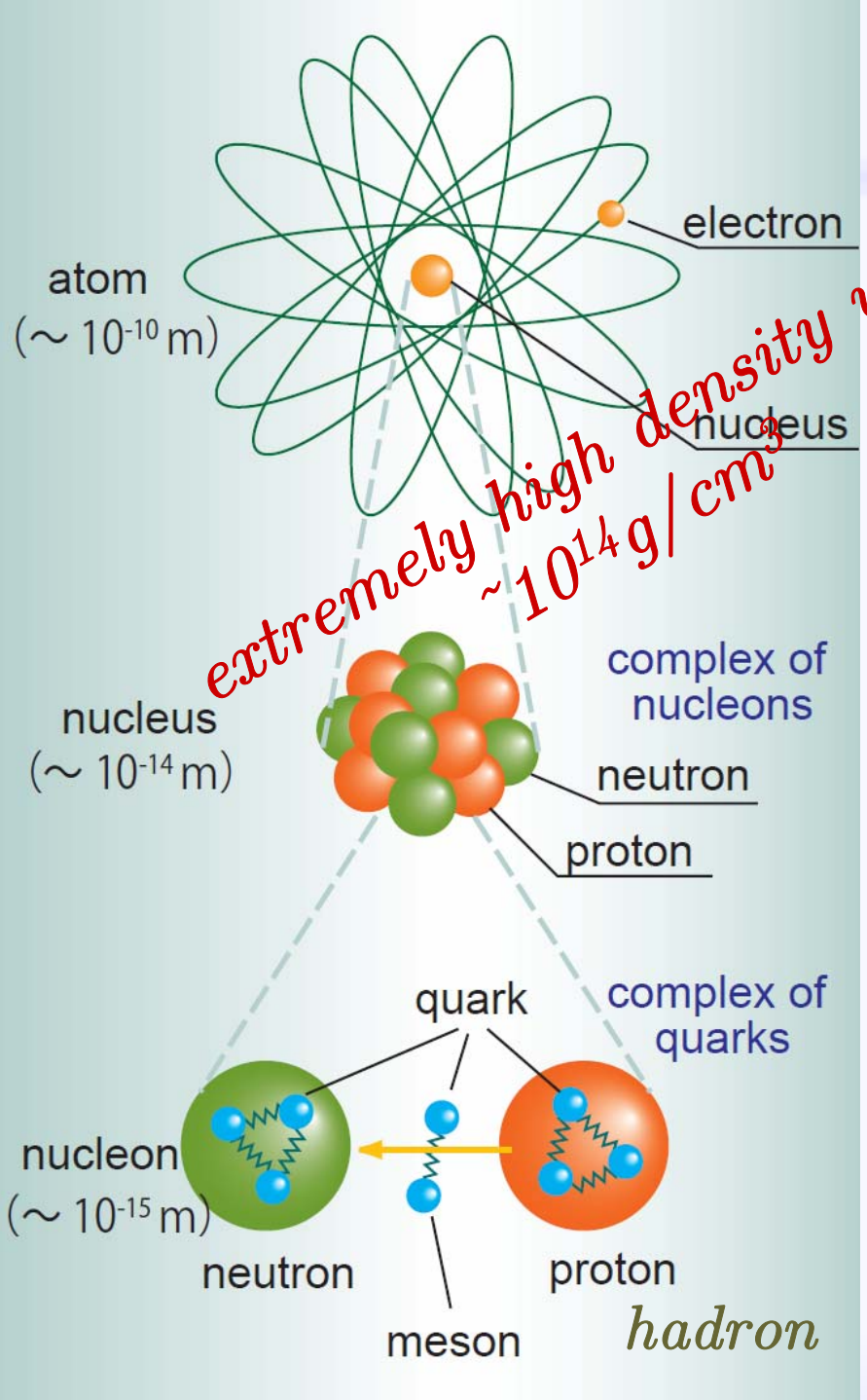
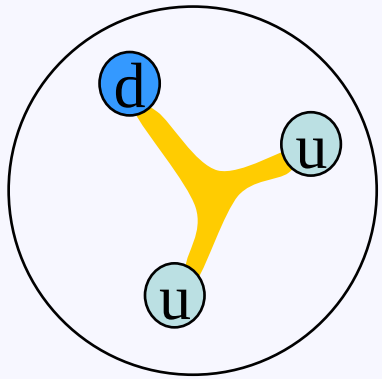


Structure of hadrons



Quark Nuclear Physics

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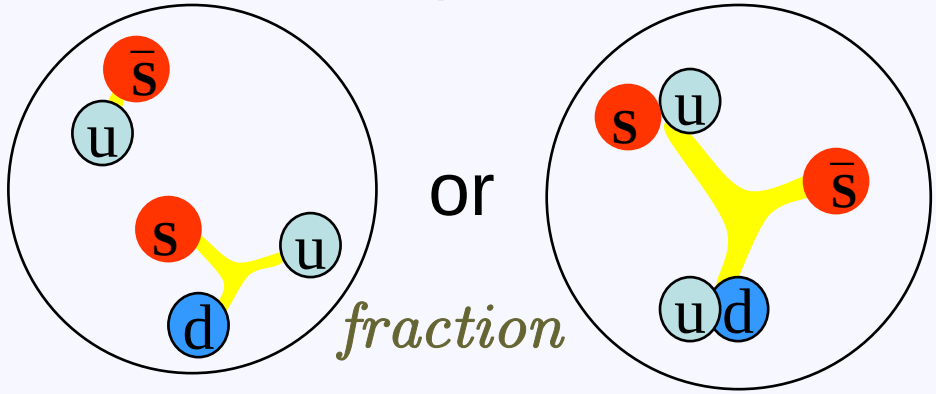


fraction

subject:

di-quark cluster (5-quark) picture:

$$|p\rangle \sim |uud\rangle + \varepsilon 1\,|[ud][ud]\bar{d}\rangle + \varepsilon 2\,|[ud][us]\bar{s}\rangle + \ldots$$

Classification of hadrons (color SU(3) scheme)

- ***meson*** $q\bar{q}$ $u\bar{d}:\pi^+$ $\bar{u}d:\pi^-$

$$3\otimes\bar{3}=8\oplus\underline{1}$$

- ***baryon*** qqq $uud:p$ $udd:n$

$$3\otimes3\otimes3=10\oplus8\oplus8\oplus\underline{1}$$

QCD allows exotic hadrons having different configurations

* ***meson*** $q\bar{q}q\bar{q}$ $c\bar{c}u\bar{u}:X(3872)$

* ***baryon*** $qqqq\bar{q}$ $uudd\bar{s}:\Theta^+$

color singlet states pentaquark baryon

search for

Exotic Hadrons

in these decades

intensive work on

- ***dibaryons*** $qqqqqq$
- ***baryoniums*** $qq\bar{q}\bar{q}$
- ***hybrid hadrons*** $qqqg, q\bar{q}g$
- ***glueballs*** gg
- ……

No clear exotics were established before!

narrowness of the width

⇑ ***the key for identification of exotics*** ⇐ ***not have to be narrow (fall-apart decay)***

⇑ ***extra degrees of freedom***

Θ^+ ***came in.***

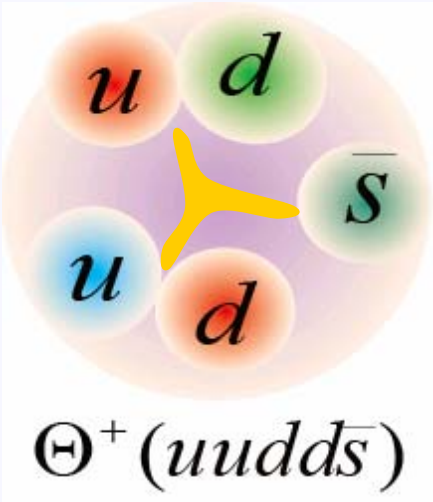
$S=+1$

- ***pentaquark*** $uudd\bar{s}$

$\overline{10}$

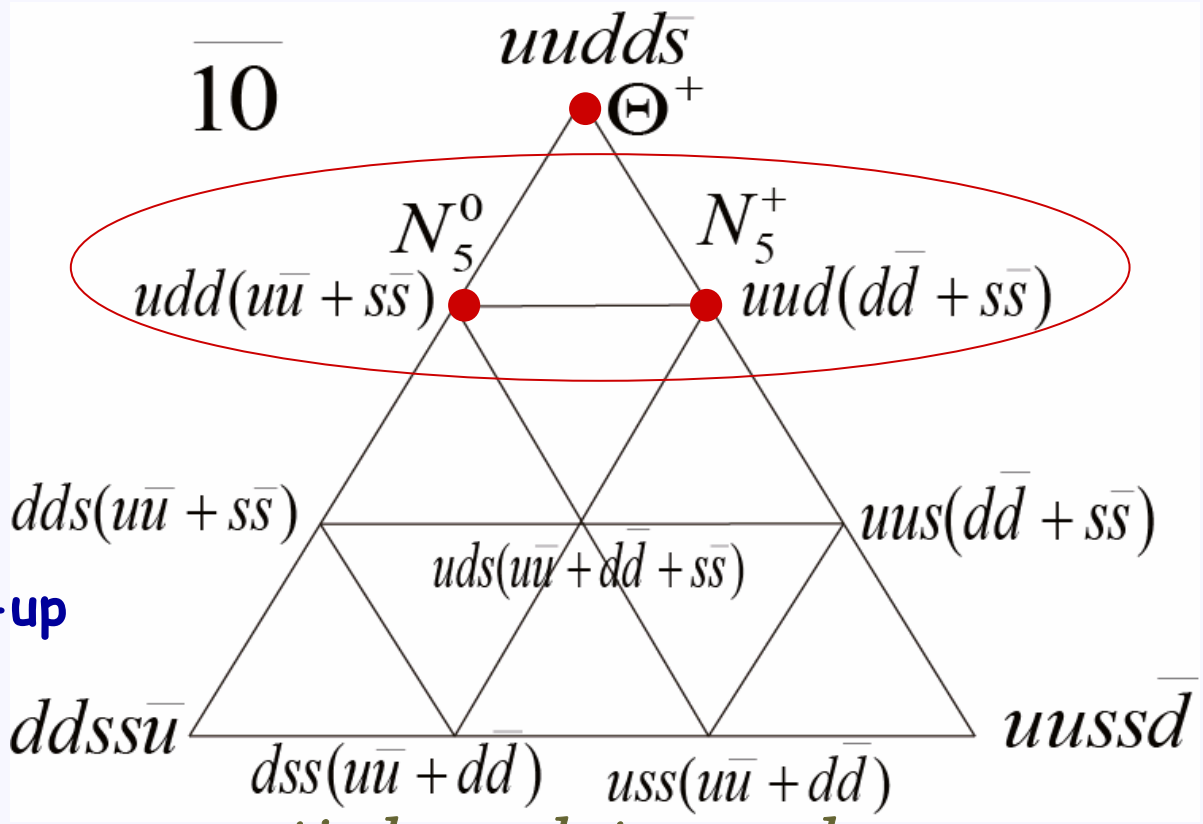
Search for other members of the anti-decuplet

Pentaquark baryons



quantum number (S=+1)

impossible to be built-up with any 3q system

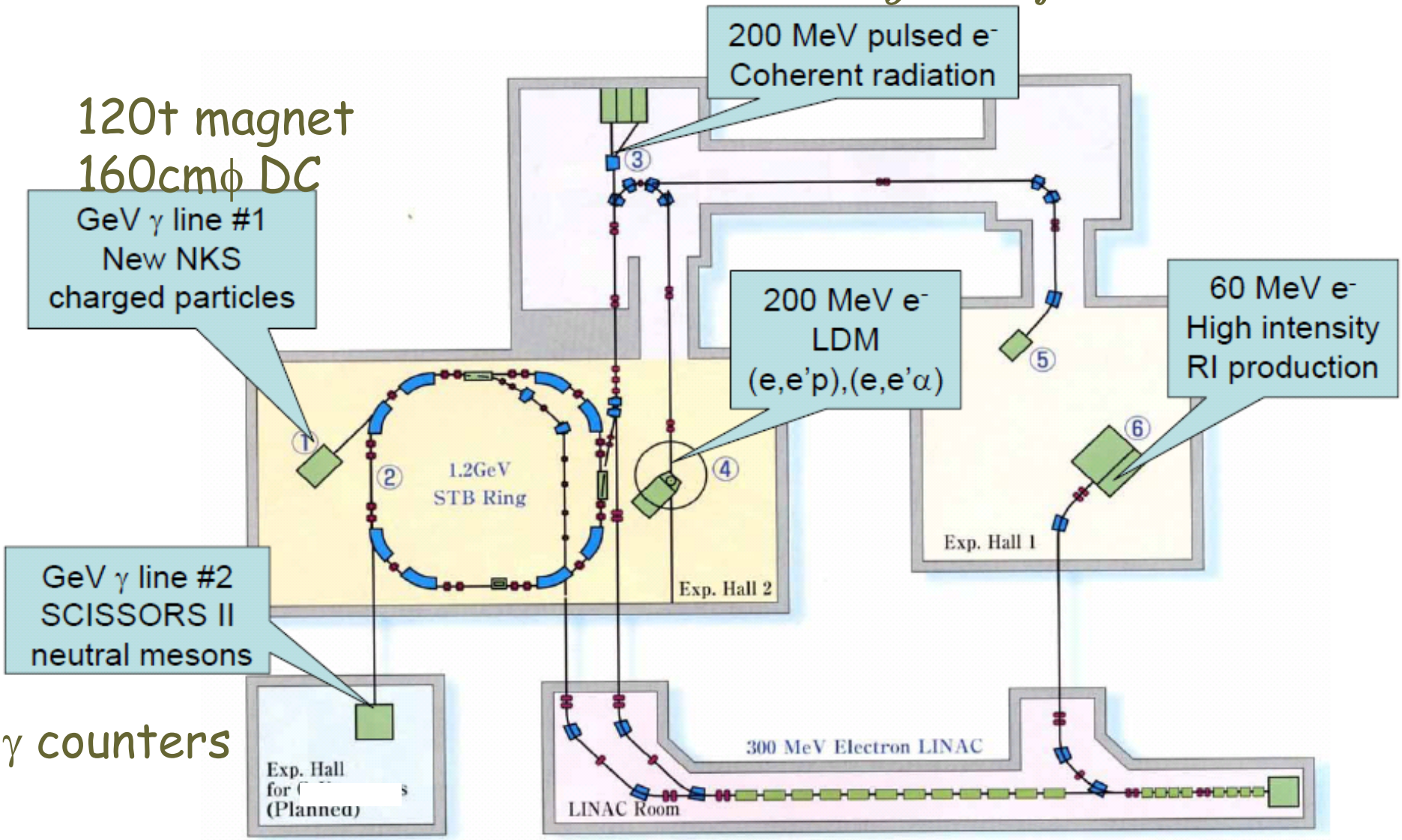


anti-decuplet members

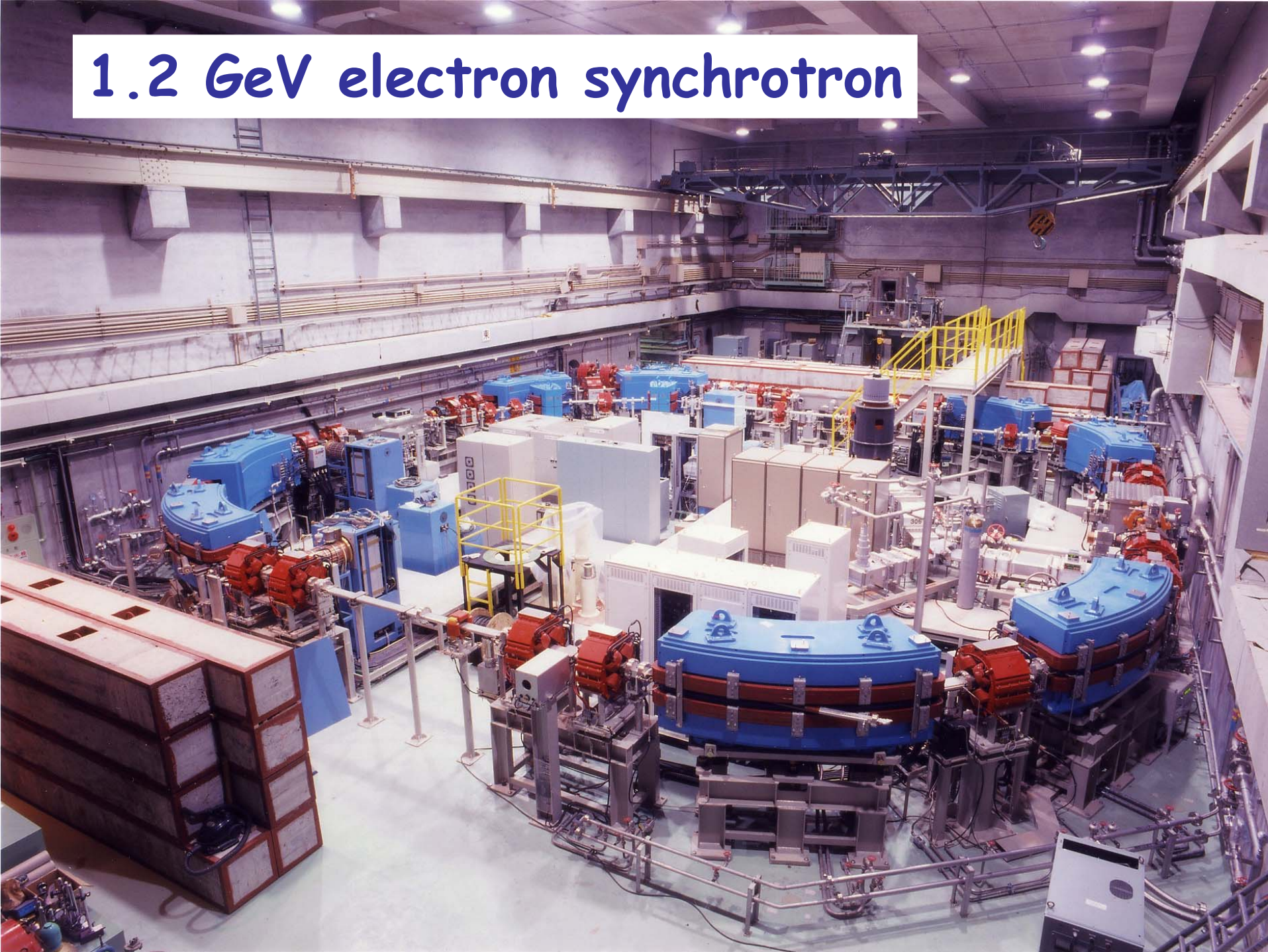
mass of N_5^0 and N_5^+ : ~1680 MeV/c^2 (prediction)

GeV γ experiments at Laboratory of Nuclear Science (LNS)

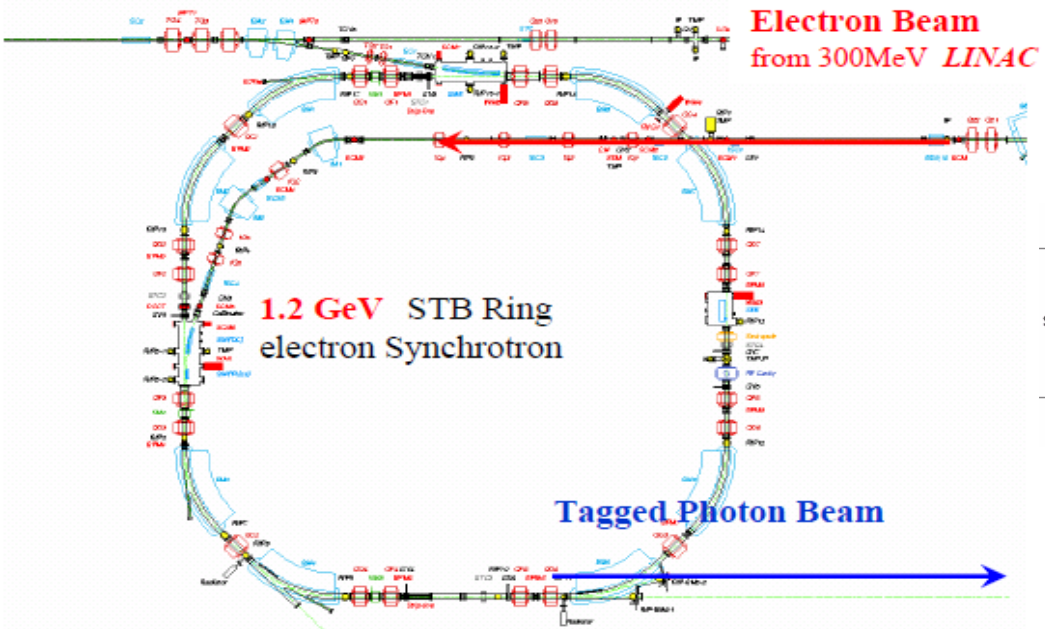
layout of beam lines



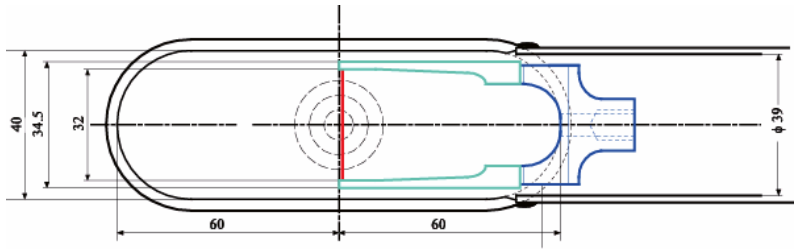
1.2 GeV electron synchrotron



GeV γ experiments at LNS



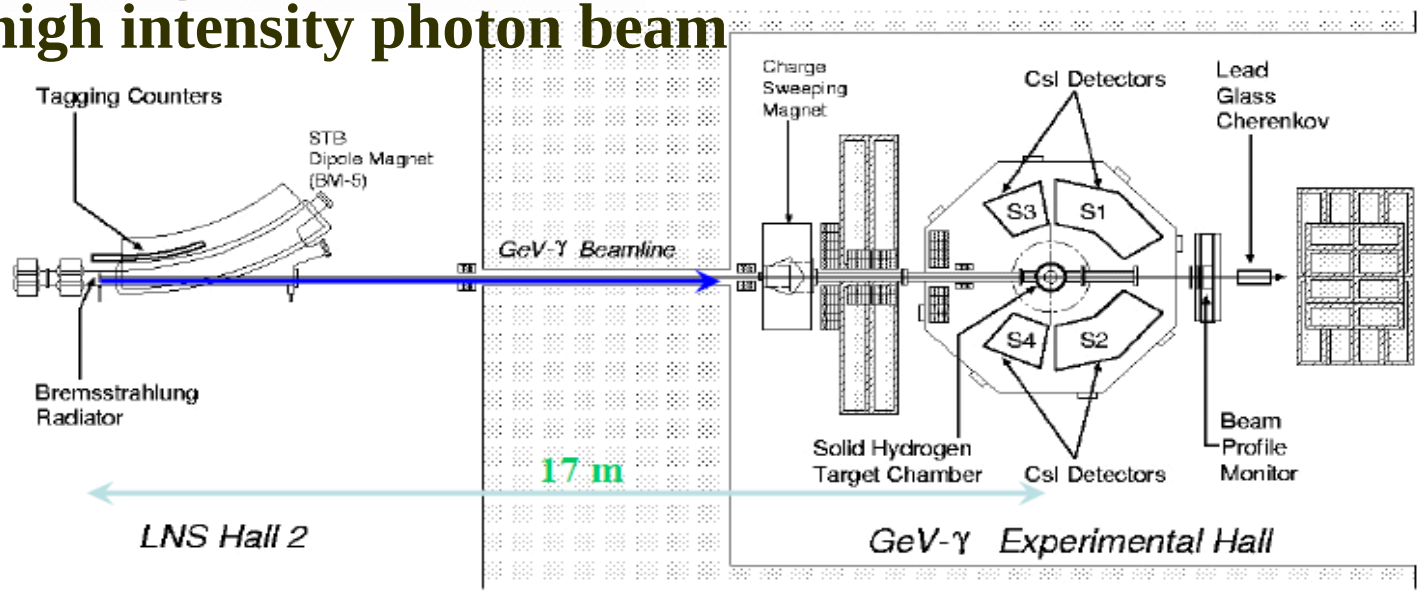
internal radiator



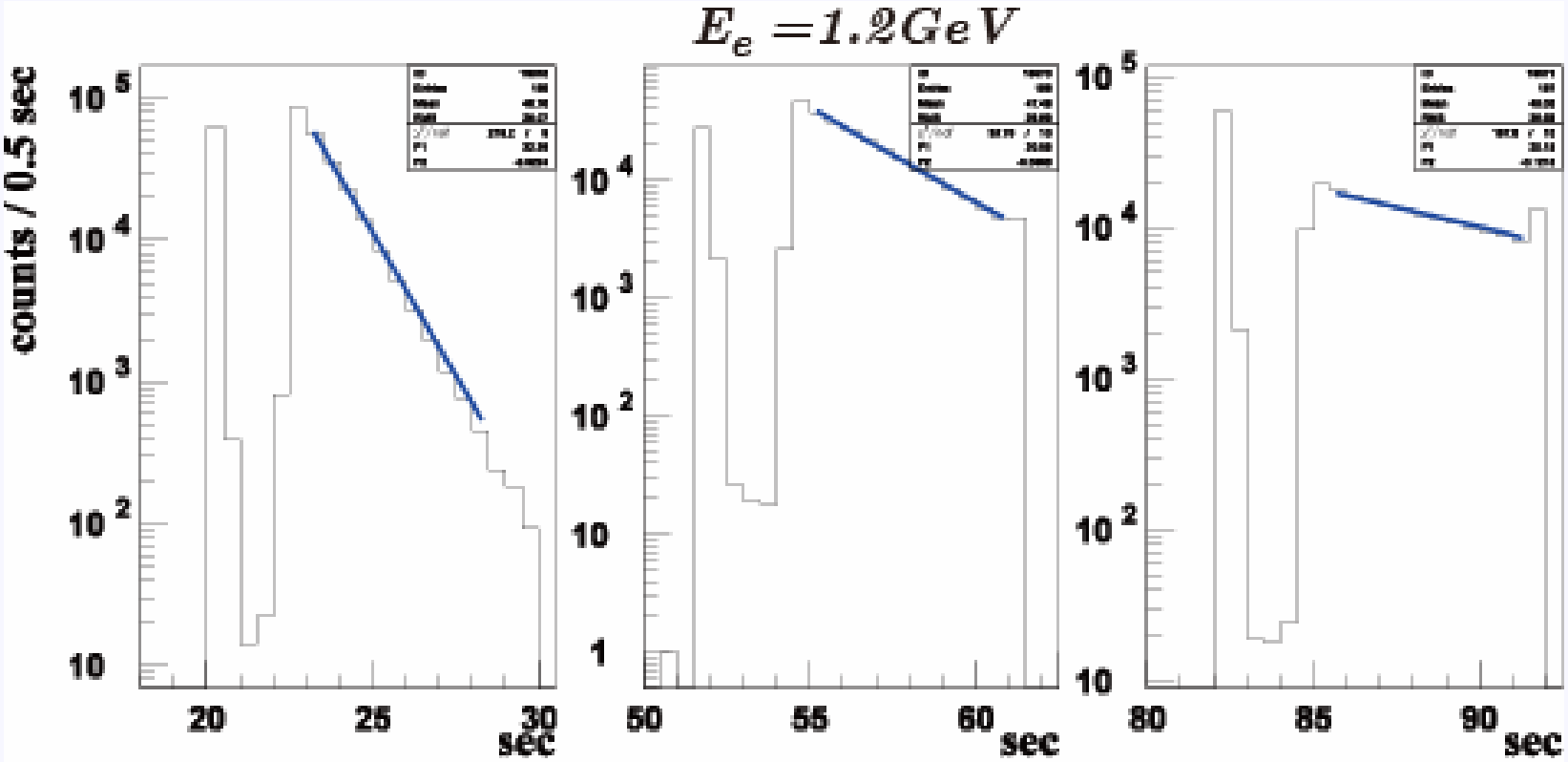
carbon fiber 11μmϕ

GeV-γ Experimental Hall

very high intensity photon beam

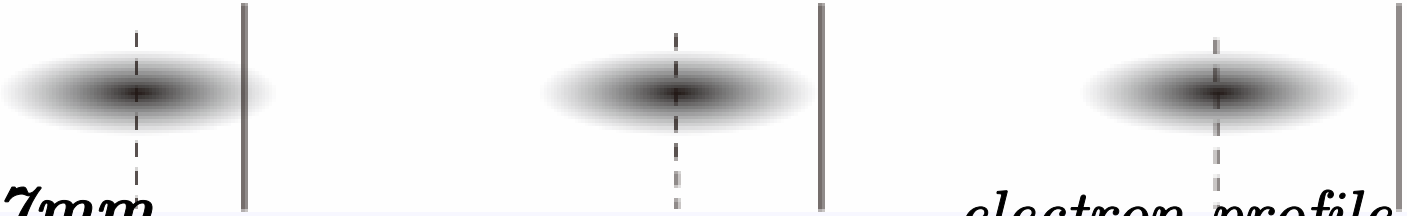


Intensity of circulating electrons



2.1 mm *2.3 mm* *2.5 mm*

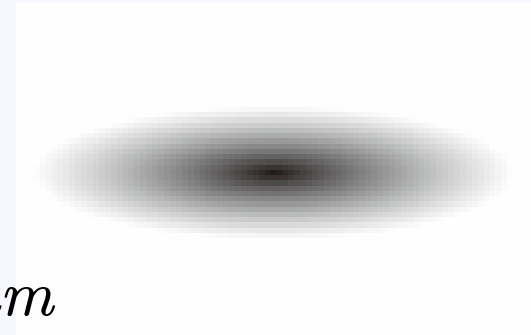
carbon fiber



$\sigma_x = 0.7mm$

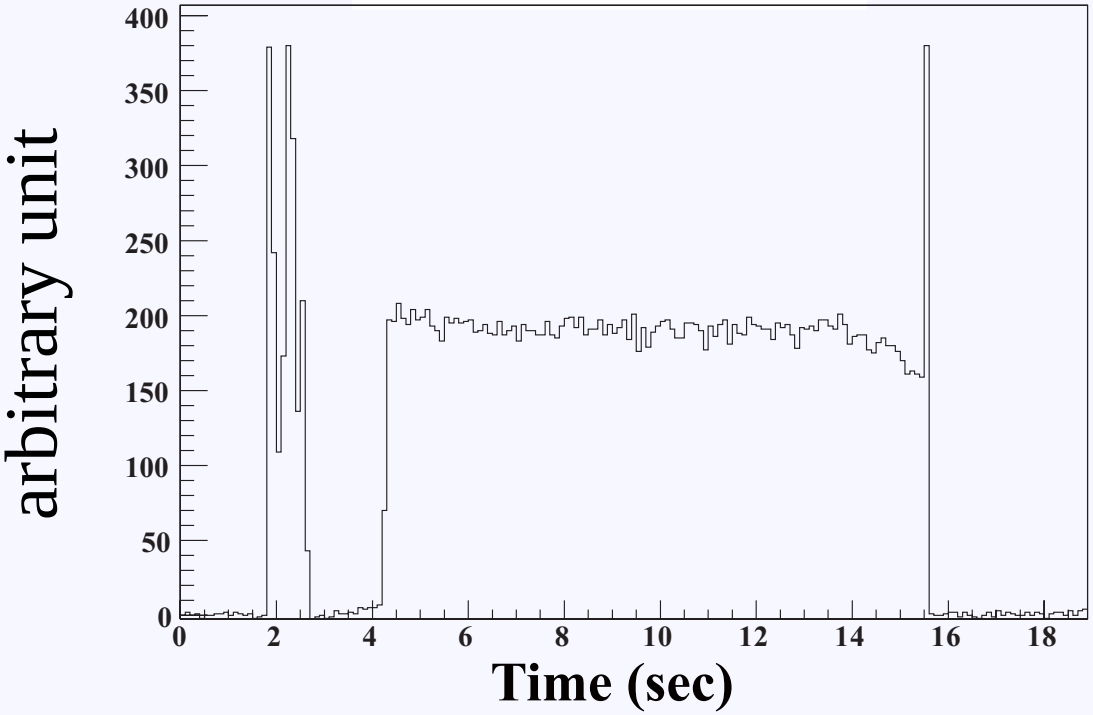
electron profile

Intensity control for the photon beam



radiator

$\sigma x \sim 0.7mm$



constant intensity

$2x10^7$photons/s

Time dependence of the photon beam intensity

previous

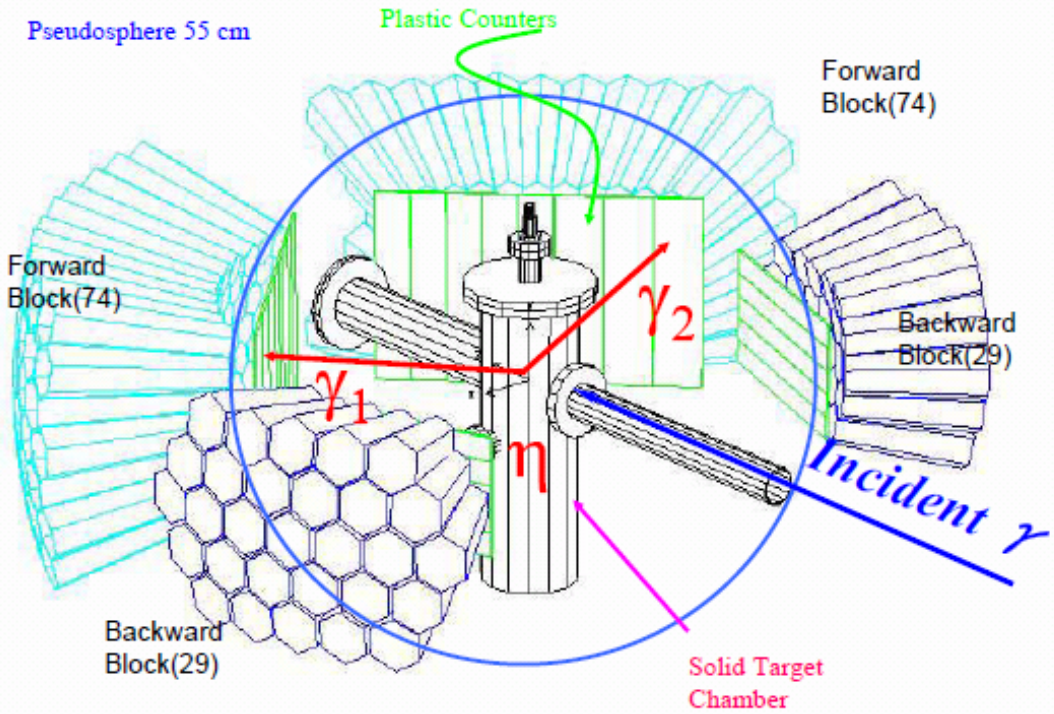
Experimental setup

SCISSORS II **:206 pure CsI Crystals**

(1.57 str = 12.5% of 4 π)

16.2 X_0 for Forward 148 crystals

13.5 X_0 for Backward 58 crystals



Hydrogen/Deuterium

Solid Target

t = 8 cm (N_T ~4 × 10^{23}/cm^2)

$$\gamma + N \rightarrow \eta + X$$

Identification of η meson

$\Gamma_{\eta-\gamma\gamma} = (39.43 \pm 0.26)\%$

→ γγ Decay Channel

γγ Invariant Mass Analysis

$$M_{\gamma\gamma}^2 = 2E_{\gamma_1}E_{\gamma_2}(1 - \cos\Phi_{\gamma\gamma})$$

Energy $:E = \Sigma E_i$

Position $:R = \Sigma R_i E_i / \Sigma E_i$

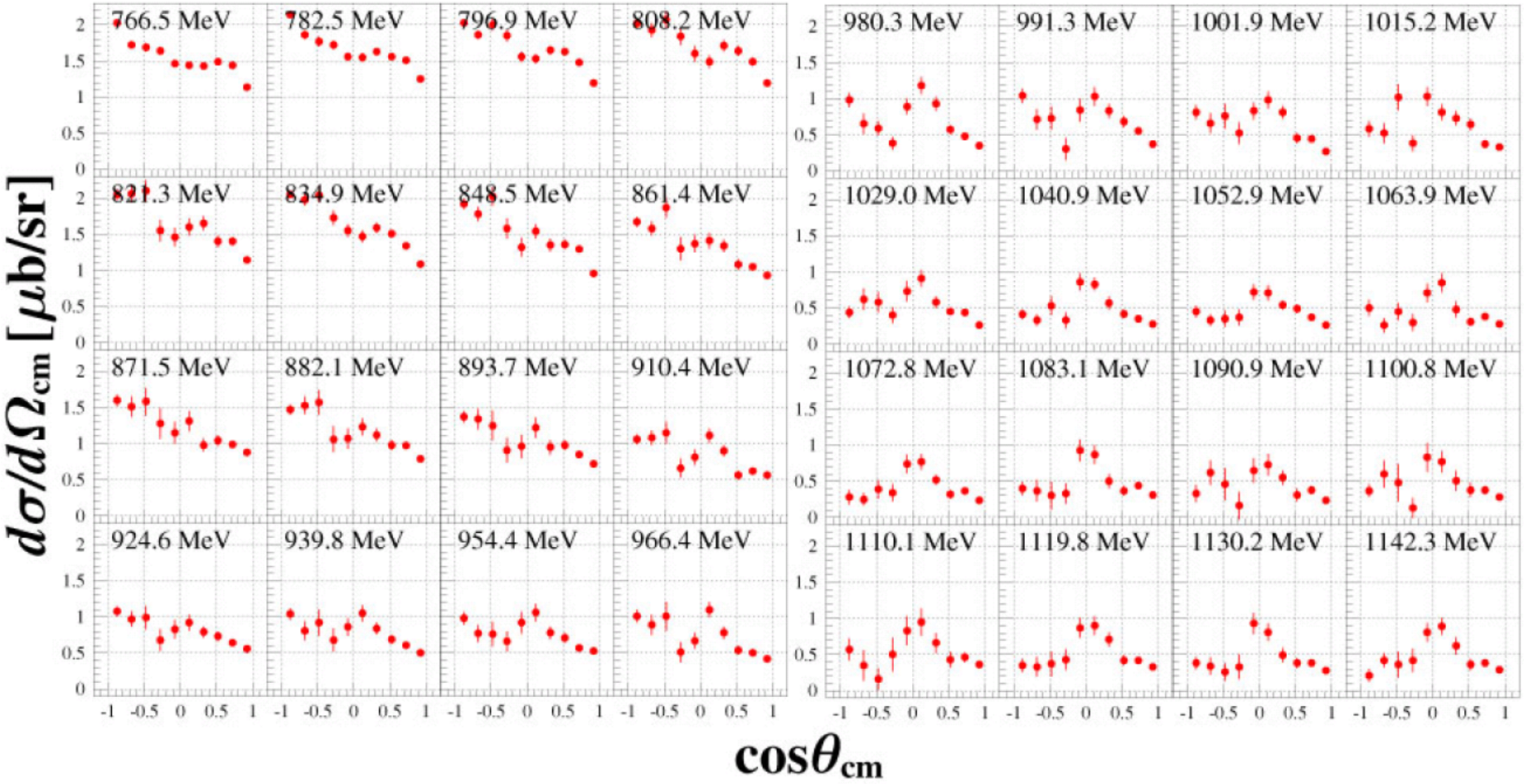
Differential Cross Section (D)

$\gamma d \rightarrow \eta np$

Normalization

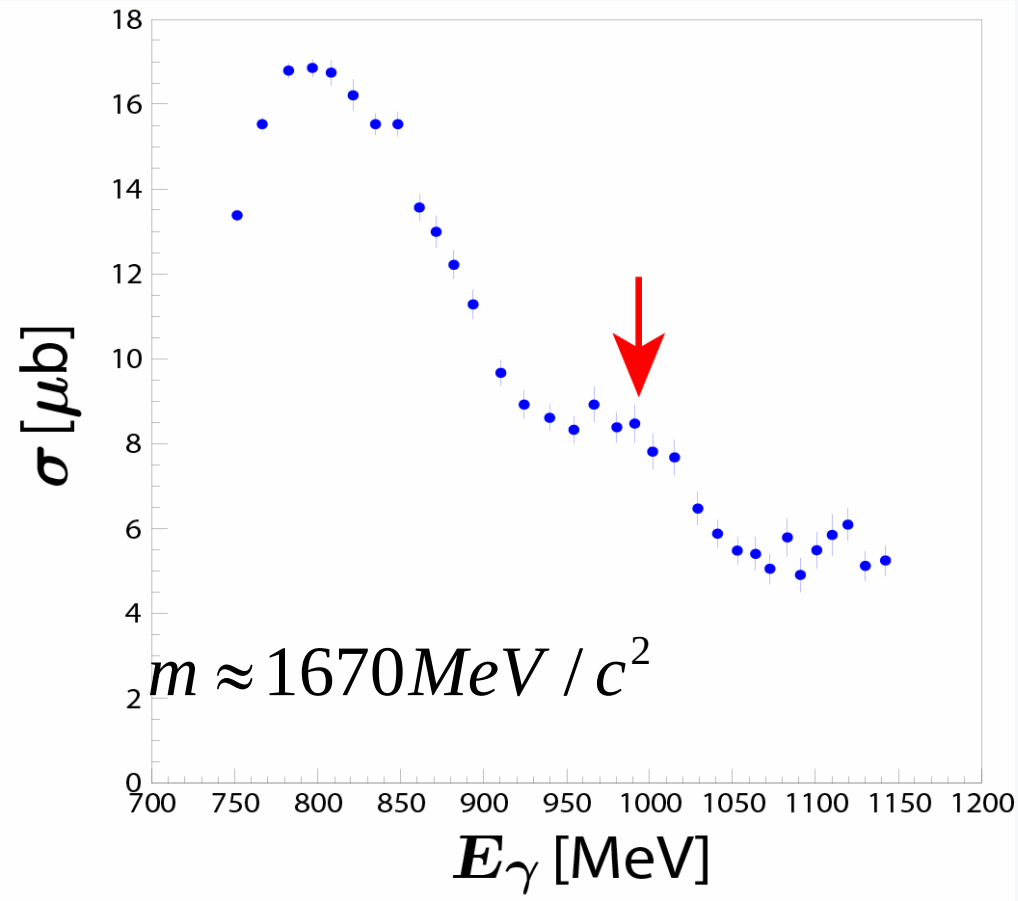
#Incident Photons, #Target Nuclei, DAQ Efficiency

Acceptance, Branching Ratio



Cross section for $\gamma d \to \eta np$

deuteron



There are several theoretical works.

U-spin conservation

EM interaction $\not\Rightarrow$ ***I-spin***
$\Rightarrow$ ***U-spin***

members of a U-spin multiplet have the same Q.

"pentaquark nucleons" N_5^0 N_5^+

$U-spin$ 1 $3/2$

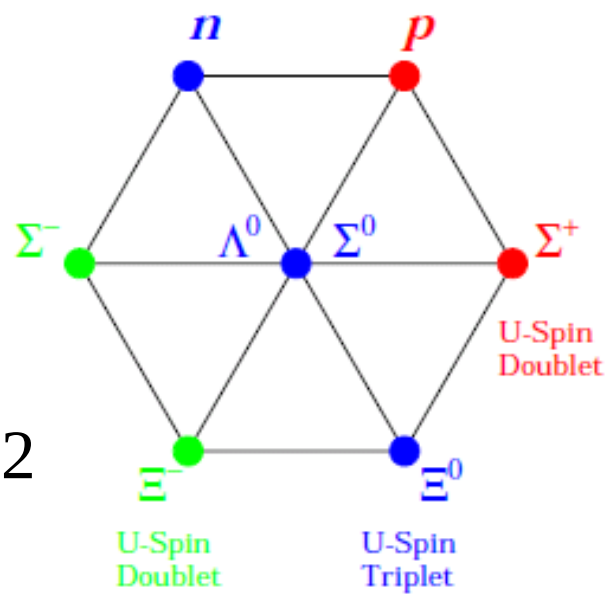
Members of $\overline{10}$ ***with hidden-strangeness***

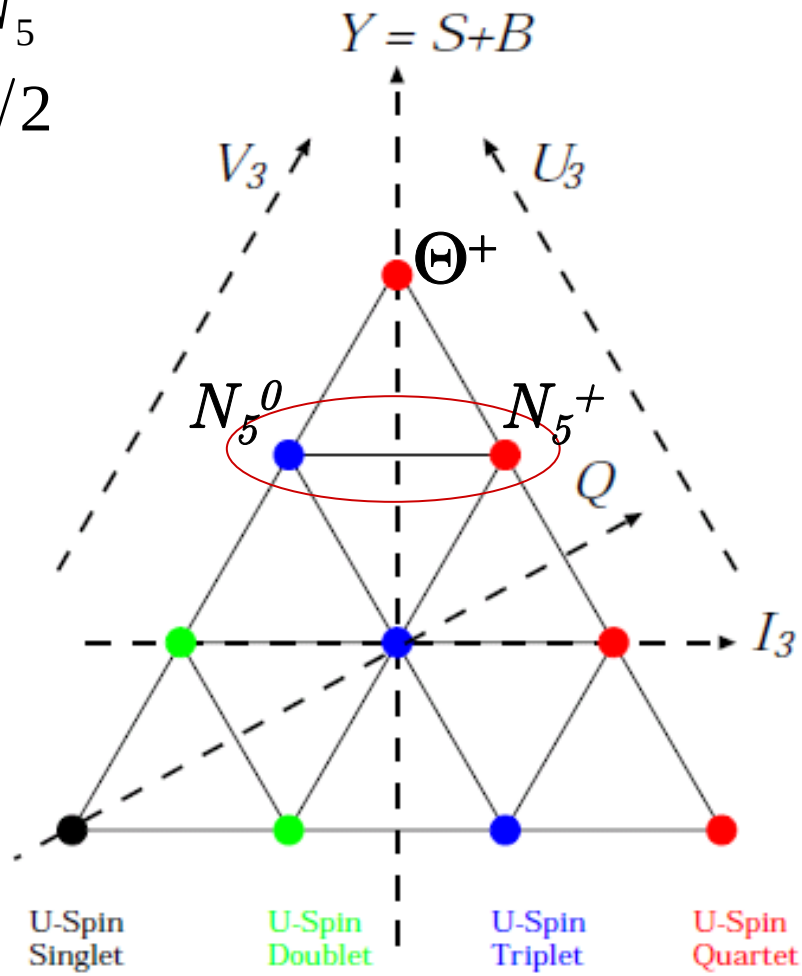
$\gamma + n \to N_5^0$

$0 \oplus 1 \to 1$

$\gamma + p \not\to N_5^+$

$0 \oplus 1/2 \not\to 3/2$





Research project

SPring-8/LEPS: *pentaquark* **$\Theta^+(1540)$**

STB ring at LNS: *narrow* **$N^*(1670)$**

⇒ *to reveal structure of hadrons*

aim

- ***to determine the spin and parity of N*(1670)***
  detection of neutral mesons decaying into photons

  ⇒ **4π γ *detector***

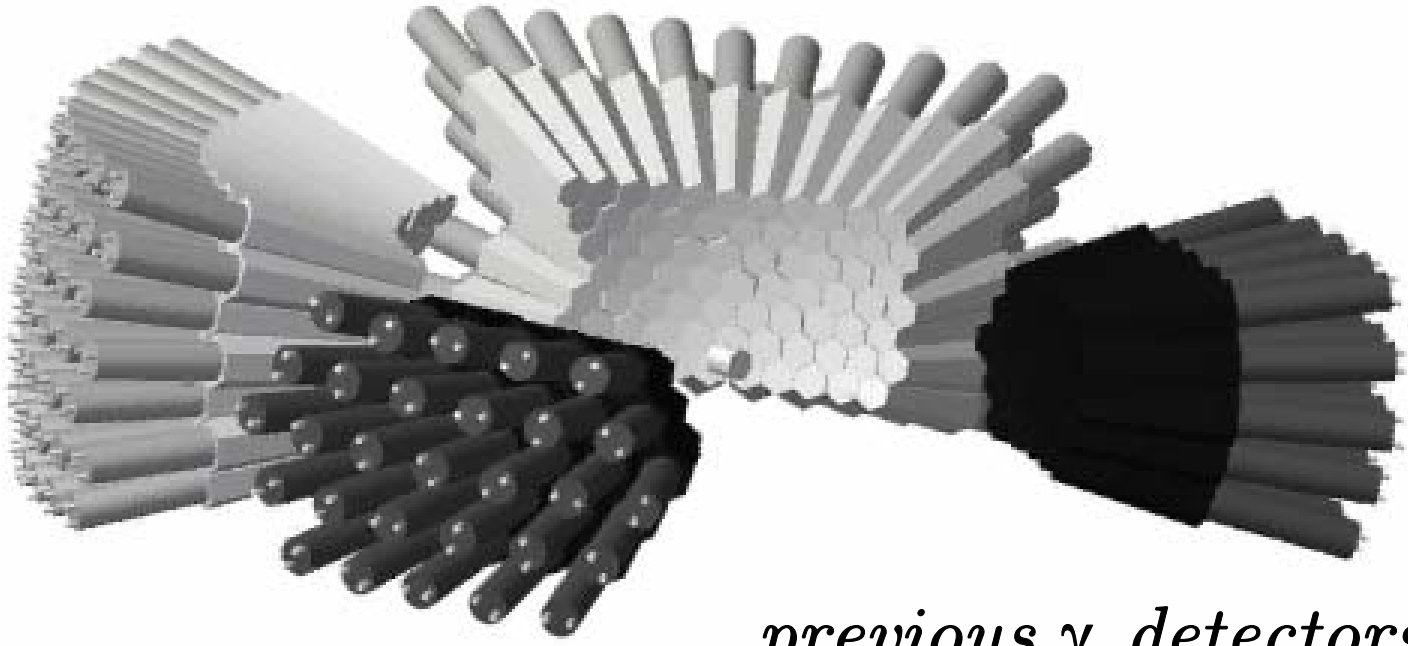
  $N^*(1670) \rightarrow \eta n$

  $N^*(1670) \not\rightarrow \pi^0 n$

- ***to establish anti-decuplet scheme experimentally***

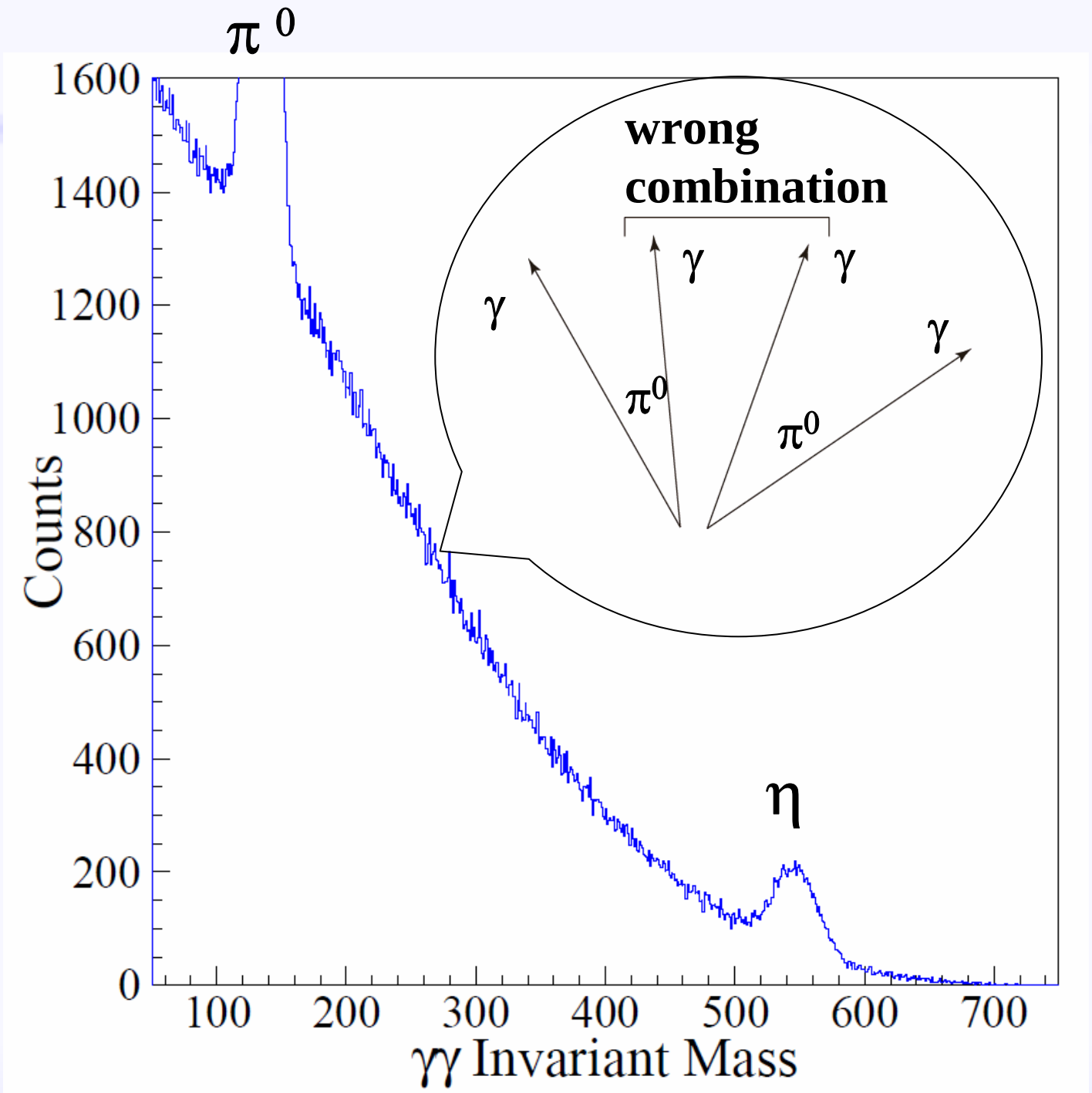
one of the most important subjects
in quark nuclear physics

Demonstration for multi photon detection



previous γ detectors

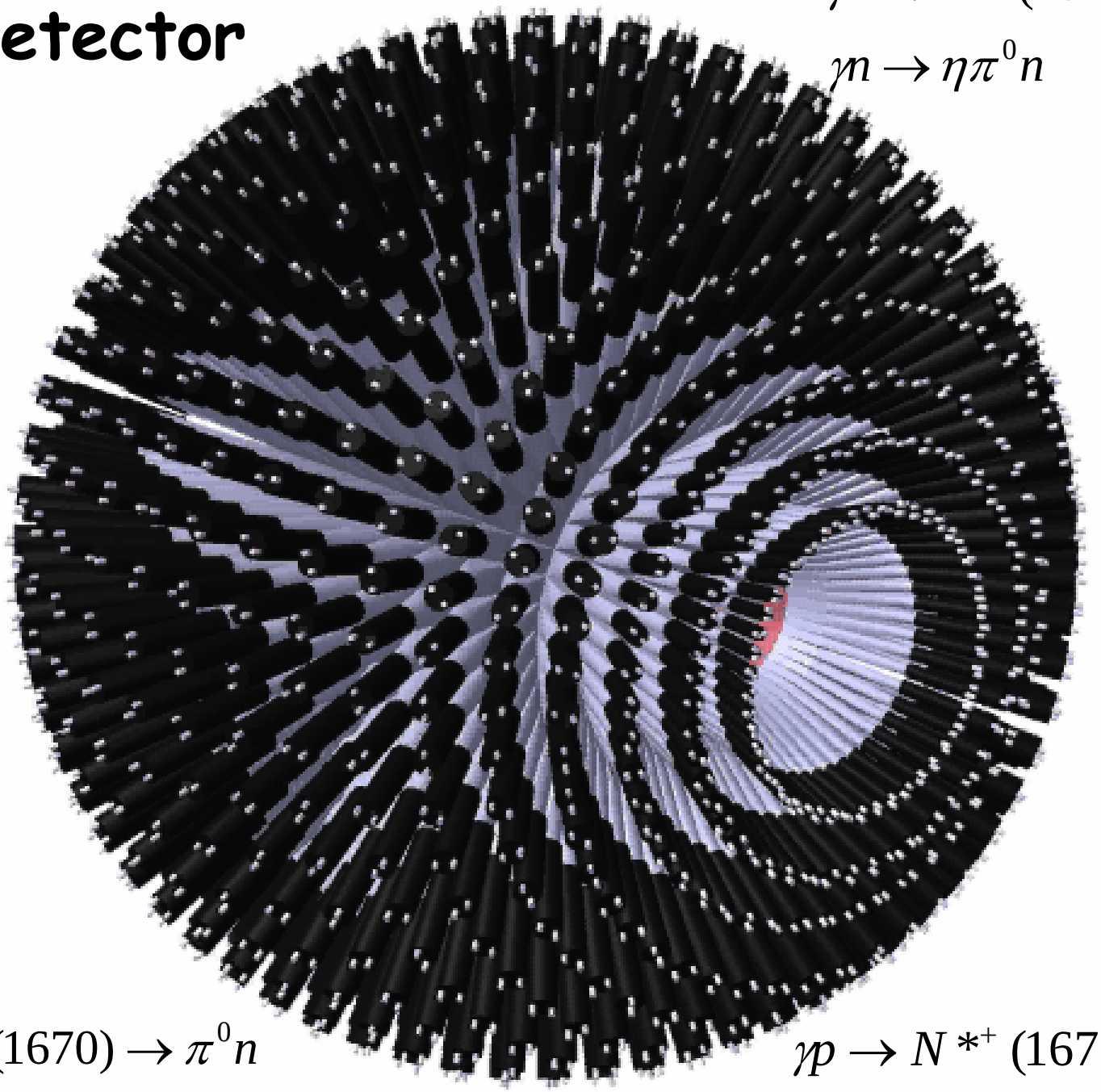
$2\pi^0$ *production:* $\pi^0 \to \gamma\gamma$, $\pi^0 \to \gamma\gamma$ + *single* π^0, *single* η


π 0
wrong
combination
γ
γ
γ
γ
γ
π0
π0
η
Counts
γγ Invariant Mass
0
200
400
600
800
1000
1200
1400
1600
100
200
300
400
500
600
700

$4\pi\,\gamma$ detector

$\gamma n \to N^*(1670) \to \eta n$

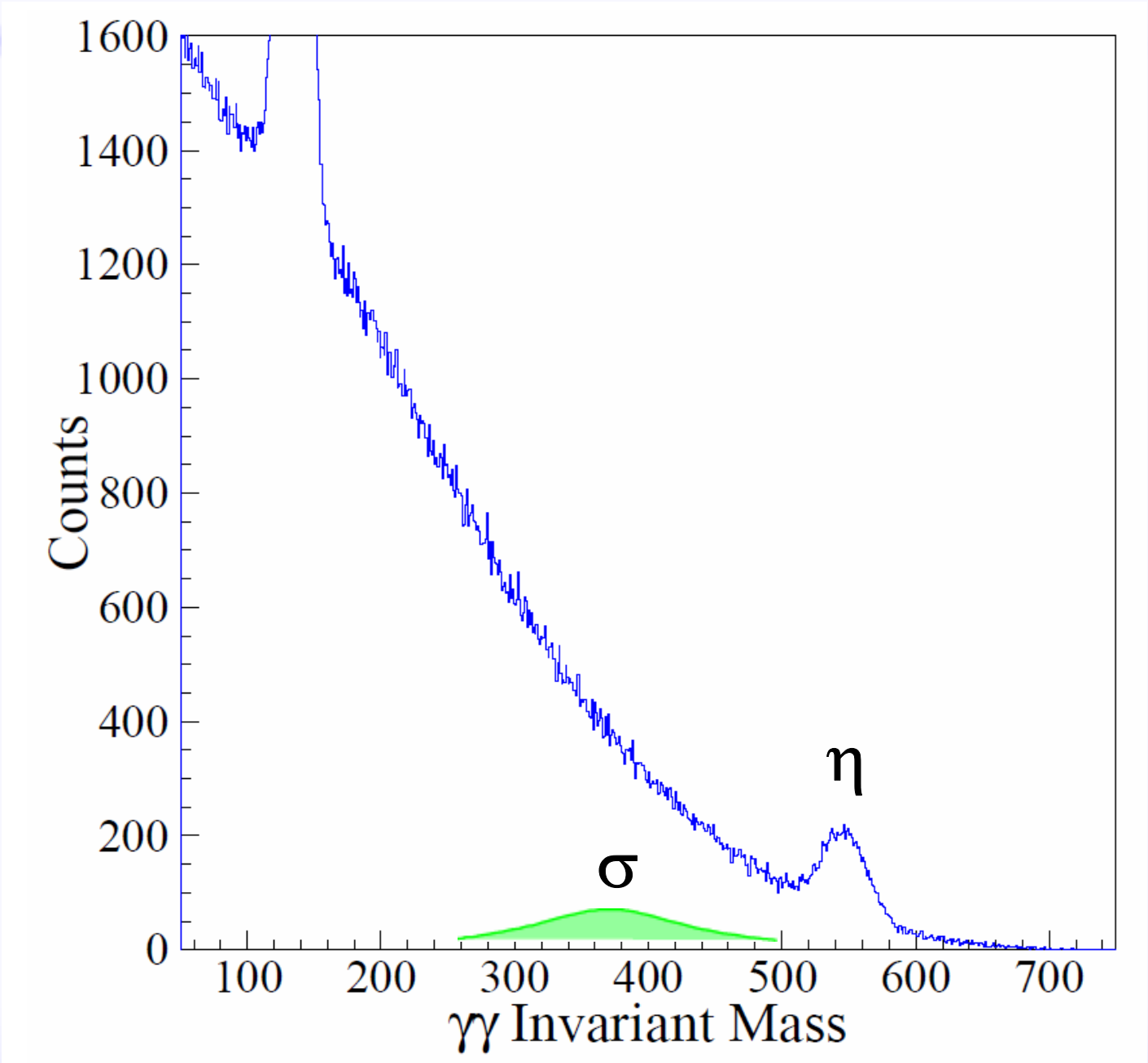
$\gamma n \to \eta \pi^0 n$



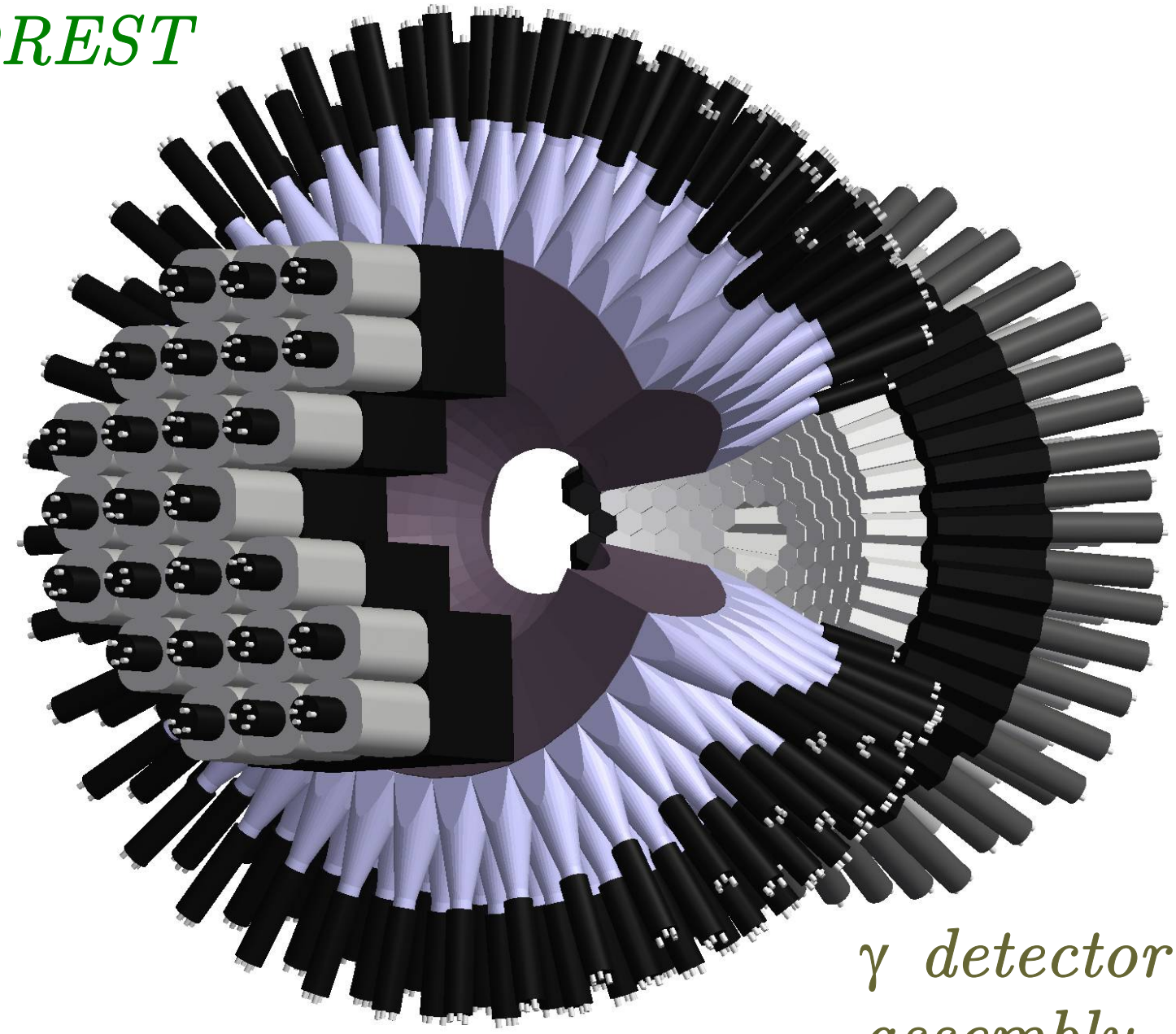
$\gamma n \to N^*(1670) \to \pi^0 n$

$\gamma p \to N^{*+}(1670) \to \eta X$

π^0


1600
1400
1200
1000
800
600
400
200
0
Counts
100
200
300
400
500
600
700
γγ Invariant Mass
η
σ

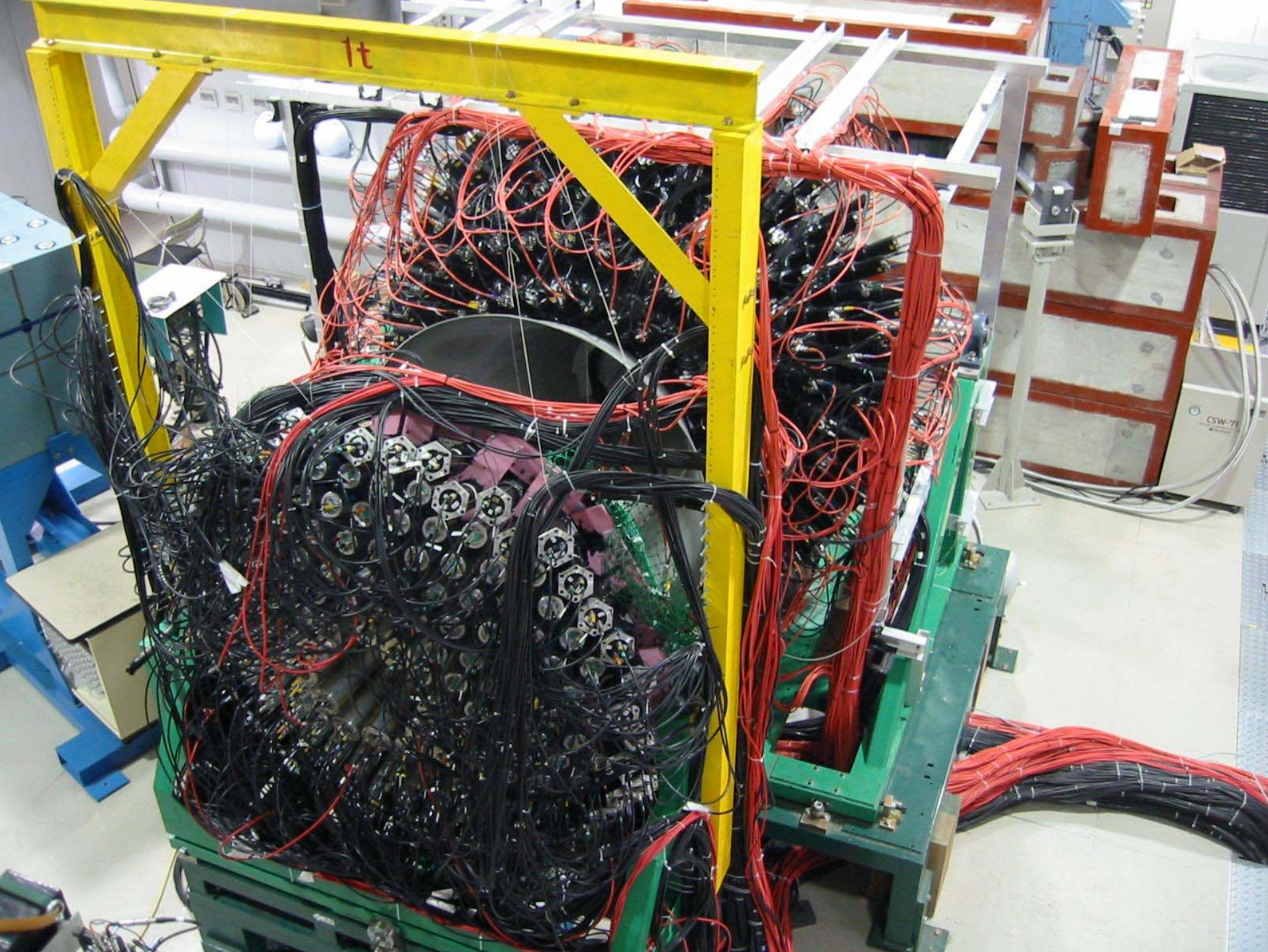
FOREST

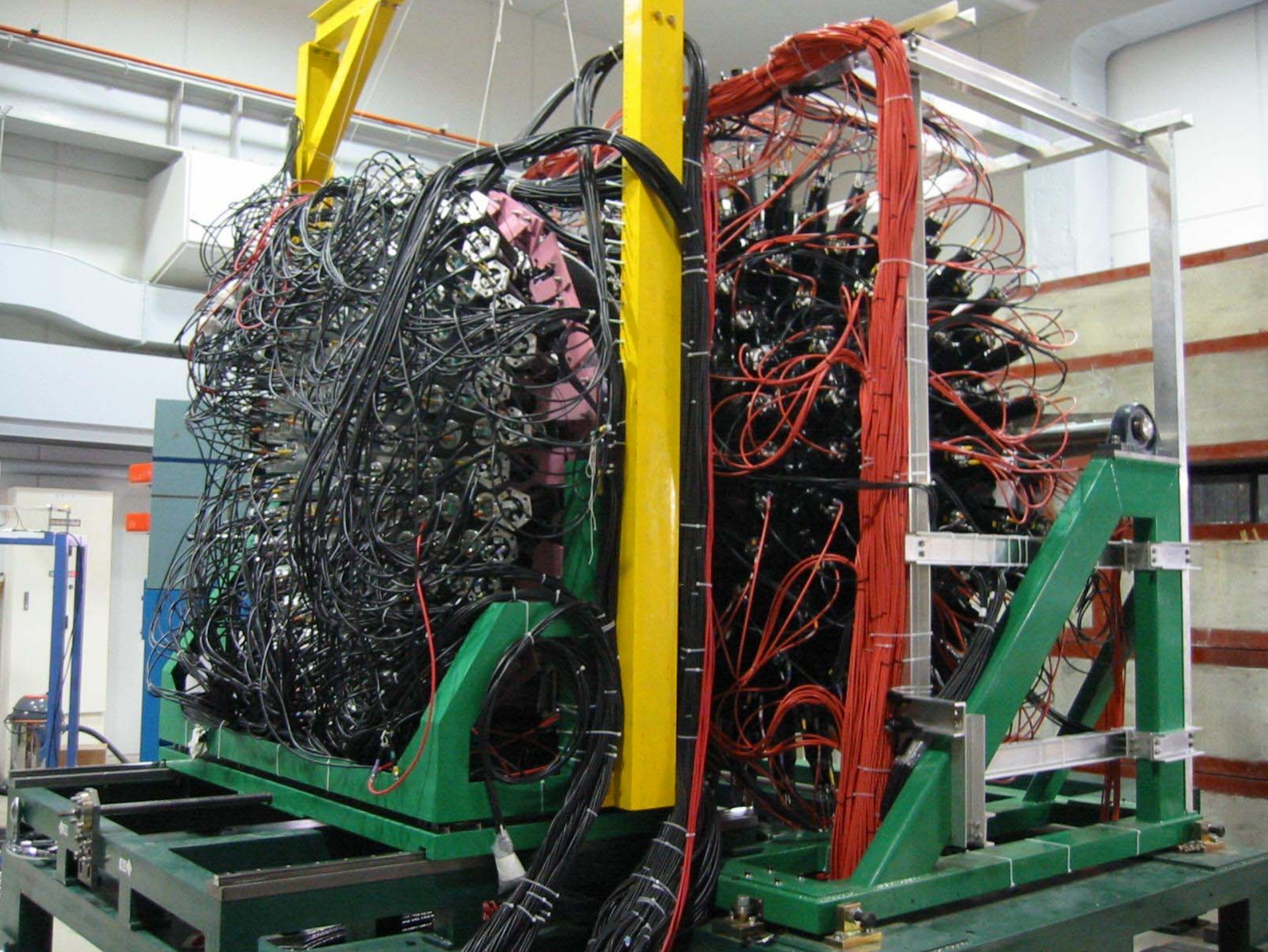


γ detector assembly

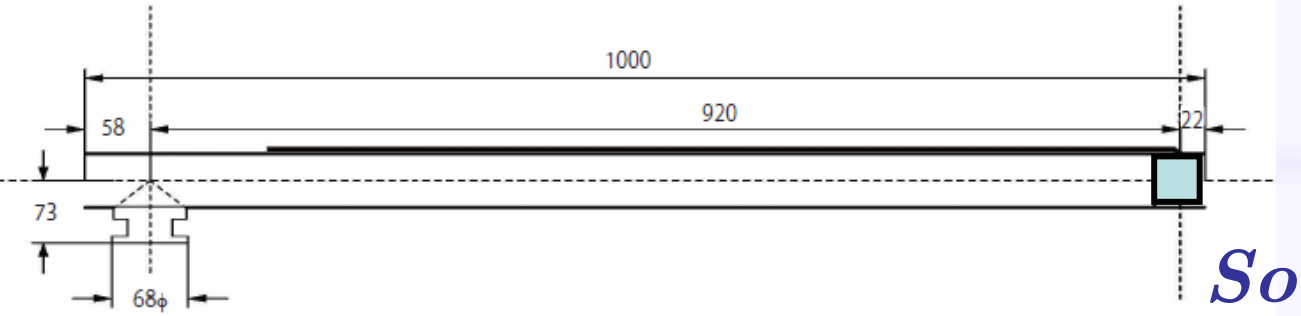

7.5 TON

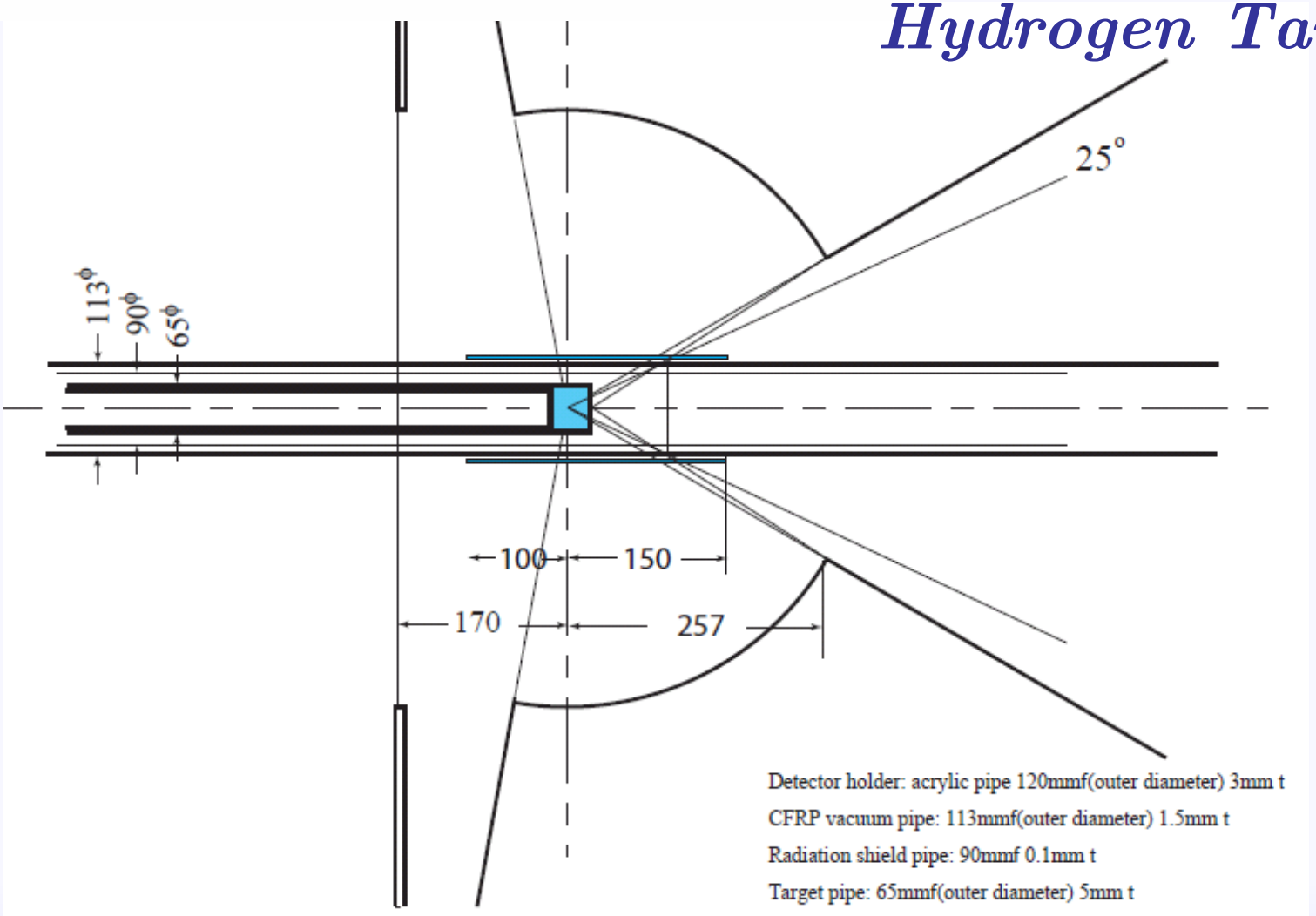

2006.5.13


1t



Solid/Liquid Hydrogen Target



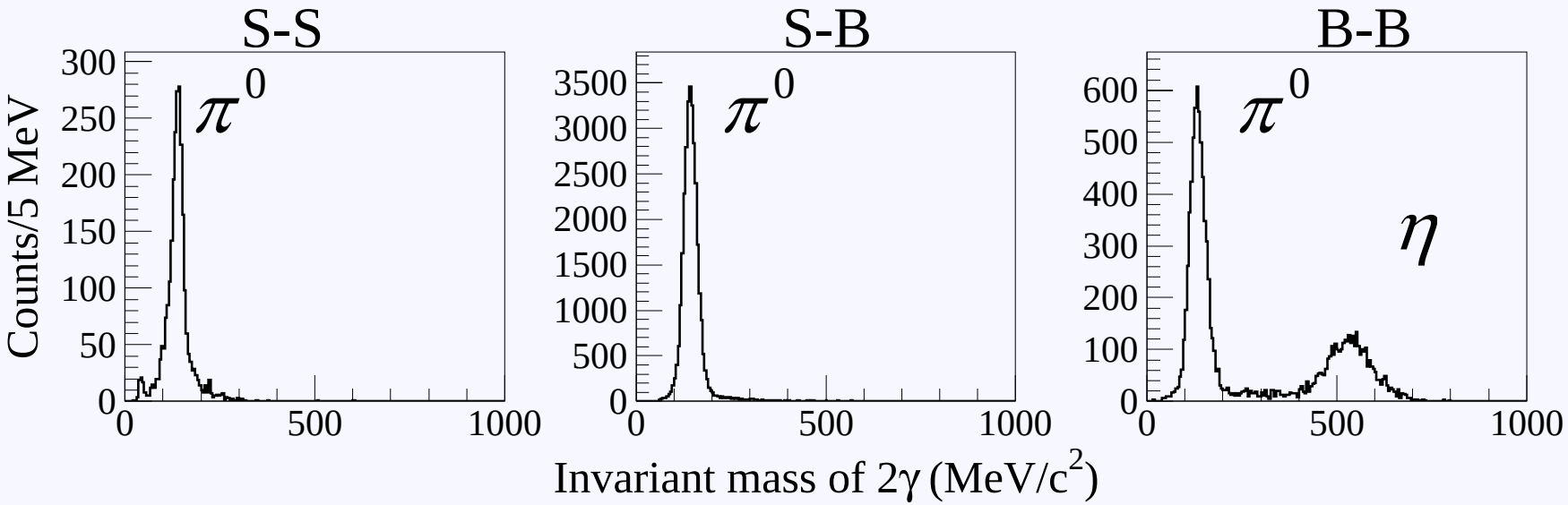


Solid/Liquid Hydrogen Target

- *feeding pipe (4N pure Al)*
  cooled by a GM cooling system
  - *length:* *1000 mm*
- *target cell*
  cooled down to 4.7 K
  - *target thickness:* *40 mm*
  - *inner diameter:* *61 mm*
  - *outer diameter:* *65 mm*
  - *window (Aramid):* *12.5 μm x 2*
- *operation*
  - *pre-cooling:* *3 hours*
  - *target making:* *2 hours*
  - *target vaporizing:* *1 hour*

2γ invariant mass distributions

Data taking started a couple months ago.



π^0 ~2M events/day

η ~40k events/day

Fast DAQ system efficiency of 76% trigger rate: 2kHz for the data size of 2.6kB/event

Summary

- *up to now*

  We observed a narrow baryon resonance N*(1670) in the total cross section for the $\gamma d \to \eta np$ reaction. N* shows up on the neutron, but not on the proton. N* would be the first candidate for a pentaquark with hidden strangeness in the anti-decuplet.

- *research project*

  We aim to determine the spin and parity of N*(1670). We started taking data with a fast DAQ system. We look into the π channel $\gamma n \to \pi^0 n$ and the coupling of N* with the proton with high statistics.