Overview of LEPS2 Project

Outline

- Physics Motivation
- Beamline
- Detector
- Schedule
- Collaboration

Quantum Chromo Dynamics

Perturbative region → Non-Perturbative region

Current quark

Chiral symetry is a good symmetry

Parton model

↓

Precise determination of spin structure functions: GPD

Color confinement

Spontaneous breakdown of chiral symmetry

Generation of Hadron mass

Creation of NG bosons: π, K, η

Consitituent quark

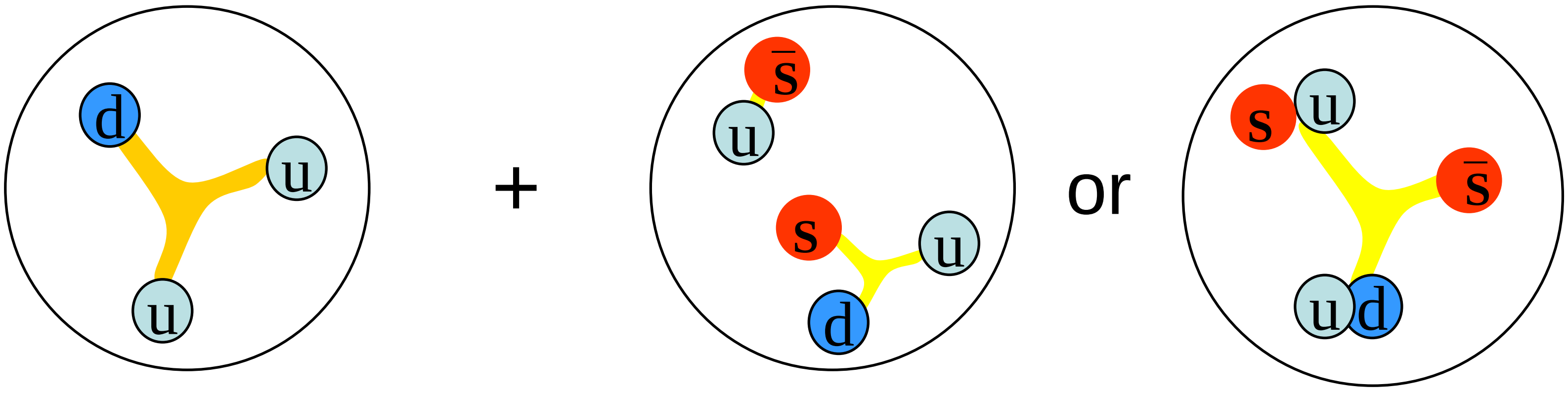
Flavor SU(3) symmetry is a good symmetry

Quark model

↓

Multi quark hadron physics: pentaquark, tetraquark, meson-baryon resonances

What are effective degrees of freedom ?



Meson cloud picture: **Thomas, Speth, Weise, Oset, Jido, Brodsky, Ma, …**

$$| p > \sim | uud > + \varepsilon_1 | n (udd) \pi^+ (\bar{d}u) >$$
$$+ \varepsilon_2 | \Delta^{++} (uuu) \pi^- (\bar{u}d) > + \varepsilon' | \Lambda (uds) K^+ (\bar{s}u) > \ldots$$

Di-quark cluster (5-quark) picture: **Zou, Riska, Jaffe, Wilczek**

$$| p > \sim | uud > + \varepsilon_1 | [ud][ud] \bar{d} > + \varepsilon_2 | [ud][us] \bar{s} > + \ldots$$

How to study multi-quark hadron physics?

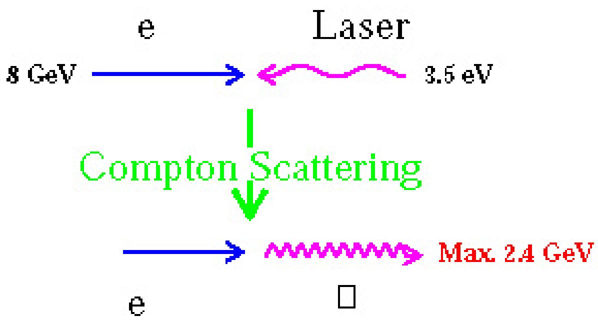
- Complete the hadron table (m,J,P). ← tedious!
- Study reaction mechanism and production rates of possible multi-quark dominant states.
- Study decay properties of possible multi-quark dominant states.
- Find a pentaquark.

$SU(3)_f$ symmetry will be a key to understand the nature of multi-quark states.

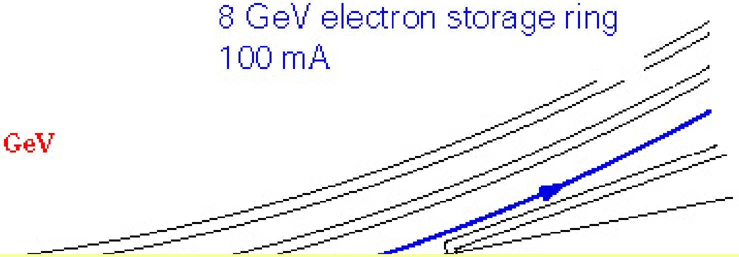
→ Study relations among various reactions and decays.

LEPS

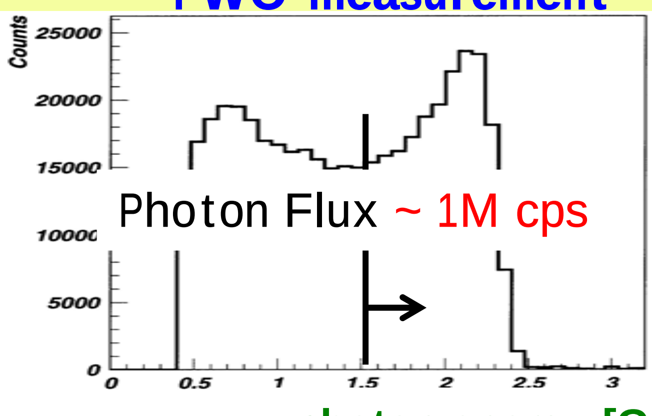
Laser Electron Photon at SPring-8



SPring-8:
8 GeV electron storage ring
100 mA

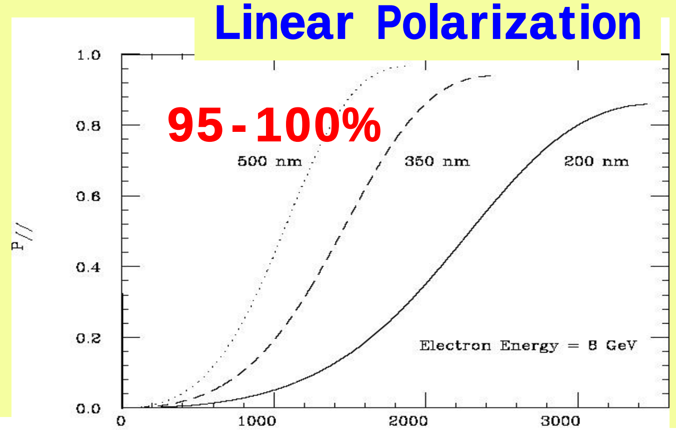


PWO measurement



photon energy [GeV]

Linear Polarization



photon energy [MeV]

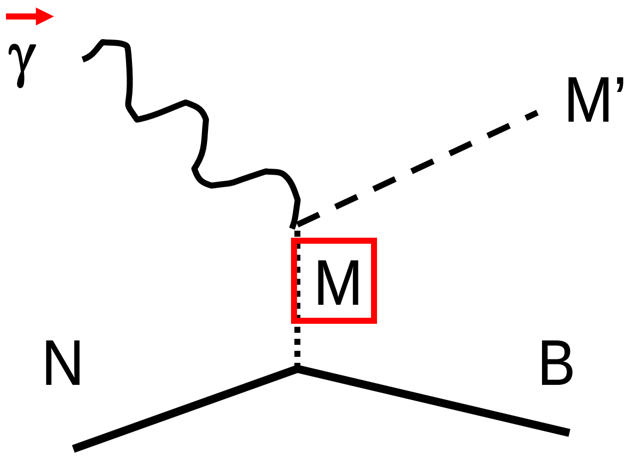
Advantage of Laser-Electron Photon Beam for Hadron physics

- **Hadronic component of a photon contains a large fraction of $s\bar{s}$.**
- **Isospin dependence is not trivial because a γ contains both I=0 and I=1 components.**
- **Linear polarization can be used as a parity filter.**
- **The polarization can be changed easily.**

Disadvantage is low interaction rates. → Require high beam intensity and large detector acceptance.

t-channel process

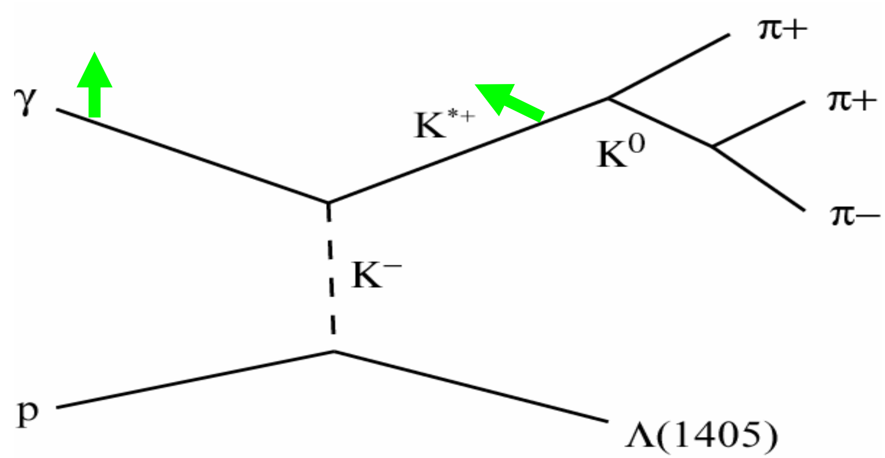
- dominates in the forward angles.
- can access to a baryon below MB.
- Linearly polarized photons work as a parity filter.



$\gamma p \to K^* \Lambda(1405)$

- K^- must be virtual because $\Lambda(1405)$ is lighter than pK^-.
- K^- exchange can be enhanced by selecting events where $\vec{\gamma}$ is perpendicular to K^*.
  - z1=1390+66i
  - z2=1426+16i

→

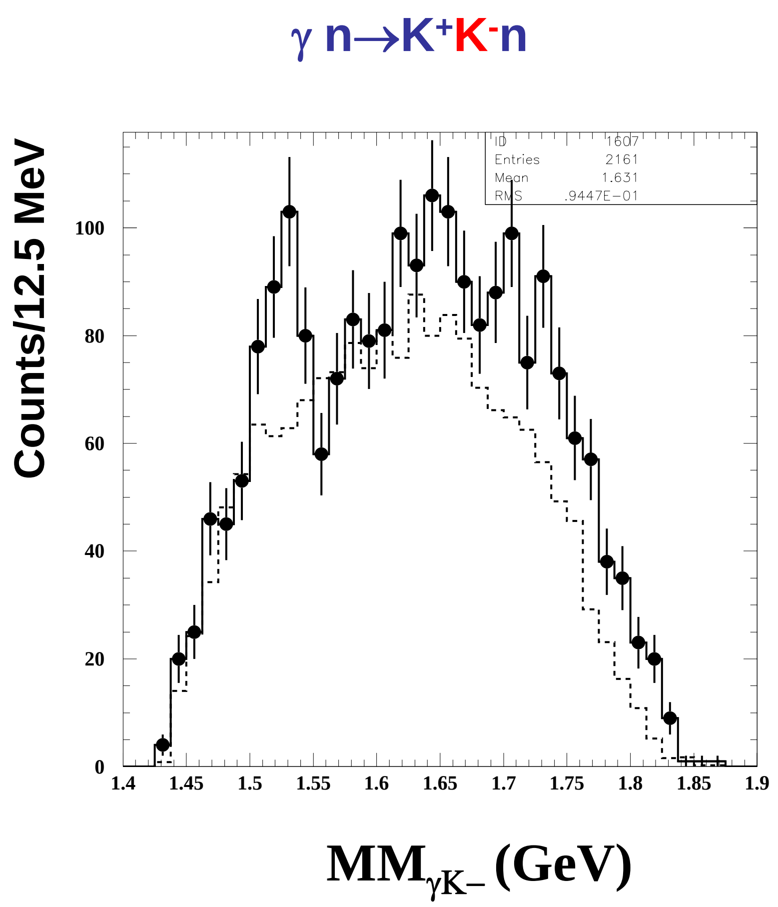


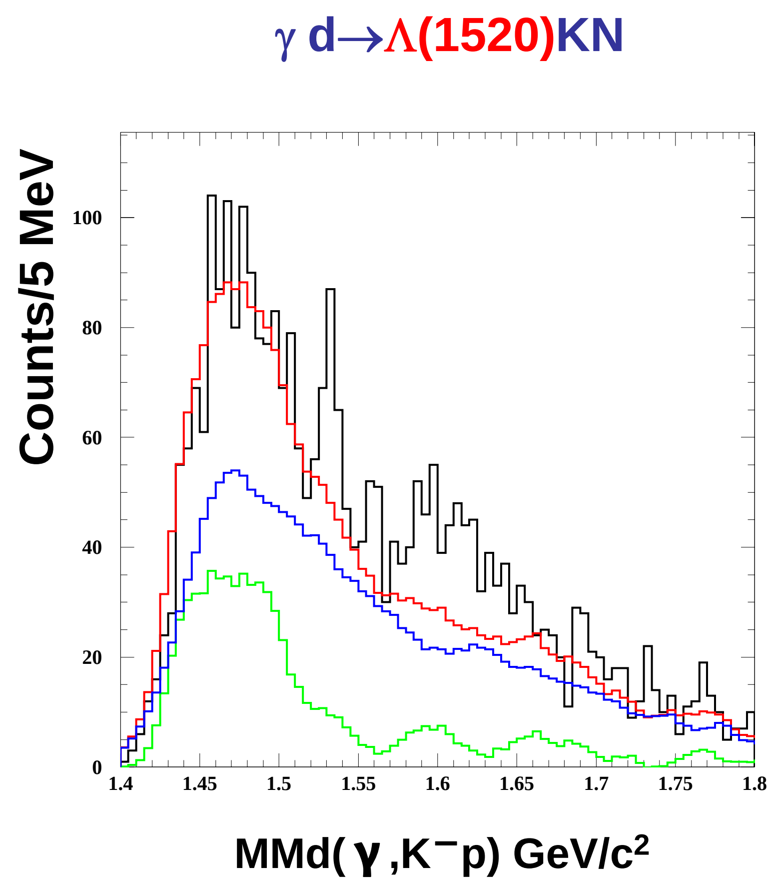
The study requires:

- high energy
- high intensity
- high polarization
- wide acceptance

Not enough at LEPS

Pentaquark Θ^+ at LEPS





In the both reactions, K^+ exchange is possible and should be dominant. → require good forward acceptance.

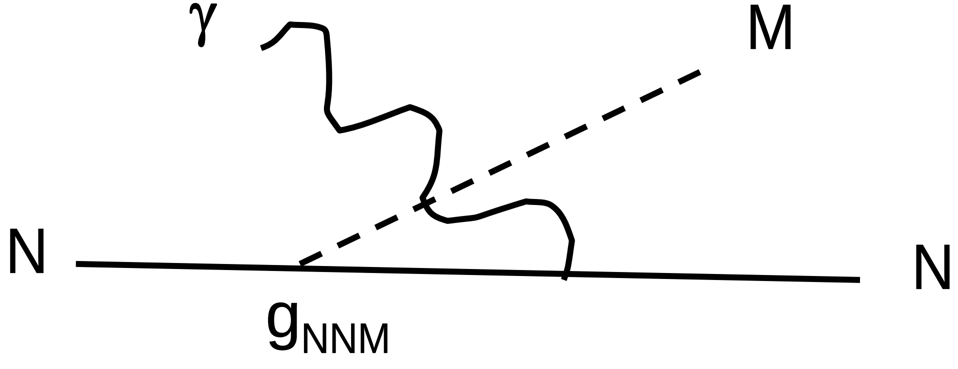
Can we still believe in the existence of the Θ^+?

- What do we have seen and what have not seen?
- How strong are the evidences?
- What does make it difficult to confirm the state?
- How important is a good resolution?
- How important is background rejection?.
- What should we do to prove its existence?

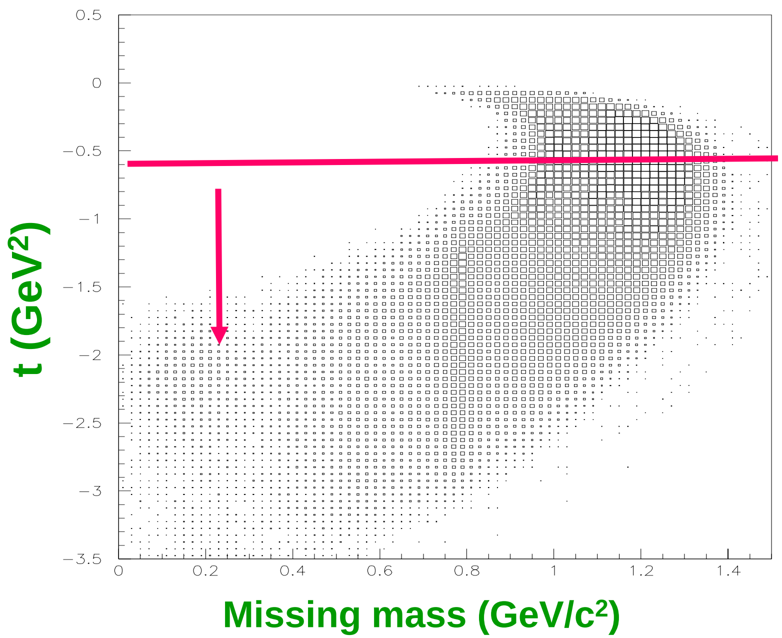
I will answer these questions tomorrow.

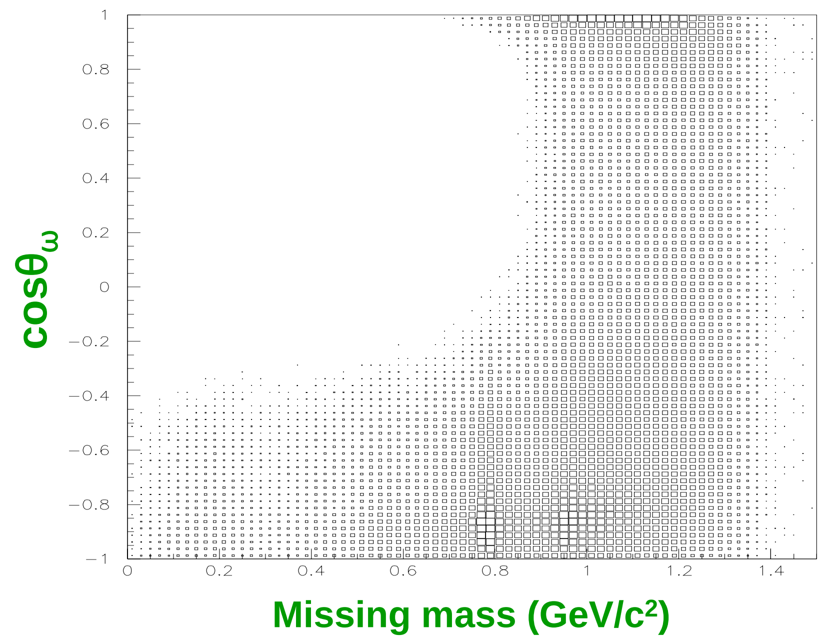
u-channel process

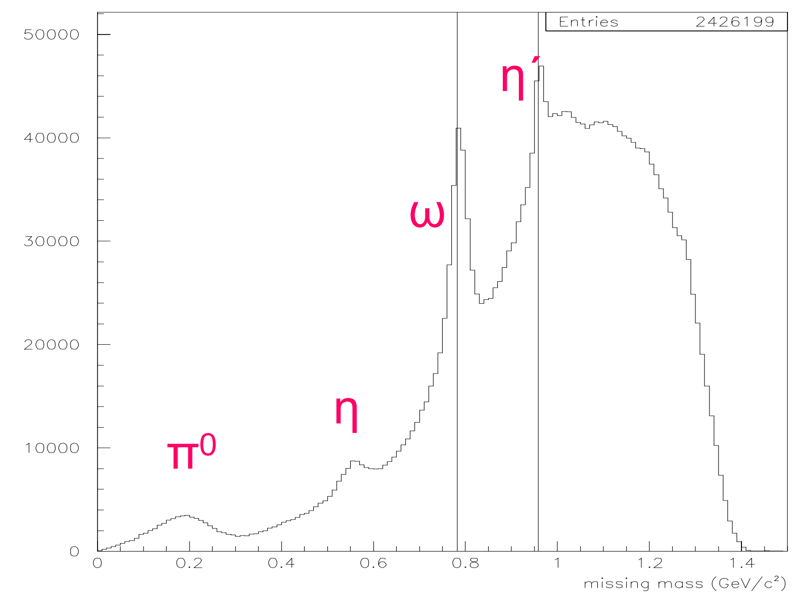
- **dominates in the backward angles (forward angles in terms of a nucleon).**
- **is sensitive to g_{NNM}.**



Missing mass distribution



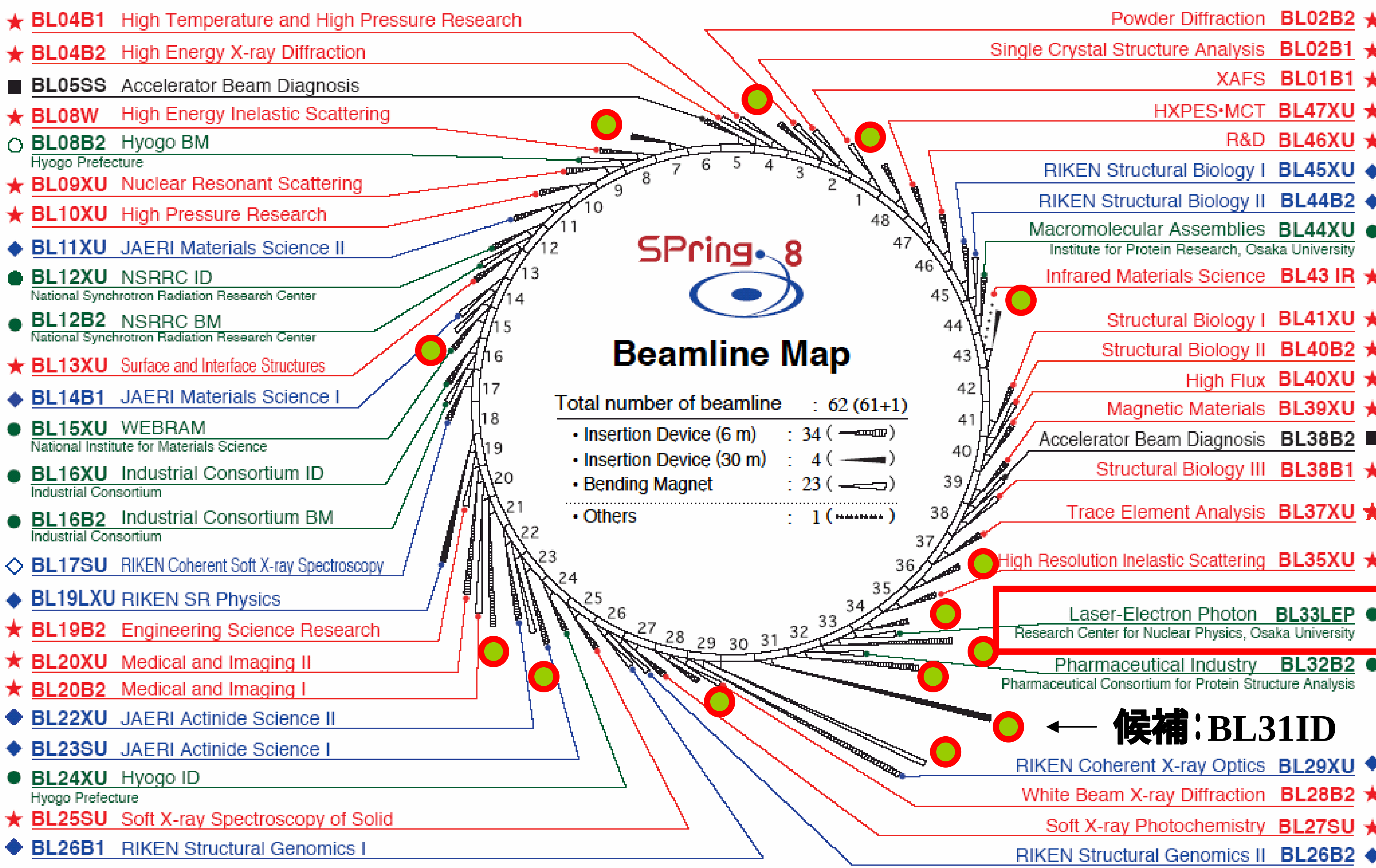




η ' peak is clarified
by requiring $t < -0.6$

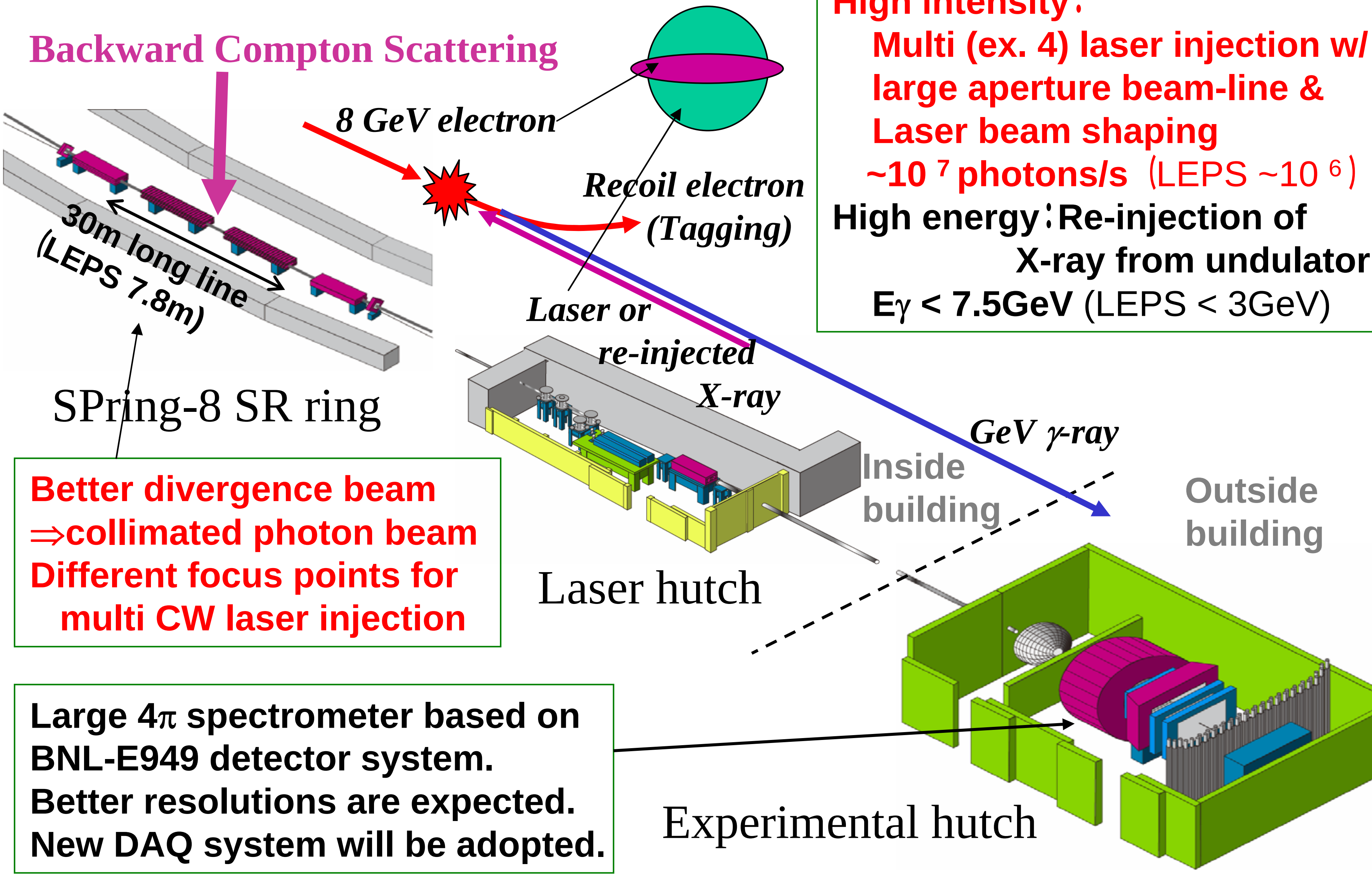
~9000 events in 2001 data

Beam line map of Spring-8



BL status:14 Beam lines available (30m x3, 6m x8, Bending x3)

New Beamline Project at SPring-8

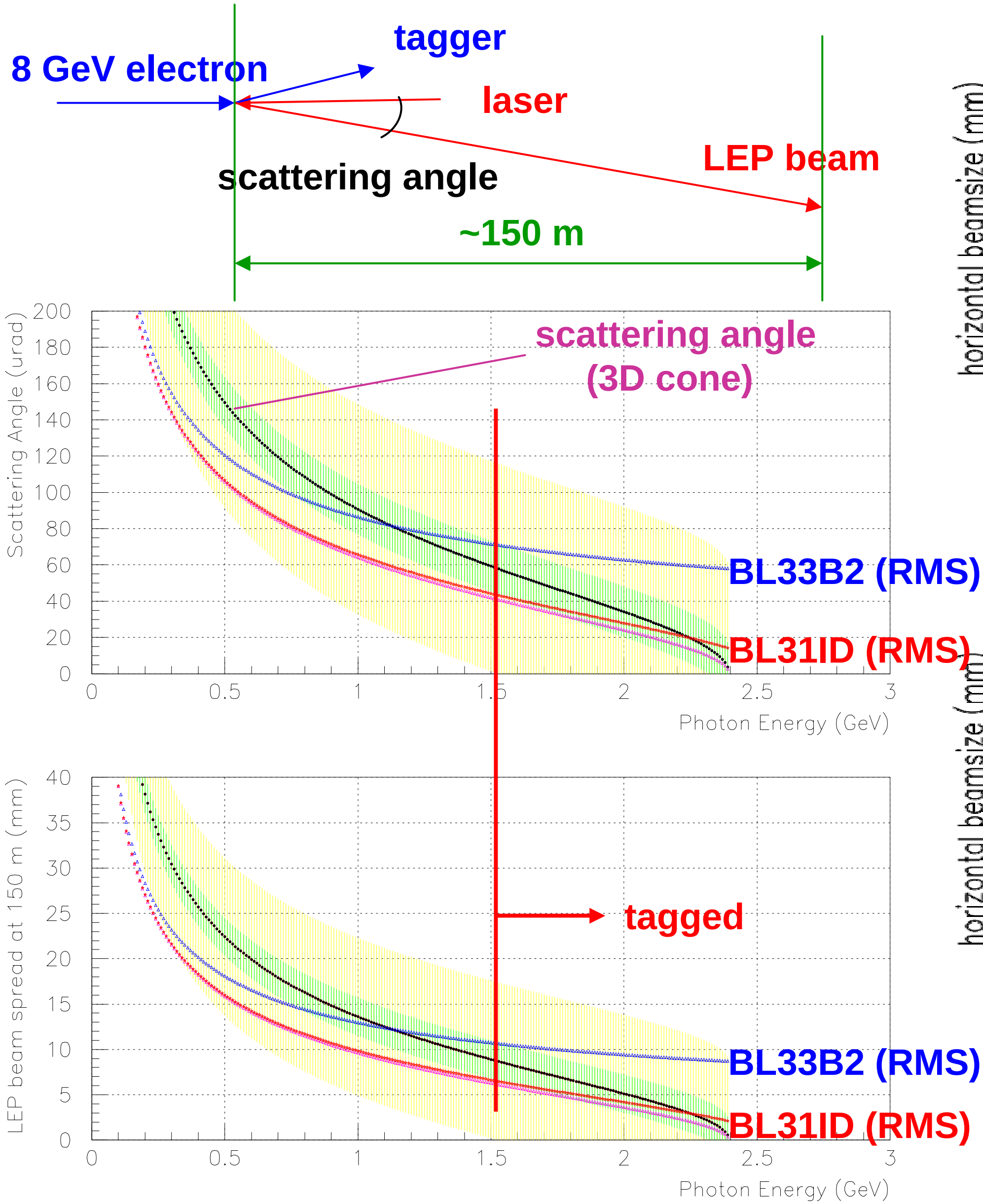


High intensity：
Multi (ex. 4) laser injection w/ large aperture beam-line & Laser beam shaping
~10^7 photons/s (LEPS ~10^6)
High energy：Re-injection of X-ray from undulator
Eγ < 7.5GeV (LEPS < 3GeV)

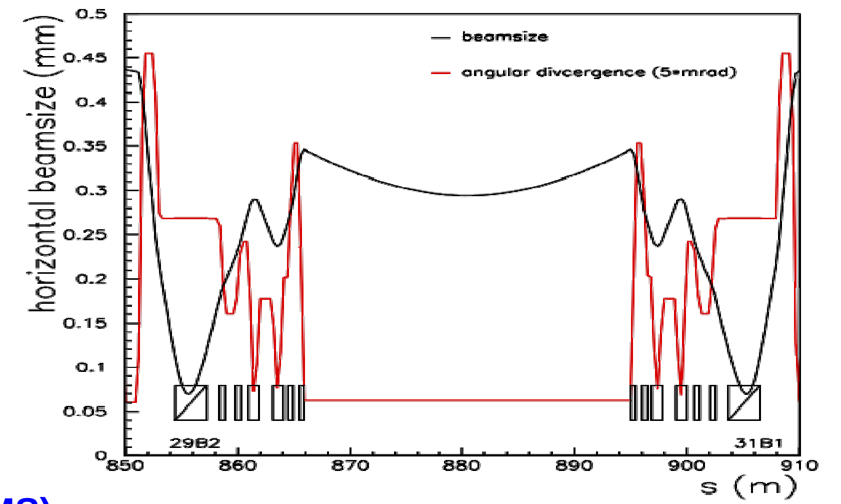
Better divergence beam
⇒collimated photon beam
Different focus points for multi CW laser injection

Large 4π spectrometer based on BNL-E949 detector system.
Better resolutions are expected.
New DAQ system will be adopted.

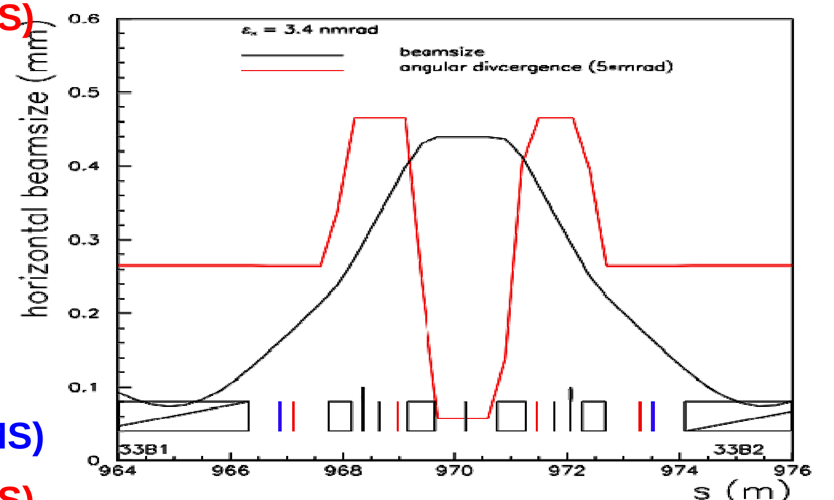
Divergence of LEP beam



BL31ID $<\sigma_{x'}>=14\ \mu m$

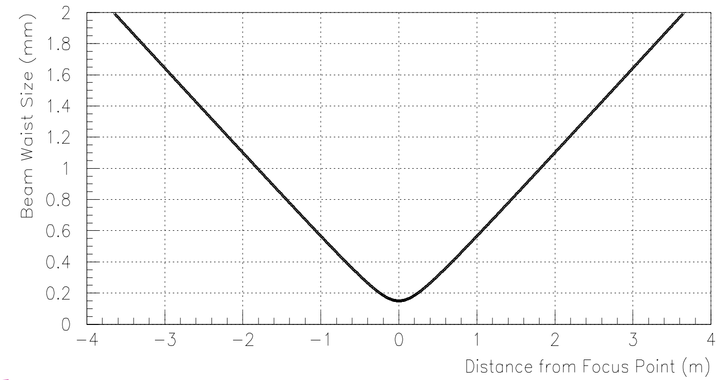


BL33B2 $<\sigma_{x'}>=58\ \mu m$

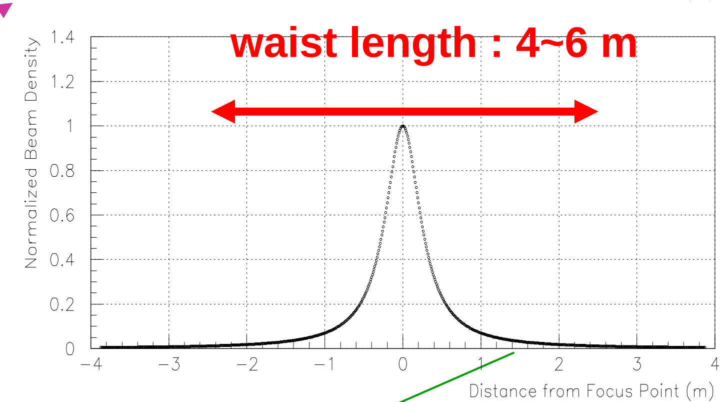


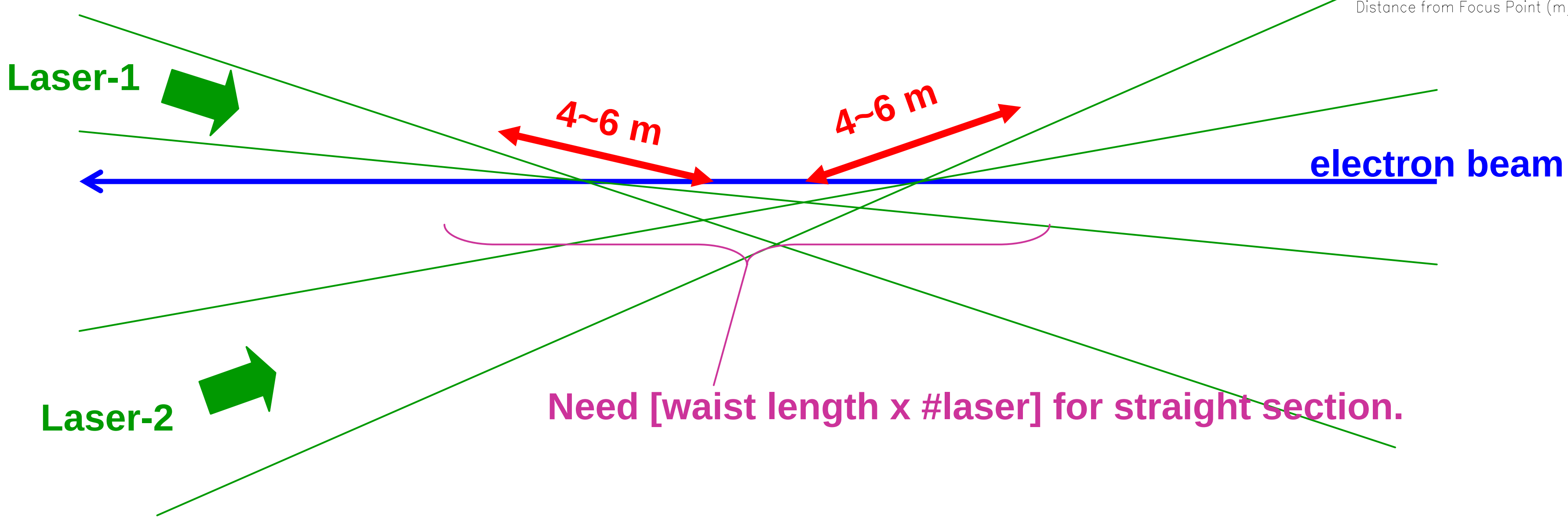
30 m-long straight section

Multi-injection of CW laser
⇒Interference is problematic.
⇓
Need to differ focus points.



Focused at 36 m by using X28.5 expander





Expected Intensity

- LEP Intensity with Ar laser [351 nm, 6.5 W, CW] : ~800 Kcps

  ⇒ Paladin (Solid state & 80 MHz pulsed laser) [355 nm, 8 W]

  - 4-laser injection w/ larger aperture beamline x4
  - Paladin 16 W model may be available in future. (x2)
  - Twice energy density by laser beam shaping in vertical direction x2

  ⇒ In total 8-16 times more intensity relative to Ar laser

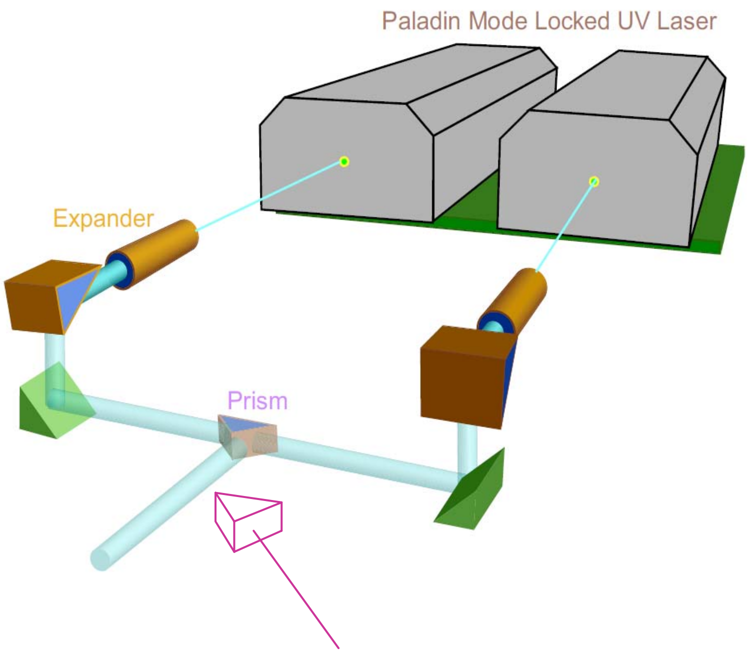
  (Note: 2 Mcps has been achieved by 2-laser injection at BL33LEP.)

- LEP Intensity with Deep-UV laser [257 nm, 1-1.5 W, CW] : ~150 Kcps
  - 4-laser injection (4-different focus points) x4
  - laser beam shaping x2
  - vertically long beam shape because of SHG → horizontally long shape (like electron beam) by mirrors [additional factor]

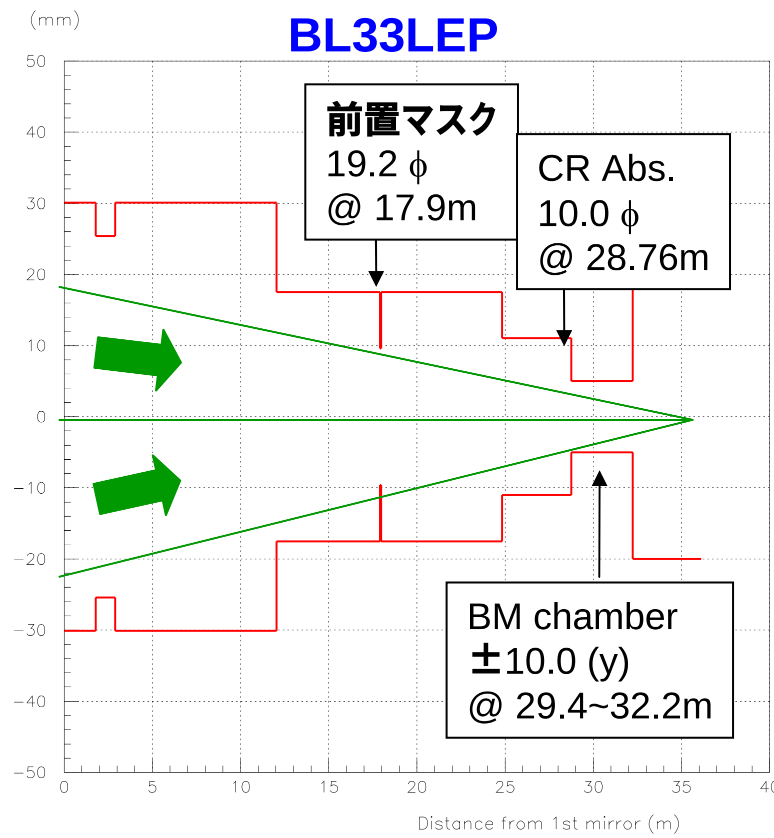
  ⇒ In total 8+α times more intensity

Multi-laser Injection

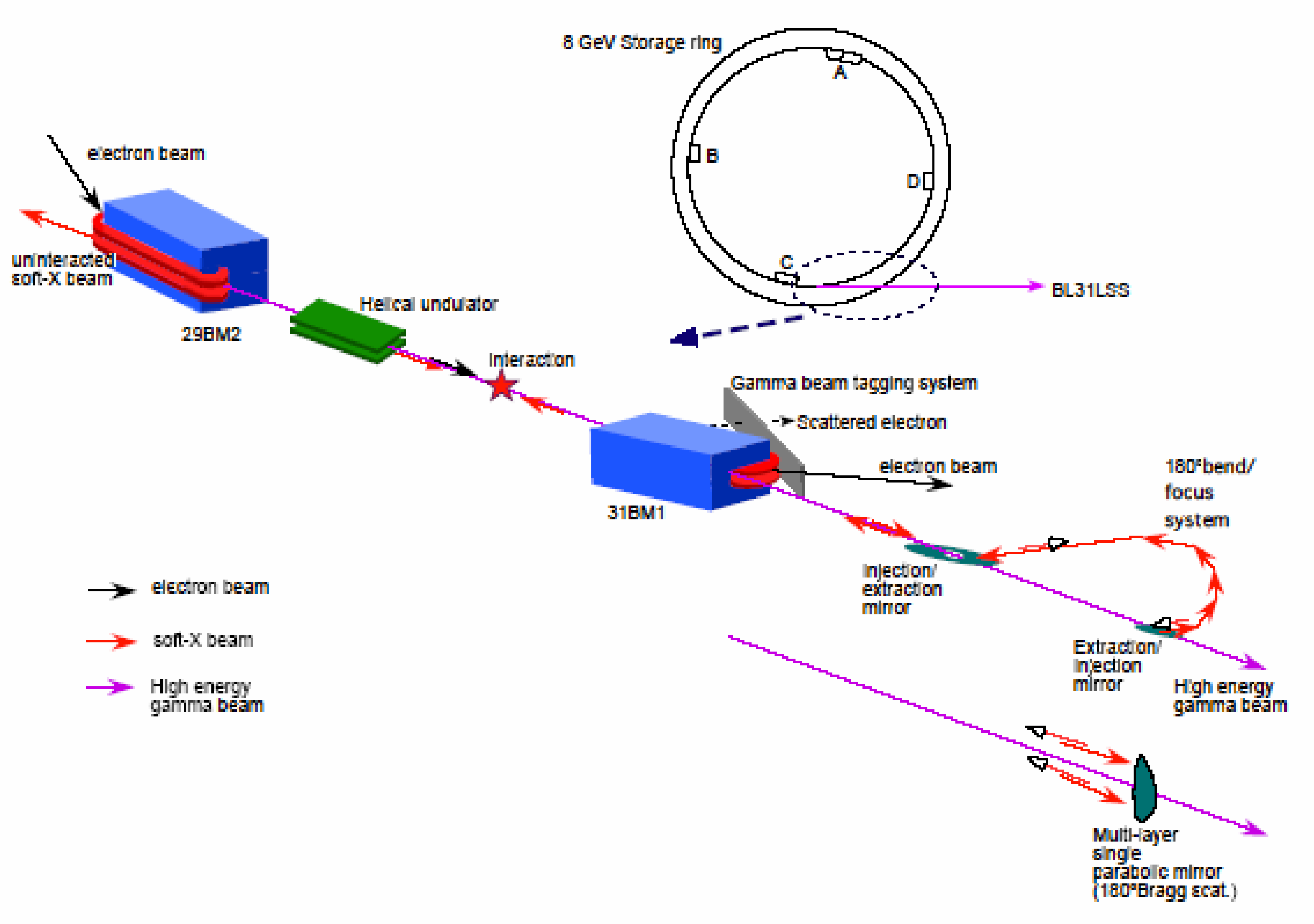
- 80 MHz pulsed laser : (1) quasi-CW (2) no interference
- 2-laser injection has been installed at BL33LEP. ⇒ ~2 Mcps
- Aperture of BL33LEP is narrow. [Only 20 mm / laser is allowed.]
  ⇒ Larger aperture will give more efficient transmission
  and allow additional laser injections.



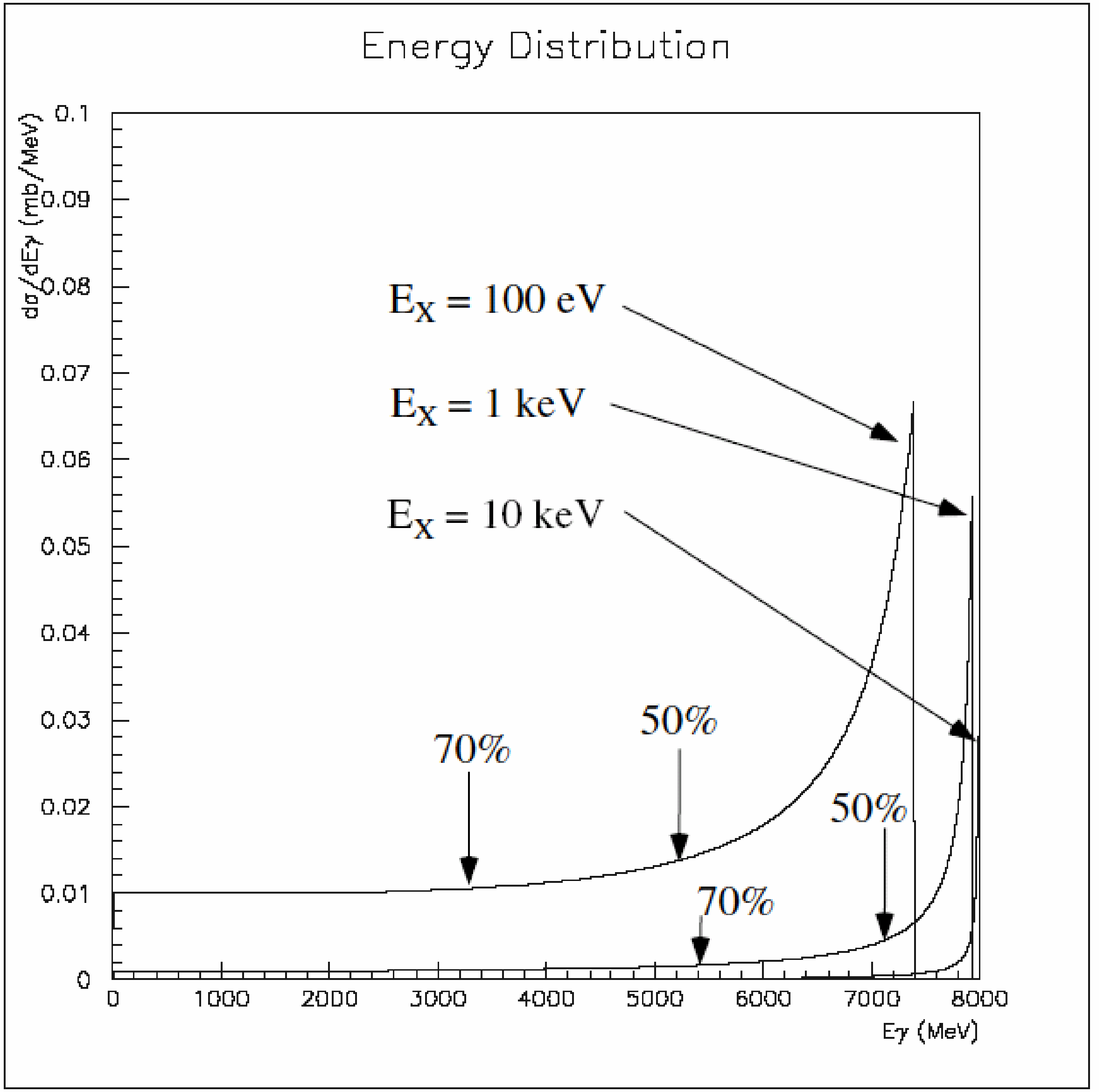
additional prism for 4-laser injection



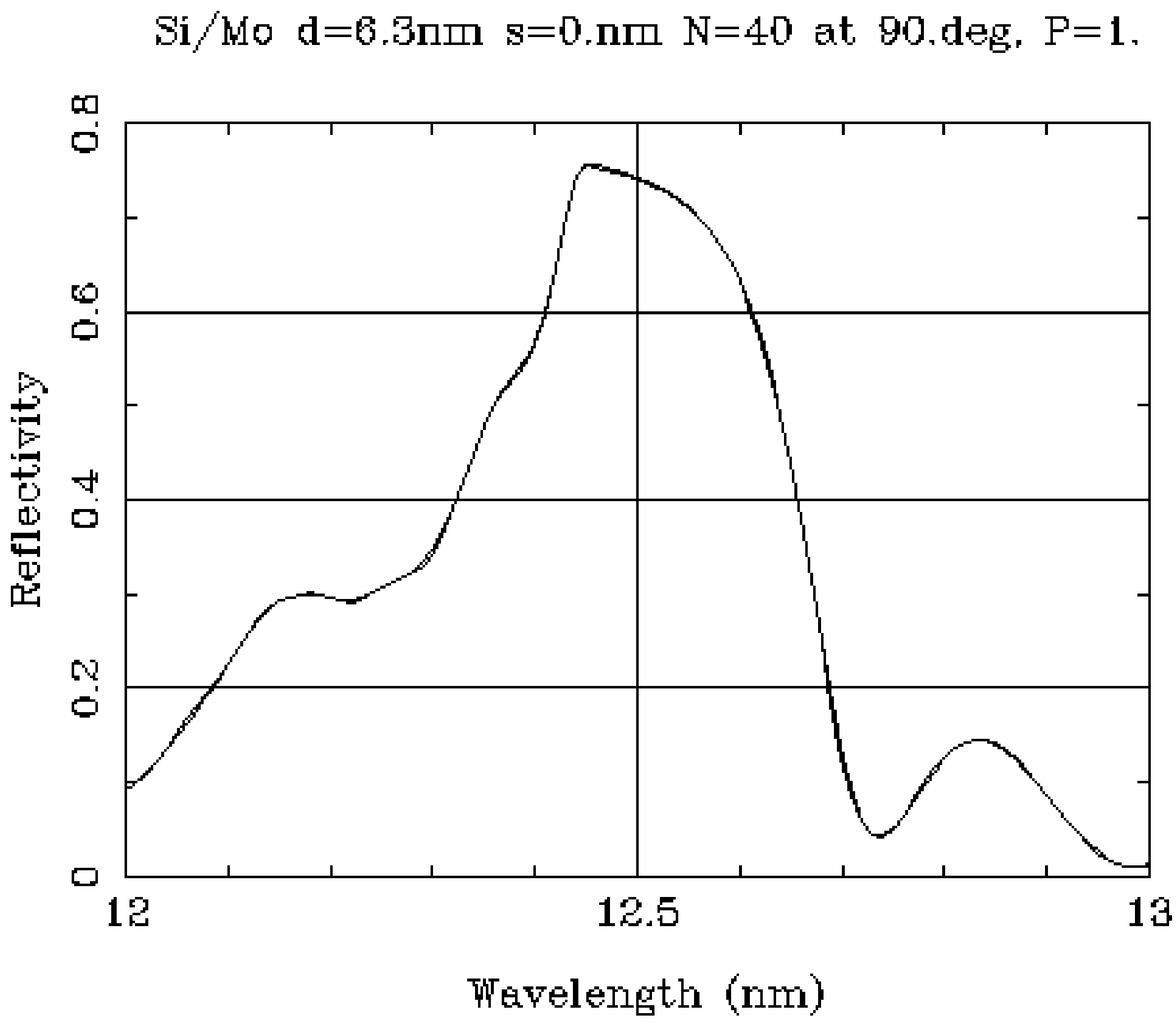
Backward Compton Scattering of X-ray for Ultra High Energy LEP



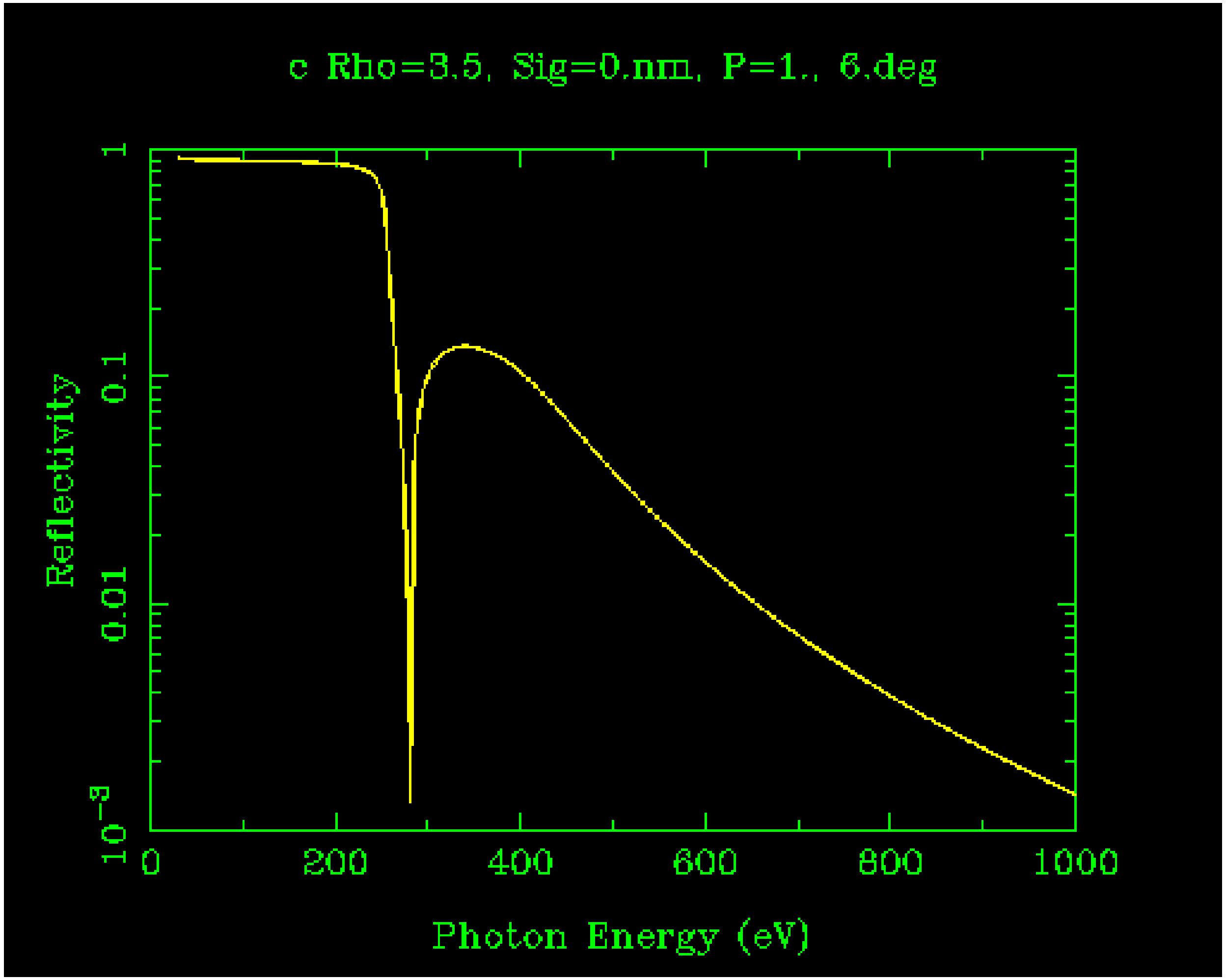
High Energy Backward Compton Photons



Multilayer Reflectivity

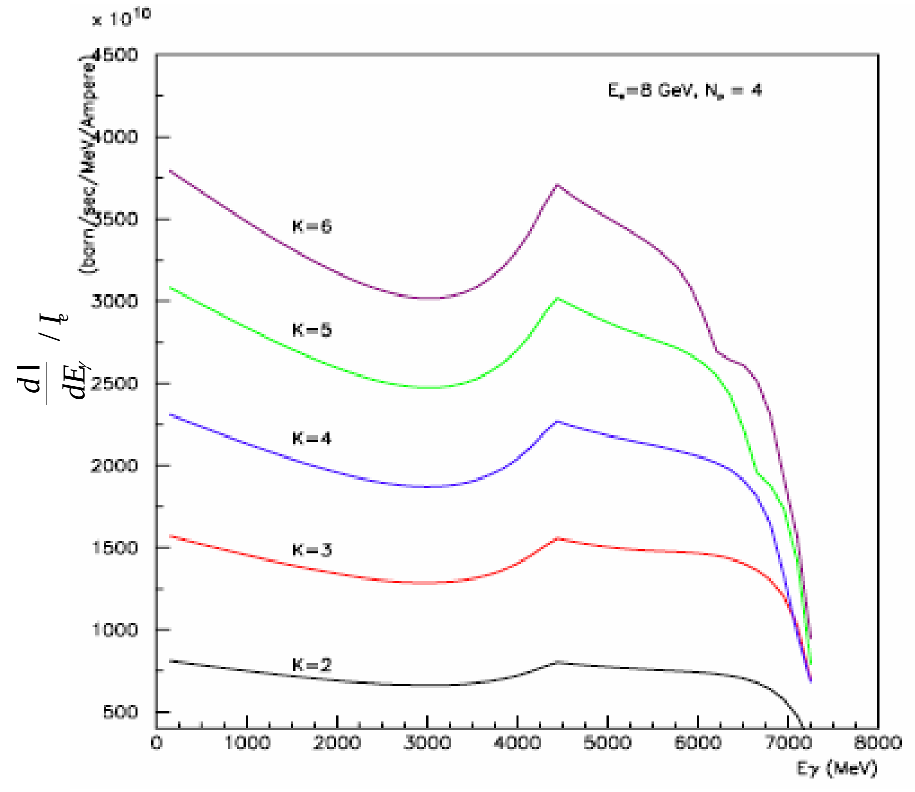


Reflectivity of Diamond

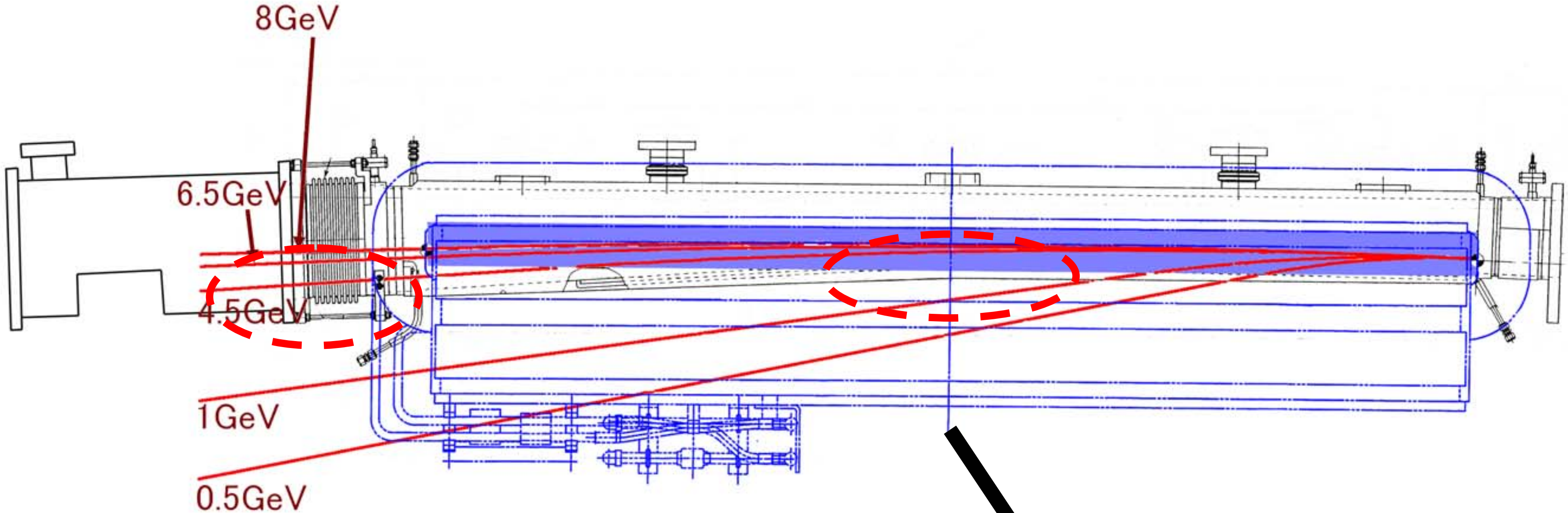


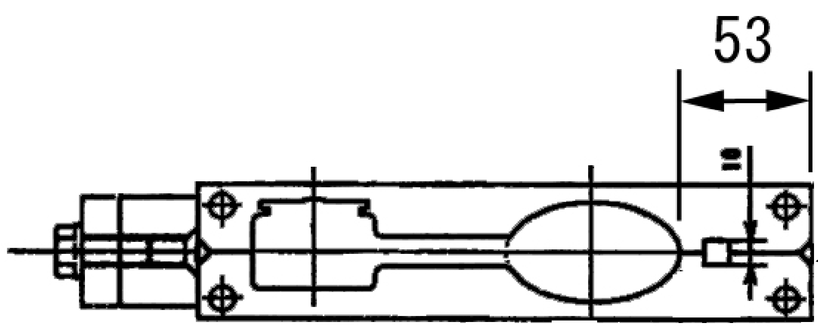
Energy Spectrum of High Energy γ

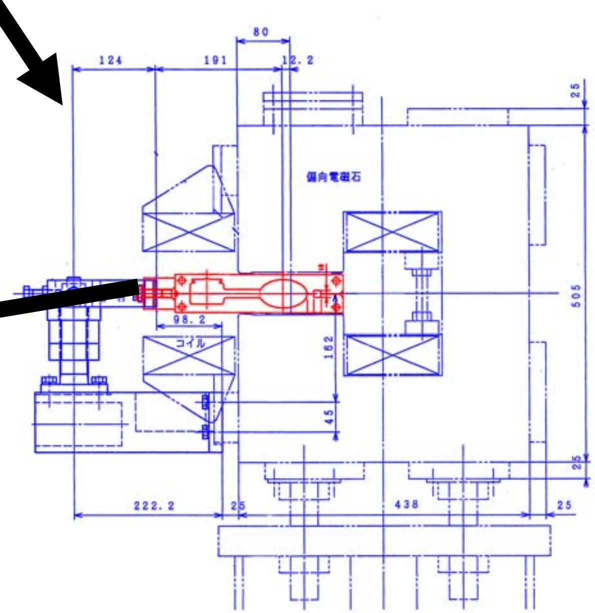
$$\frac{d\dot{I}}{dE_\gamma} = \int_{\omega_1}^{\omega_2} d\omega \frac{d\sigma}{dE_\gamma}(\omega)\, \frac{d\dot{N}_{ph}}{d\omega}$$



33 LEPS 現状

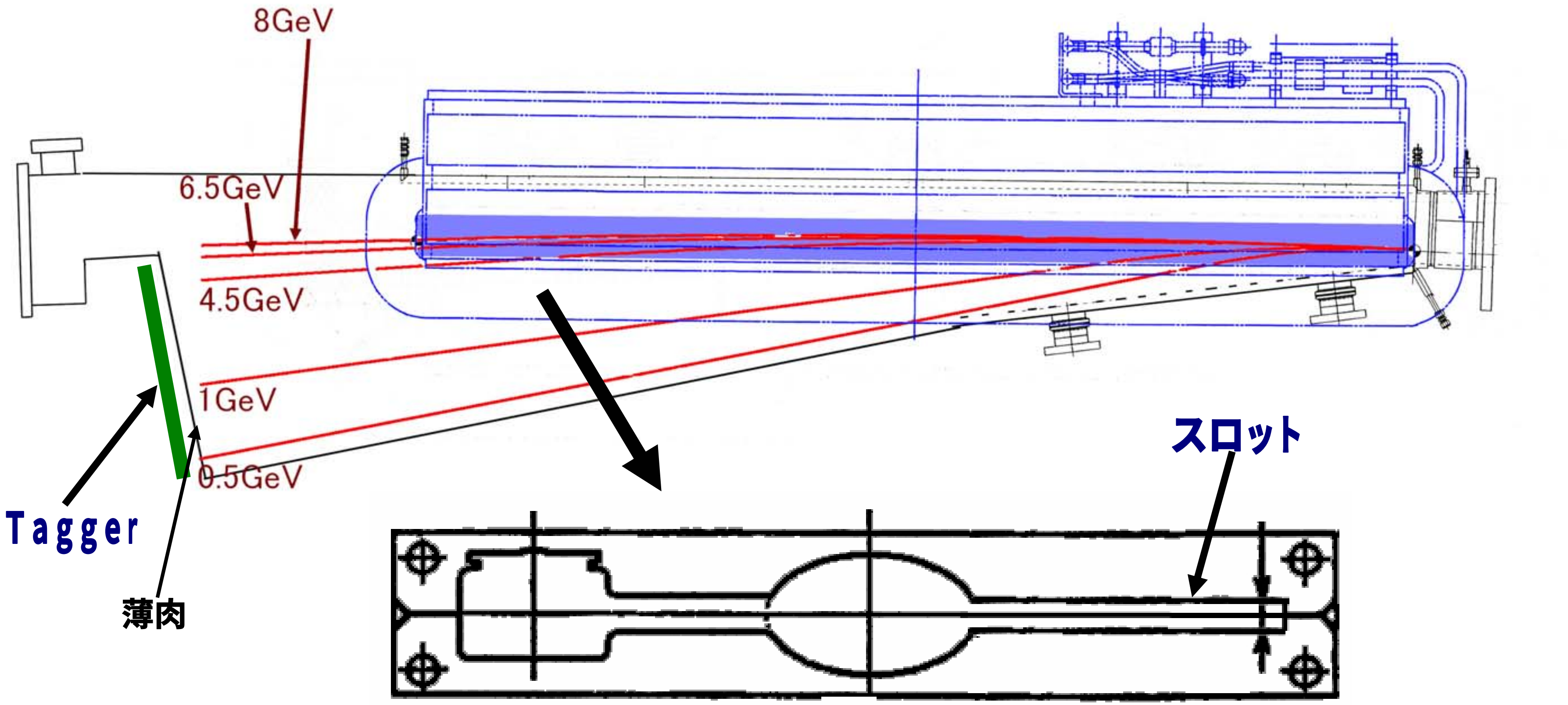






7.5GeVまでのγをtagしようとすると
特に4~6GeVのγについて
チェンバー壁の厚みやフランジがネックとなる
(X_0=89mm for Al)

LEPS2 チェンバー案



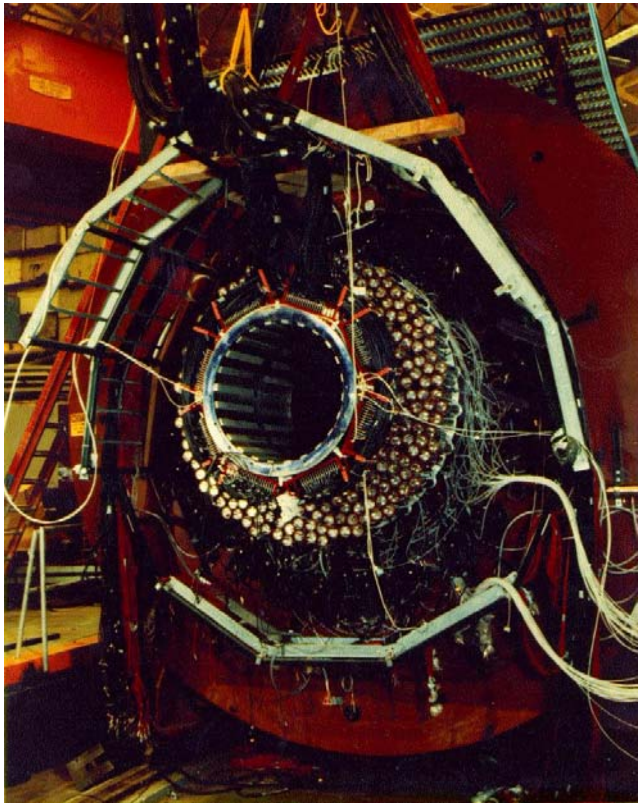
・ベンディングチェンバーＢＭ１とクロッチチェンバーＣＲ１の一体化
・反跳電子軌道上は高さ１０mm程度の扇形のスロットを作る
・反跳電子取出し口のチェンバー壁の薄肉化 (数mm、要真空力対策)
・干渉を避けるため偏向電磁石の反転
　(重心が変わるため架台も設置しなおす必要あり)
・クロッチアブソーバ改造 (後述)

Detector system

- Momentum resolution at forward angle $\Delta p/p \sim 1\%$.
- K/π identification up to ~1.5 GeV/c.
- Large and smooth acceptance azimuthally → Decay and polarization.
- Detection of decay products down to low momentum of ~100 MeV/c
- Detection of neutral particle (Photon)

BNL-E949 Detector

(As a general-purpose detector with large solid angle)



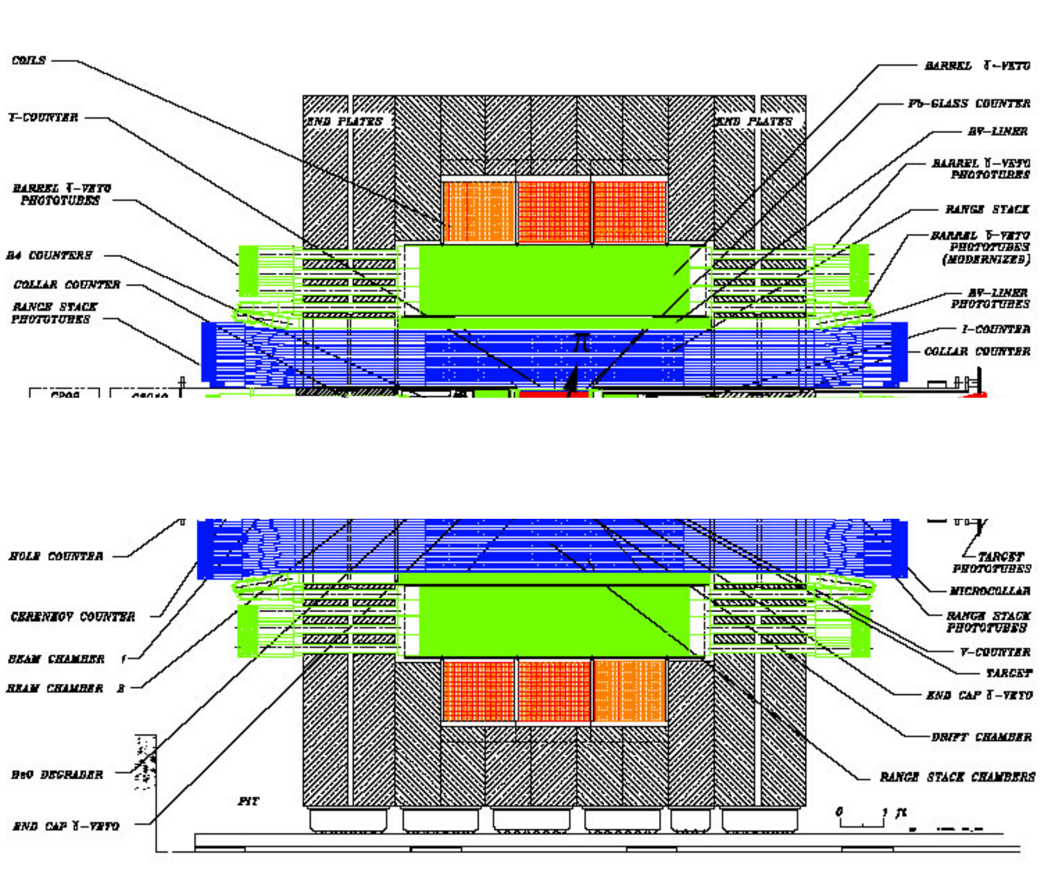
Cylindrical detector for the measurement of decay from kaon at rest

1.0 T magnet, Bore size : 2.96-m diameter ✕2.22-m length

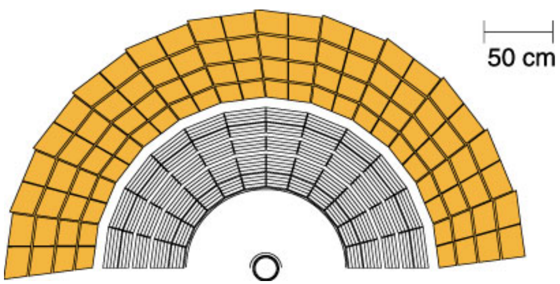
1.1 MW, 4400 A

BNL-E949 detector

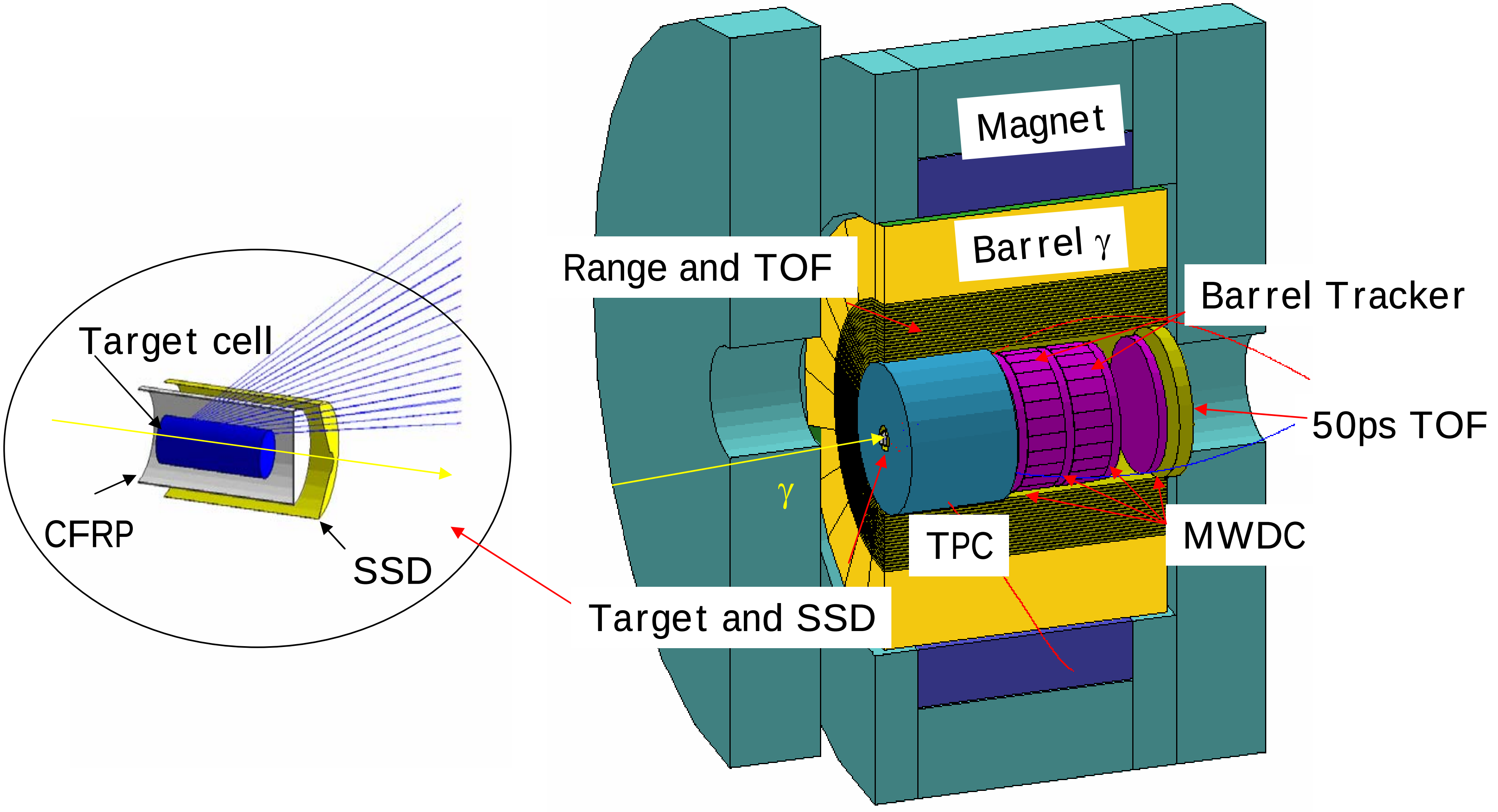
Designed for $K^+ \rightarrow \pi^+ \nu\nu$



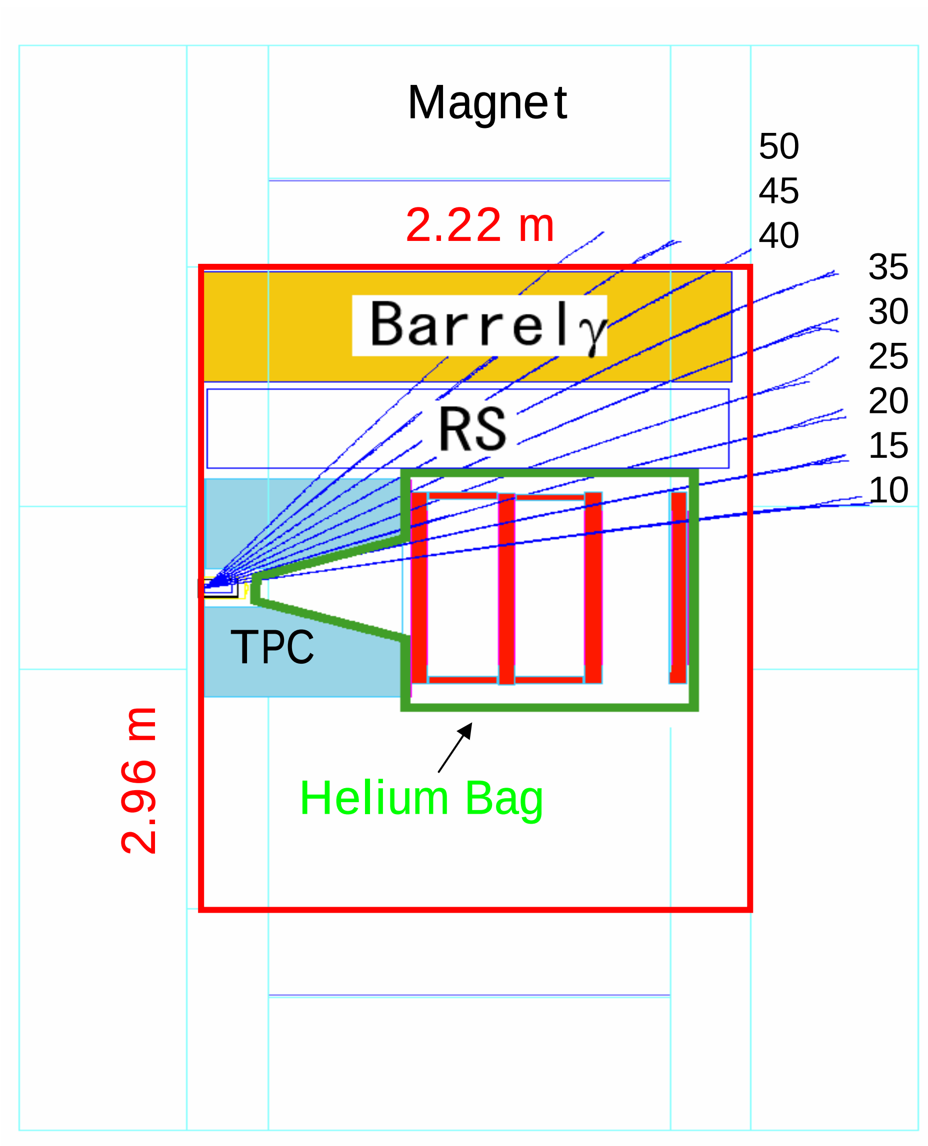
- Solenoid
  1 T
- Inner volume
  2.22x2.96 m
- Barrel Photon detector
  Plastic & lead sandwich detector
  $14.3X_0$
  Energy and position
- Range counter
  Plastic scintillators 19 layers
  Enegy and Range



Setup 3D

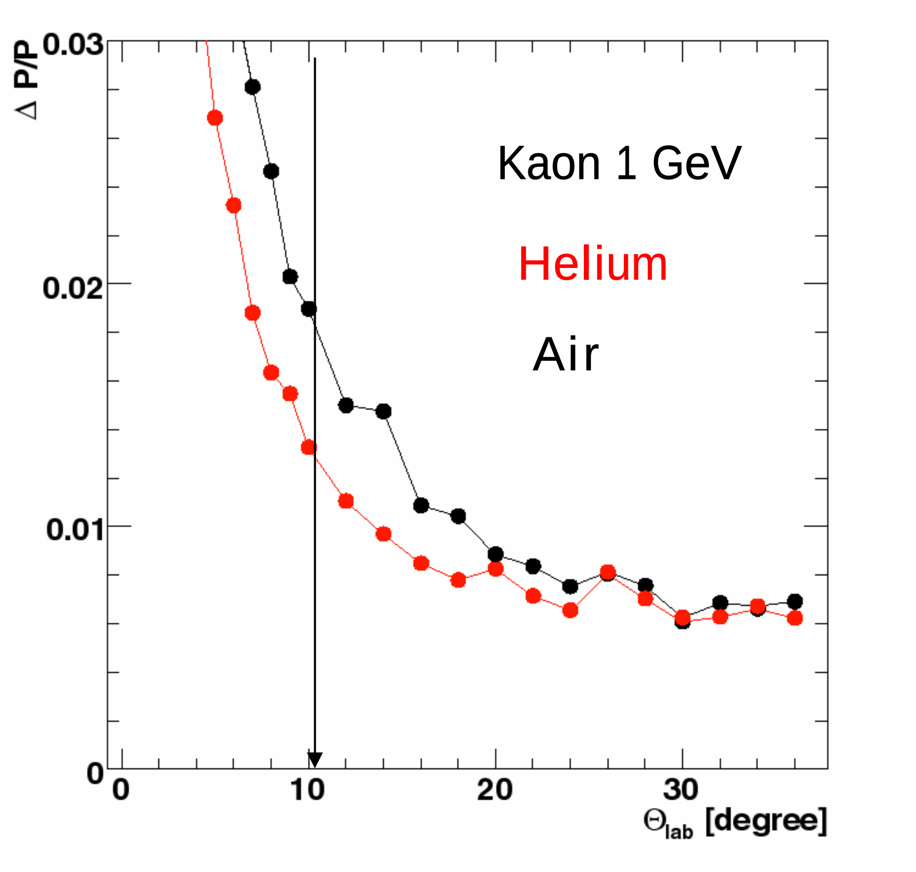

Magnet
Barrel γ
Range and TOF
Barrel Tracker
Target cell
50ps TOF
γ
CFRP
SSD
TPC
MWDC
Target and SSD

Setup for Tracking system



- **SSD (Cylindrical+ Corn)**
  Double side,
  σ=35um,
  100um thick,
- **TPC**
  Ar+Methan (P10)
  R = 500 mm (26 layer),
  $\sigma_{r\phi}$ =150um,
- **Forward MWDC chamber**
  He4+Ethane,
  R = 450 mm,
  6 wire plane,
  σ_{xy} =150um,
  $X/X_0 = 1.1\text{x}10^{-3}$,
- **Barrel tracker**
  Cathode strip + Anode wire
  $\sigma_{r\phi}$ = 250um, σ_z = 2-3 mm

ΔP/P at forward region



GEANT4 Simulation

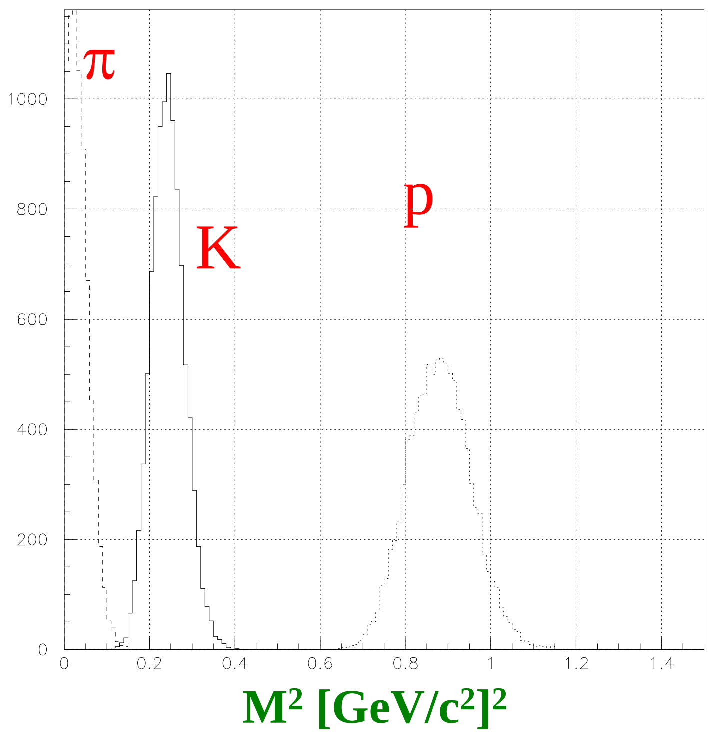
For 1 GeV kaon at 10 degree

ΔP/P = 1.4% (He4 gas)
1.9% (Air)

→ Momentum dependence

PID (TOF) at forward angle

P=1.5 GeV



N(π)/N(K) = 10^3

3 % in 2σ cut

→6σ at 1.5 GeV/c

- Forward TOF

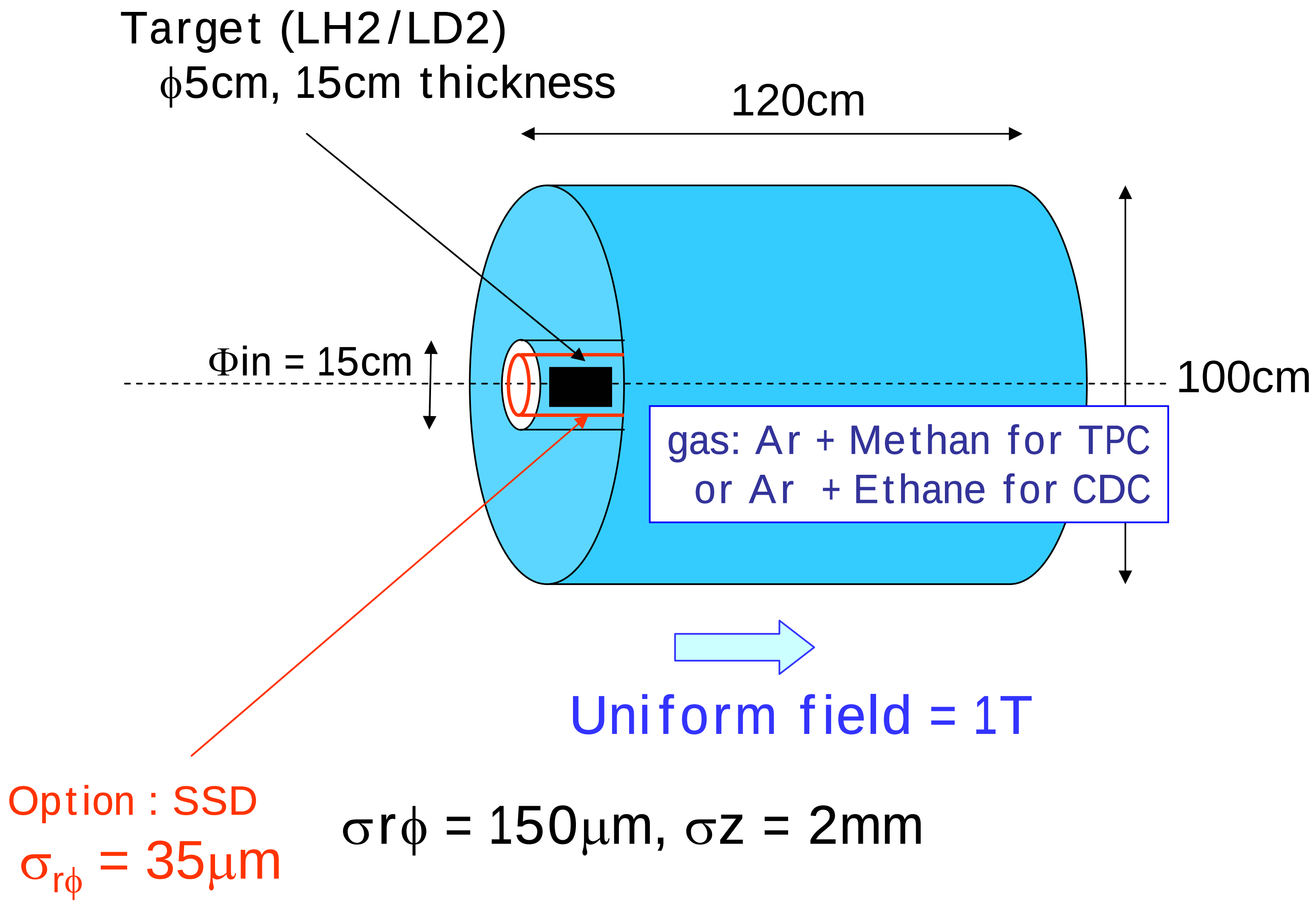
  ΔT=50 psec,

  Scintilating fiber type,

  2D information,

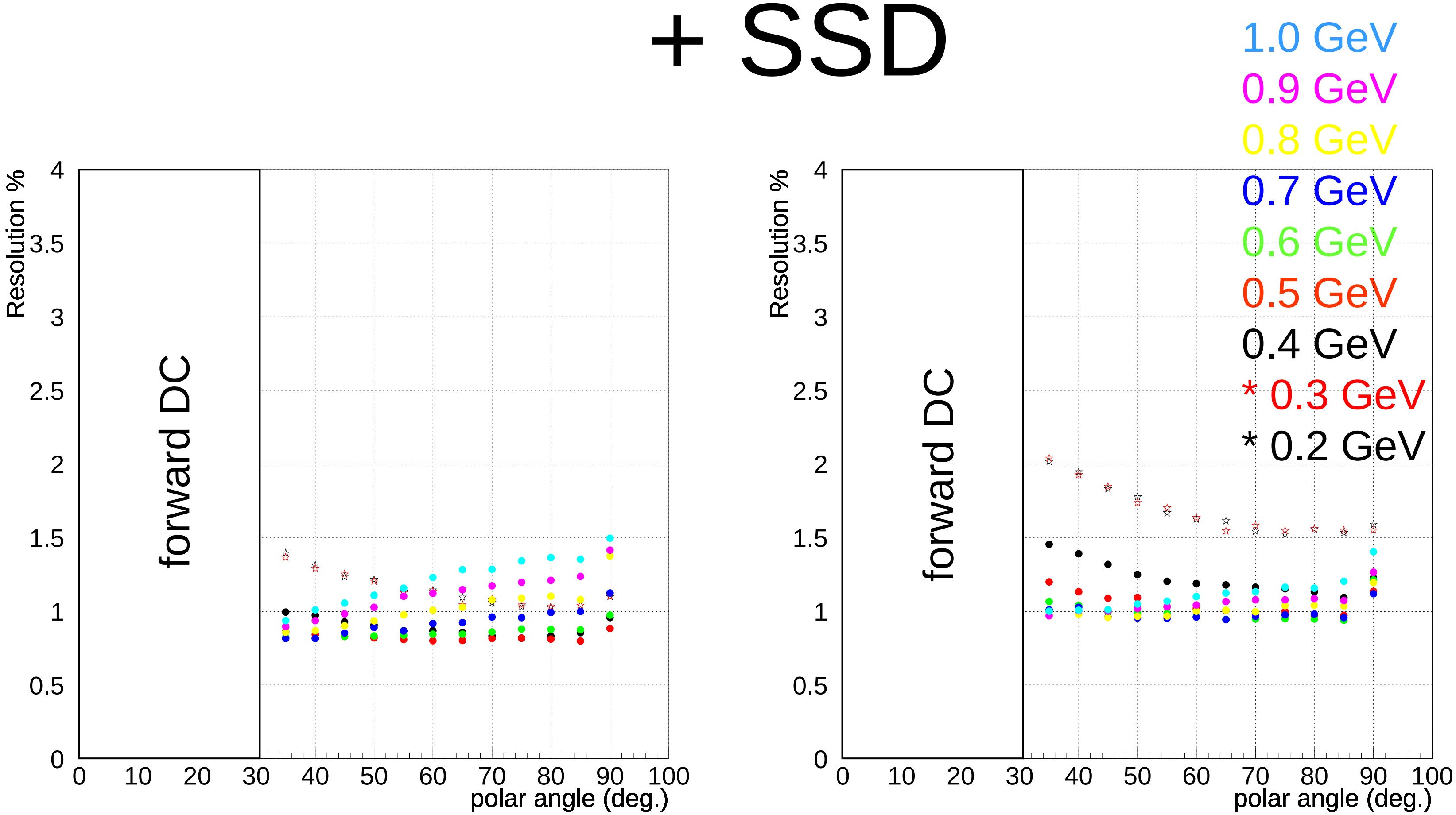
  Placed at L=190 cm

TPC or CDC



$\sigma r\phi$ = 150μm, σz = 2mm kaon

φ100cm, CDC,TPC + SSD



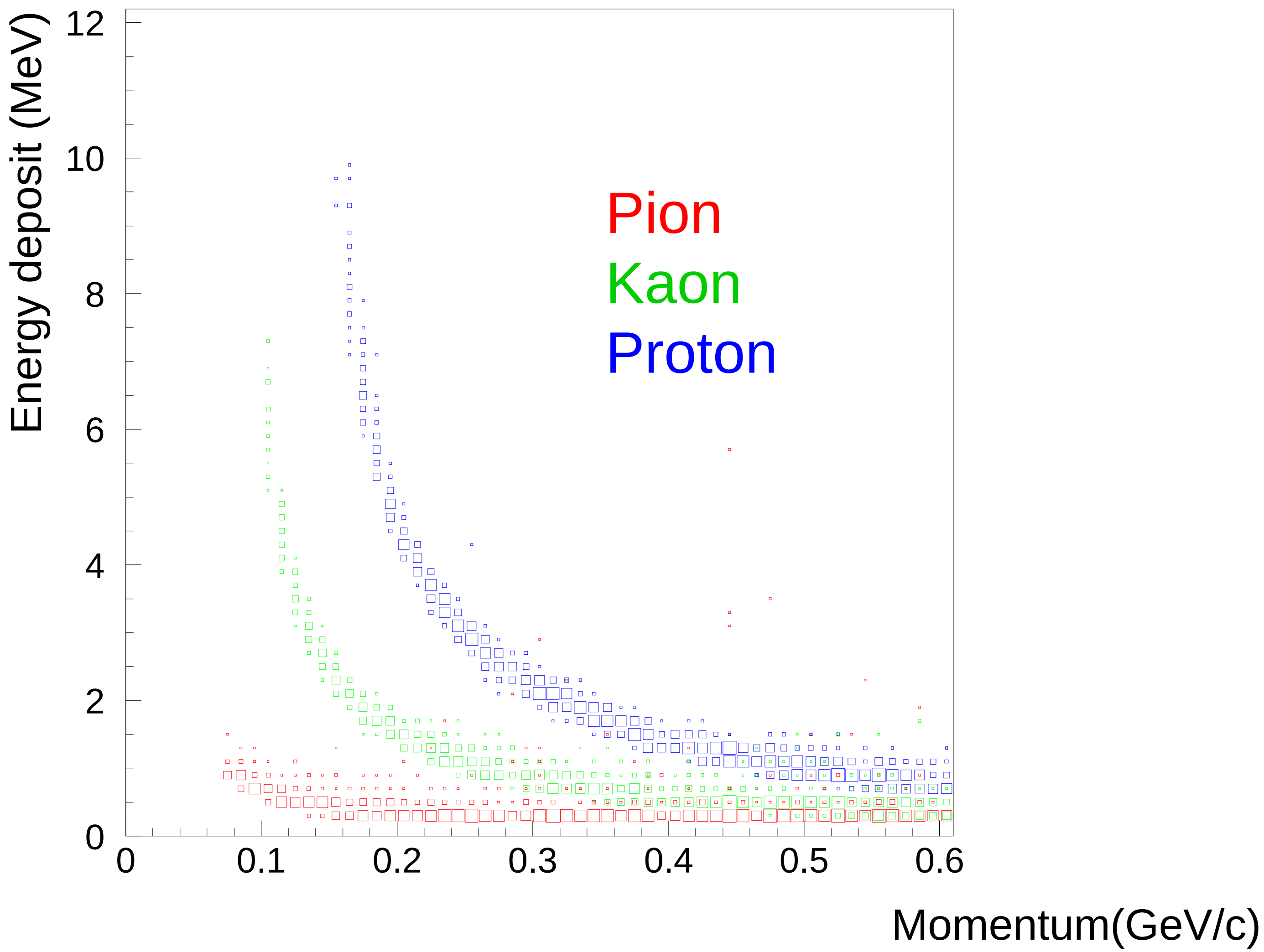
Ar(50) : Ethan(50)

CDC (3 cm pitch for rφ, z)

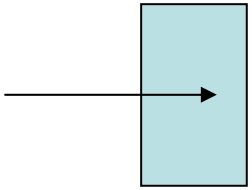
Ar(90) : Methan(10)

TPC (1.5 cm pitch for rφz)

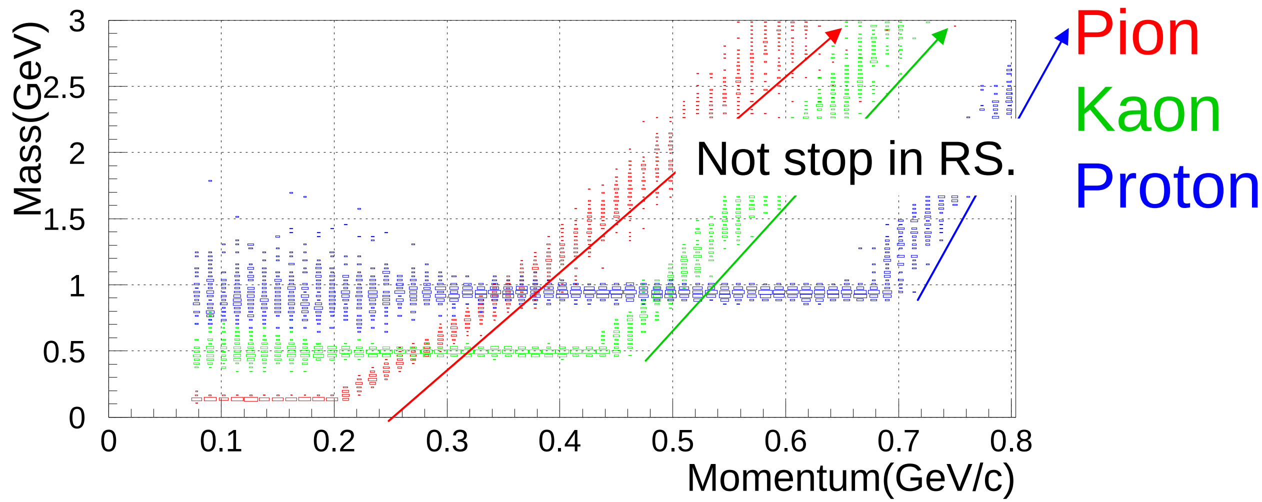
PID in TPC (Ar:Methan) for low momentum particles.



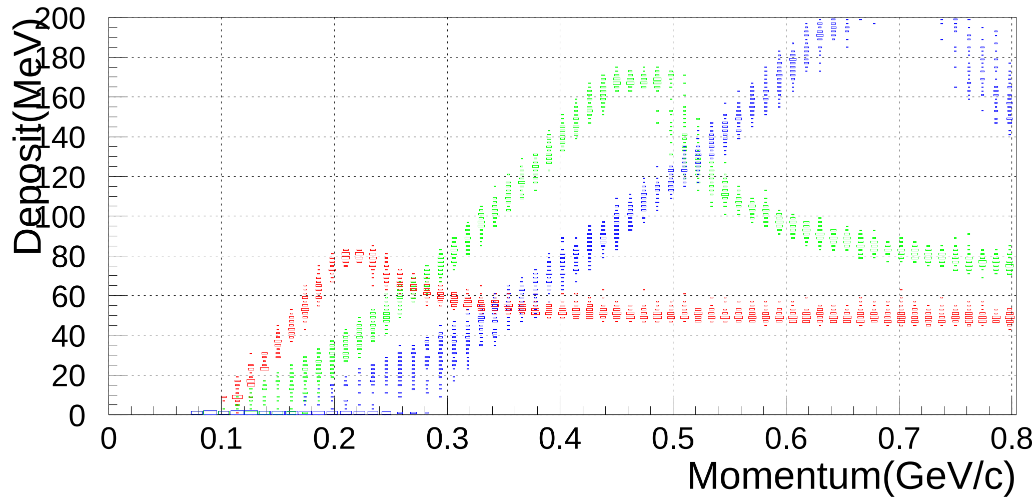
15 layers –incident angle 0º



Kinetic energy
&
momentum(σ=1.5%)



Total energy deposit



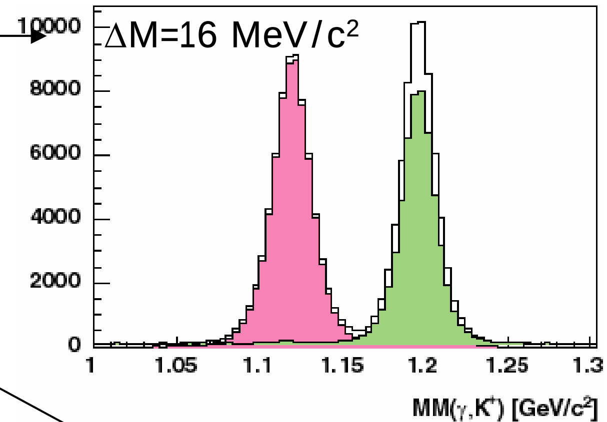
Hyperon production at Eγ=2.4 GeV

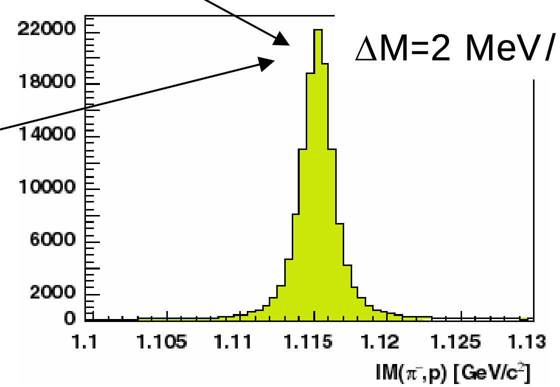
Strangeness tagging

$$\gamma + p \rightarrow K^+ + \Lambda(1116)$$
$$\rightarrow p\ \pi^-$$

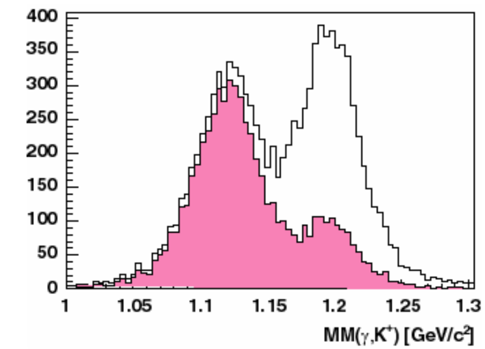
$$\gamma + p \rightarrow K^+ + \Sigma(1192)$$
$$\rightarrow \Lambda\ \gamma$$
$$\rightarrow p\ \pi^-$$

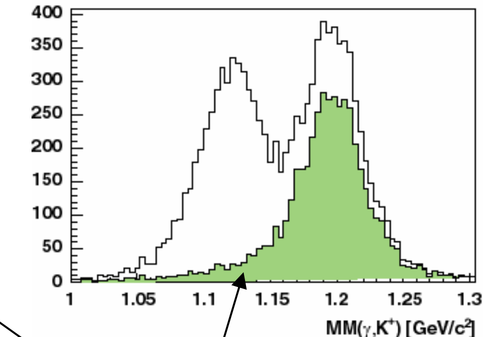
$\Theta_K >$ 15 degree



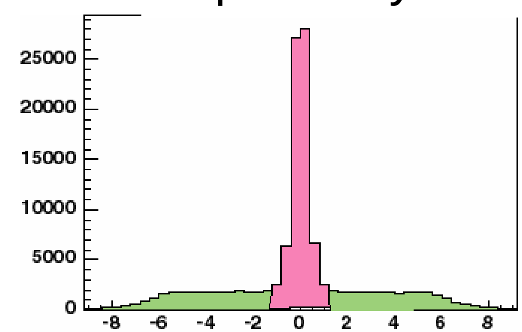


$\Theta_K <$ 15 degree





Coplanerity Cut



$\phi_{K+} - \phi_{\Lambda}$ [deg]

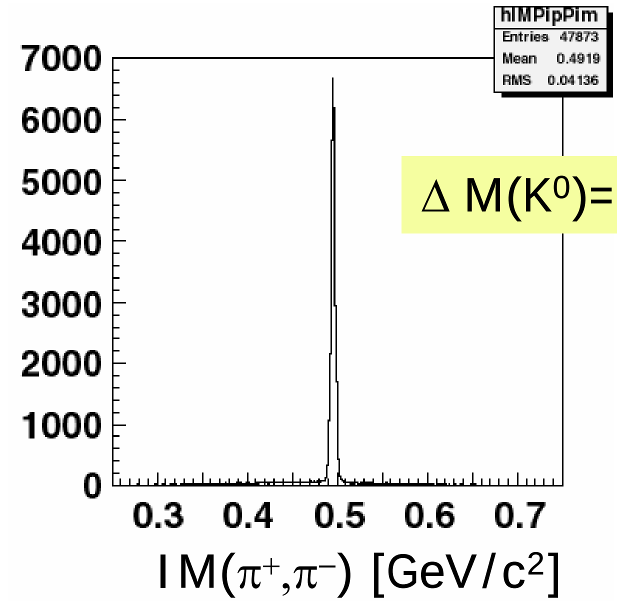
Pentaquark: Θ^+

Strangeness tagging

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

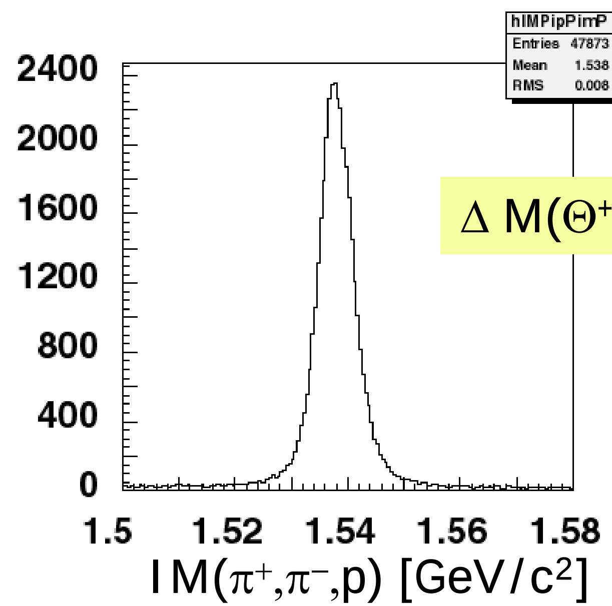
$$\rightarrow p \;\; K^0$$

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



Δ M(K^0)=2.4 MeV/c^2

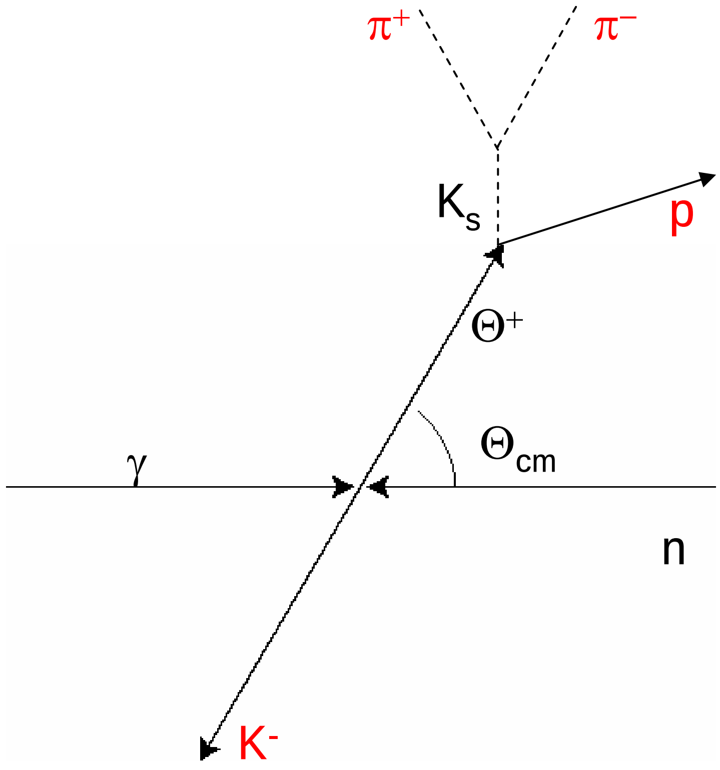
Invariant Mass measurement



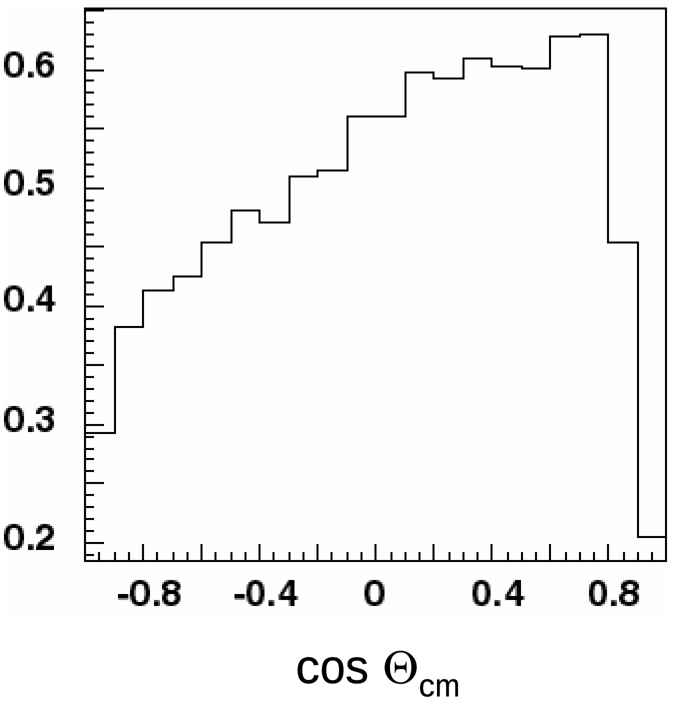
Δ M(Θ^+)=3.5 MeV/c^2

Factor of ~3 improvement in terms of the mass resolution compared to missing mass measurements.

Angular acceptance



geometrical acceptance 50%



$\gamma d \rightarrow \Lambda(1520)\Theta^+$

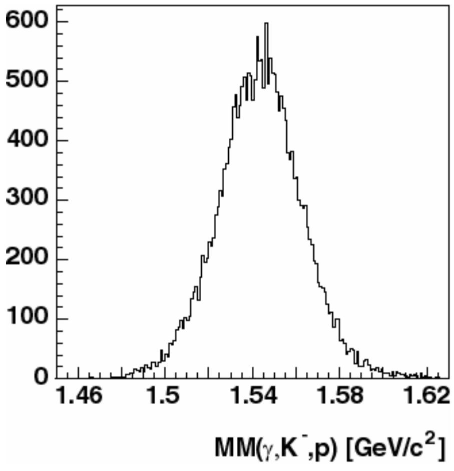
$\gamma d \rightarrow \Lambda(1520)\ \Theta^+$, $\Lambda(1520) \rightarrow K^- p$

$\gamma d \rightarrow \Lambda(1520)\ \Theta^+$, $\Lambda(1520) \rightarrow K^- p$, $\Theta^+ \rightarrow K^+ n$

$\gamma d \rightarrow \Lambda(1520)\ \Theta^+$, $\Lambda(1520) \rightarrow K^- p$, $\Theta^+ \rightarrow K_s p$

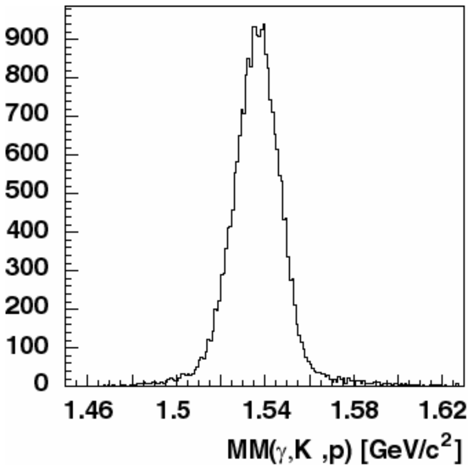
Missing Mass

$\Delta M(\Theta^+) = 17$ MeV/c^2



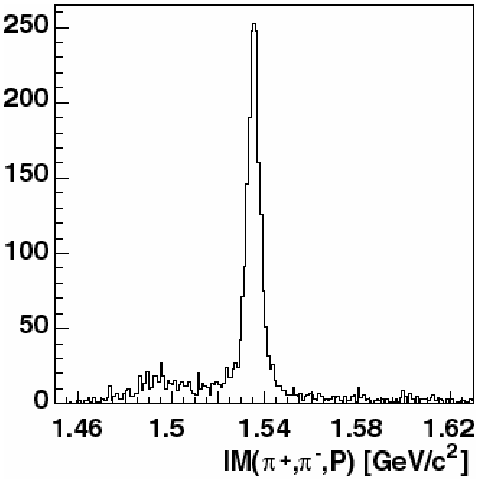
+ Kinematical fit

$\Delta M(\Theta^+) = 10$ MeV/c^2

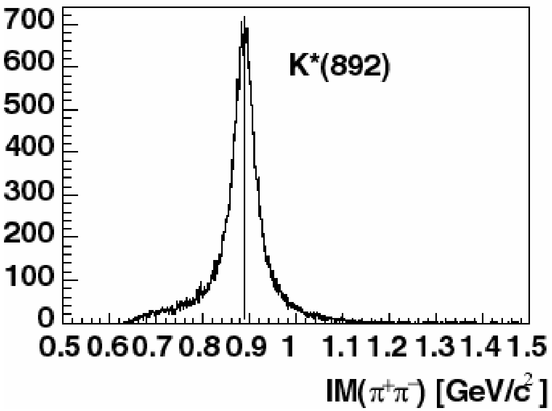


Invariant Mass

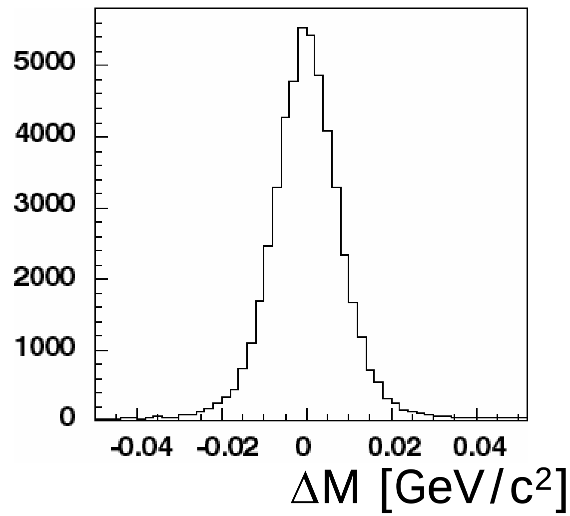
$\Delta M(\Theta^+) = 3$ MeV/c^2



$\gamma p \rightarrow K^{*}\Lambda(1405)$



Missing mass resolution for $\Lambda(1405)$
8 MeV/c^2



$$\gamma + p \rightarrow K^{*+} + \Lambda(1405)$$

- $K^{*+} \rightarrow K^0 \pi^+$
  - $K^0 \rightarrow \pi^+ \pi^-$
- $\Lambda(1405) \rightarrow \Sigma^+ \pi^-$
  - $\Sigma^+ \rightarrow n \, \pi^+$

$\Lambda(1405) \rightarrow \Sigma\ \pi$ (100%)

$\Sigma(1385) \rightarrow \Lambda\ \pi$ (88%)

$\Sigma(1385) \rightarrow \Sigma\ \pi$ (12%)

スケジュール

平成１８年	平成１９年	平成２０年	平成２１年

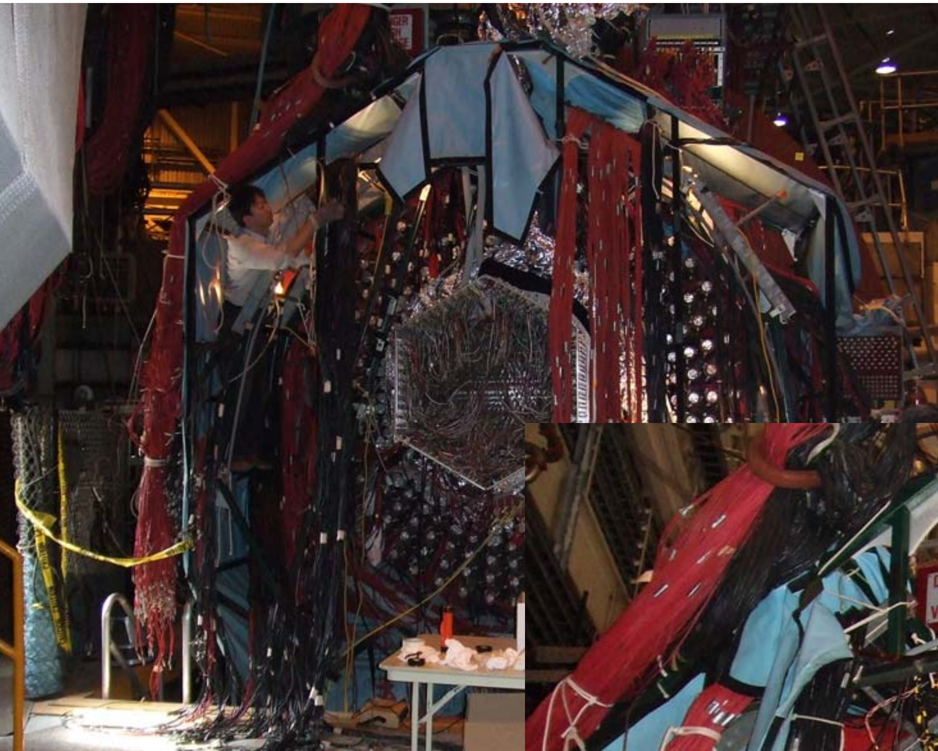
- E949検出器移設準備（BNL）
- E949検出器移動
- 崩壊解析用スペクトロメータ建設
- 反応同定用スペクトロメータ建設
- 高速データ収集システム設置
- 検出器系コミッショニング
- 蓄積リング改造
- ビームライン建設
- 実験棟建設
- インフラ整備
- 放射線遮蔽システム建設
- レーザー入射システム設置
- ビームコミッショニング
- 本実験
- 4πガンマ線検出器開発
- X線反射システム建設

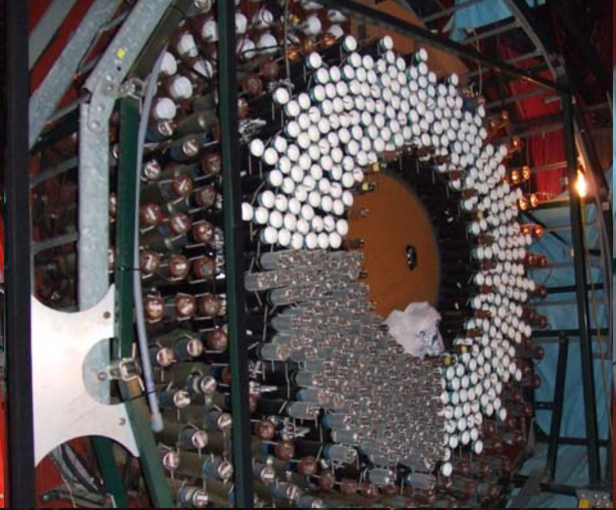
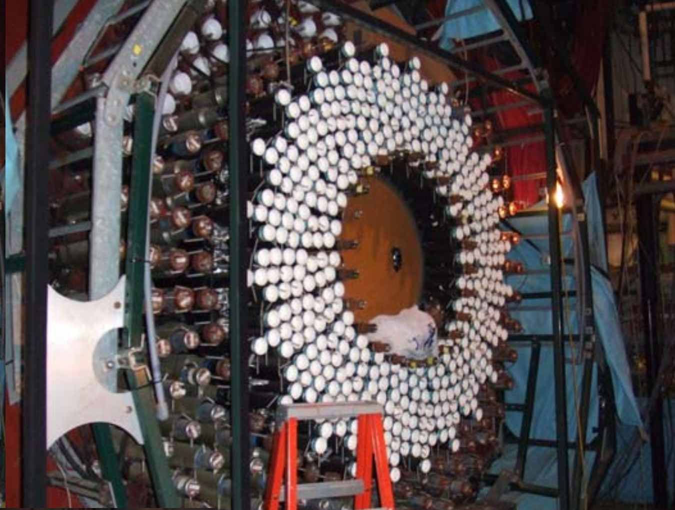
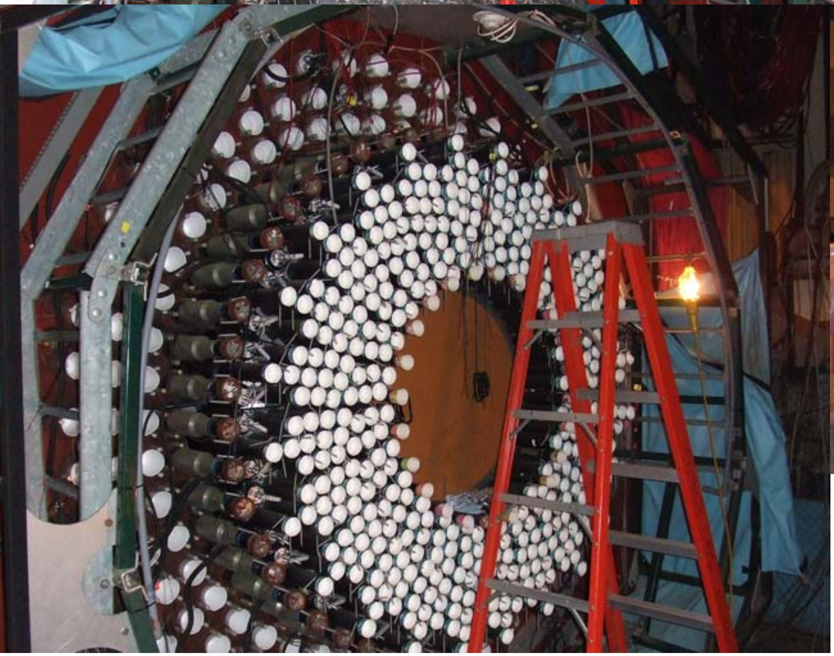
レーザーハッチを平成１９年度に開始したい。

検出器系の建設と平行して、まず、高強度ＬＥＰビームの生成を確認する。

汎用検出器の開発を急ぎ、複数のテーマを同時に研究できるようにする。

E949検出器解体作業風景



既に、例えば光電子増倍管を1296本（全体の96%）の取り外しが終了）

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LEPS2 Collaboration

検出器建設

- 荷電粒子検出器系建設

  RCNP, 理研

- ガンマ線検出器建設

  東北大

＋LEPS　(京大、中央研究院 (台湾)、阪大･理、釜山大 (韓国)、オハイオ大 (米国)、等＋α

ビームライン建設

- 蓄積電子リング改造

  JASRI

- レーザー入射系建設

  RCNP

- X線反射系建設

  東北大

実験施設建設

• 実験棟建設	理研
• インフラ整備	JASRI
• 放射線遮蔽システム	RCNP