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Search for narrow pion-proton states in s-channel at EPECUR: experiment status.

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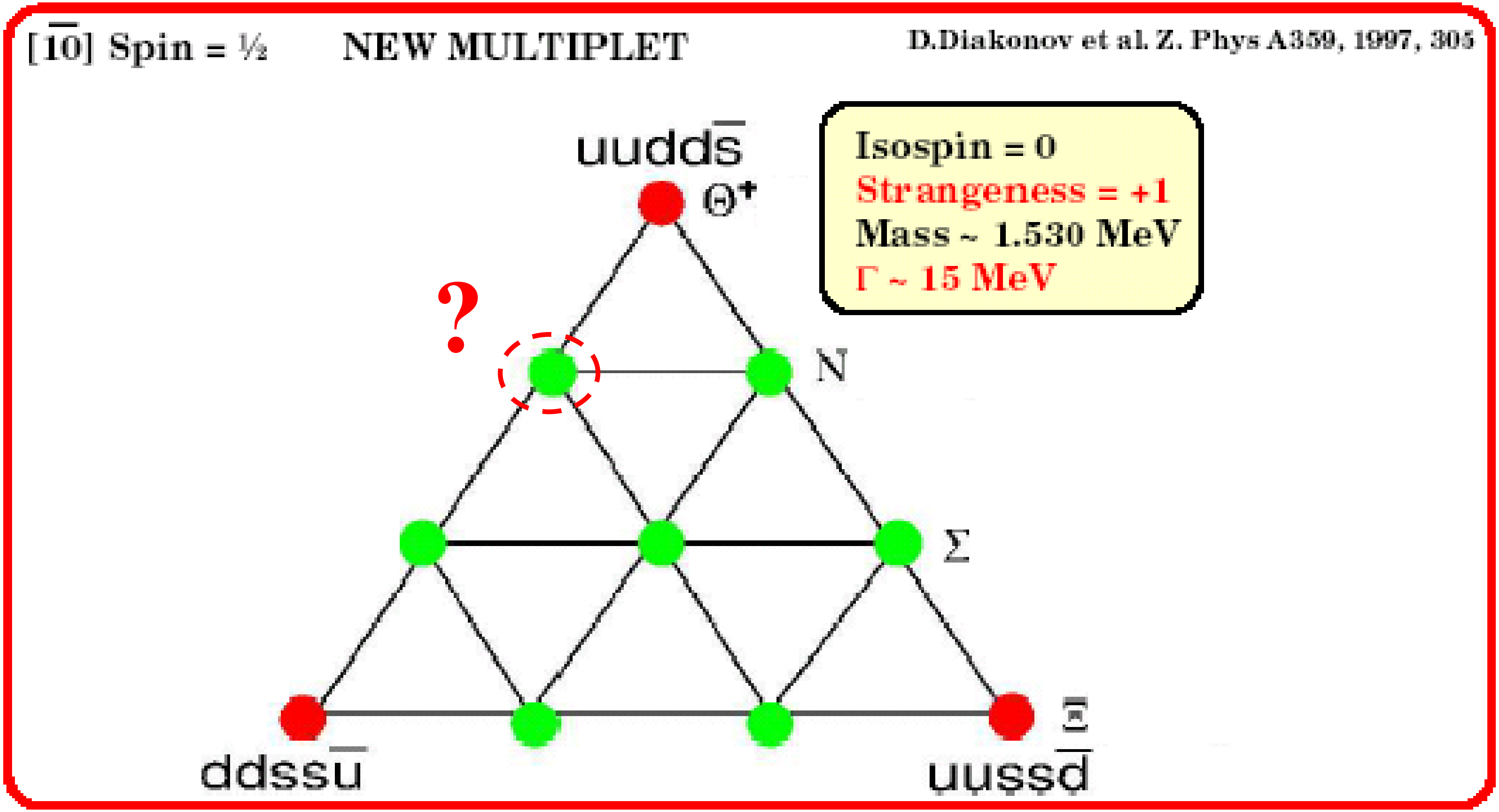
Pentaquark antidecuplet



$\pi^- p \to \pi^- p$ and $\pi^- p \to K_S^0 \Lambda$

What is special in our experiment:

- "Formation"–type experiment.
- Extremely high invariant mass resolution (~0.6 MeV), provided by high momentum resolution of the magneto-optic channel 0.1%.
- Magnetless spectrometer with drift chambers.
- Liquid hydrogen target.
- Very small amount of matter on the particle paths.
- High statistical precision: 0.5% for elastic scattering and 1% for KΛ-production.

Not only pentaquark…

- Precise cross section measurements:

$\pi^- p \to \pi^- p$: $d\sigma/d\Omega$ – 0.5% statistical precision and 1 MeV momentum step

$\pi^- p \to K^0\Lambda$: σ_{REAC} – 1% statistical precision and the same step

$\Rightarrow$ Very important data for PWA

- Usual resonace P11 N(1710)***
- Λ-polarization in the reaction $\pi^- p \to K^0\Lambda$ - an order of magnitude better precision then the best data available now - NIMROD (78)

Some formalizm

Elastic scattering amplitude could be presented as a sum over partial waves:

$$f_{el}(\theta, E) = \frac{1}{2ik} \sum_{l=0}^{l_{max}} (2l+1)(\eta_l \cdot e^{2i\delta_l} - 1) P_l(\cos\theta)$$

δ_l – phase of wave l, η_l - elasticity of wave l.

Partial amplitude:

$$f_l = \frac{\eta \cdot e^{2i\delta} - 1}{2ik}$$

near the resonance one can wrote: $f_l(E)=f_l^B+f_l^r(E)$, where f_l^B has a weak energy dependence.

Partial cross section: $\sigma_l=4\pi(2l+1)|f_l^B+f_l^r|^2$

Breit-Wigner resonance:

Elastic scattering:

$$f_l^r(E) = -\frac{e^{i\varphi}\Gamma_{el}}{2k\left[(E-E_r)+i\Gamma/2\right]}$$

$$f_l^r(E_r) = i\frac{e^{i\varphi}X}{k}, \quad X = \frac{\Gamma_{el}}{\Gamma}$$ - elasticity

Reaction $\pi p \to K\Lambda$:

$$f_l^r(E) = -\frac{e^{i\varphi}\sqrt{\Gamma_{el}\Gamma_{K\Lambda}}}{2\sqrt{kk_{K\Lambda}}\left[(E-E_r)+i\Gamma/2\right]}$$

$$f_l^r(E_r) = i\frac{e^{i\varphi}\sqrt{X \cdot BR}}{\sqrt{kk_{K\Lambda}}}, \quad BR = \frac{\Gamma_{K\Lambda}}{\Gamma}$$ - branching

Sensitivity

P_{11}-wave resonance cross section for m_r=1.7 GeV/c

Elastic scattering

$$\sigma_{el}^{r} = (2l+1)\cdot\frac{4\pi}{k^2}\cdot X^2$$

X=0.05

σ_{el}^{r}=0.12 mb, $\sigma_{el}\approx$10 mb

$\sigma_{el}^{r}/\sigma_{el}$=1.2%

⇒ Not very good sensitivity

KΛ-production

(k=0.56 GeV/c, $k_{K\Lambda}$=0.2 GeV/c)

$$\sigma_{K\Lambda}^{r} = (2l+1)\cdot\frac{4\pi}{kk_{K\Lambda}}\cdot X\cdot BR$$

X=0.01, BR=0.1

$\sigma_{K\Lambda}^{r}$=0.13 mb, $\sigma_{K\Lambda}$=0.9 mb

$\sigma_{K\Lambda}^{r}/\sigma_{K\Lambda}$ =15%

⇒ Excellent sensitivity

Total cross section of KΛ-production ⇒ a good method.

Total elastic cross section ⇒ not a good method.

This means that in the elastic scattering we should measure differential cross sections, where resonance will manifest itself in an interference of P_{11}-amplitude with the sum of all other amplitudes. Then the effect will be proportional to X and not to X^2. We chose an angular range where sensitivity to P_{11}-wave is reasonably good.

Argand diagram

- Парциальная Amplitude:

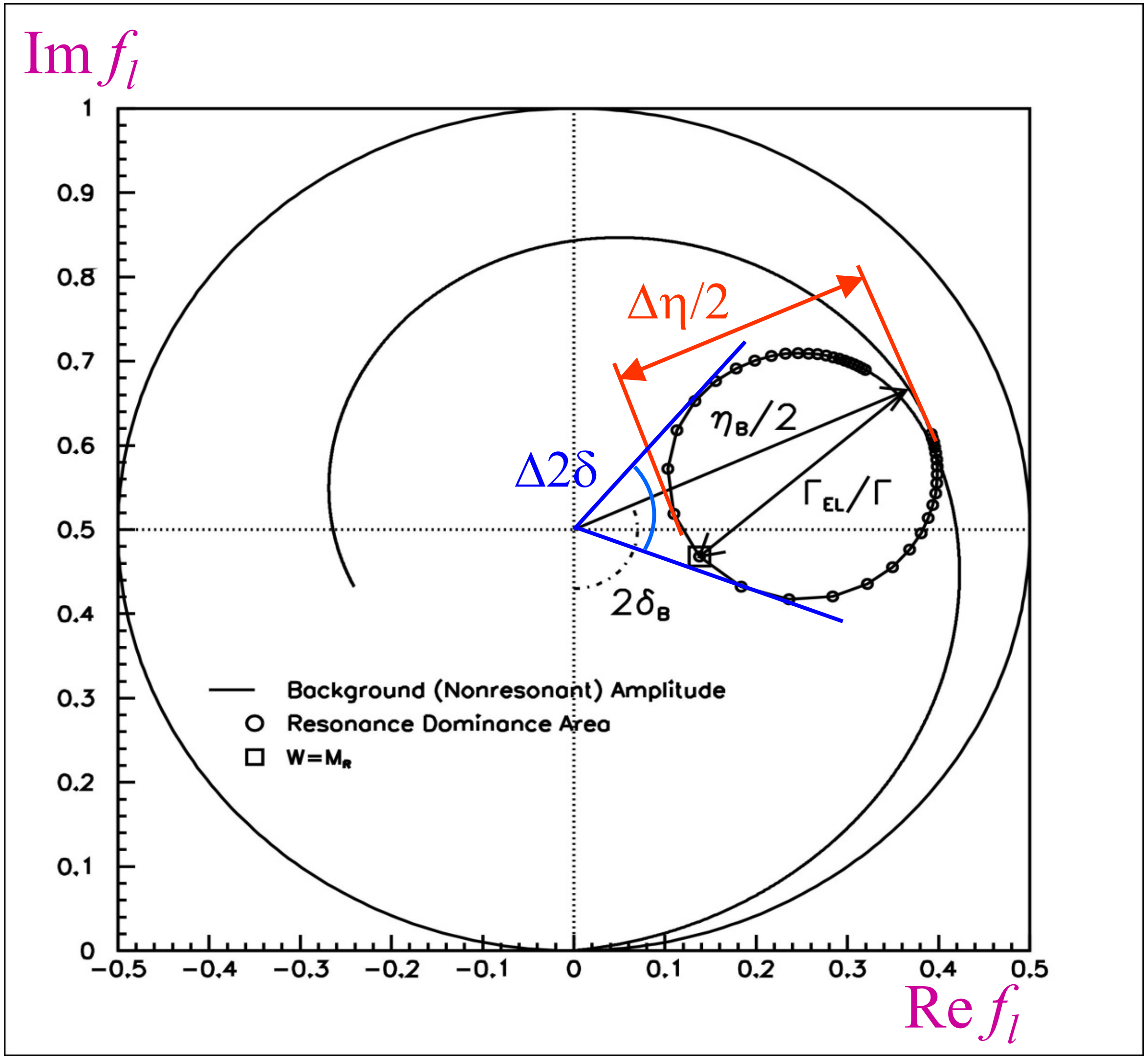
$$f_l = \frac{\eta_l \cdot e^{2i\delta_l} - 1}{2i}$$

- When $\Gamma_{EL}/\Gamma << 1$
- Change of elasticity η in the resonance:

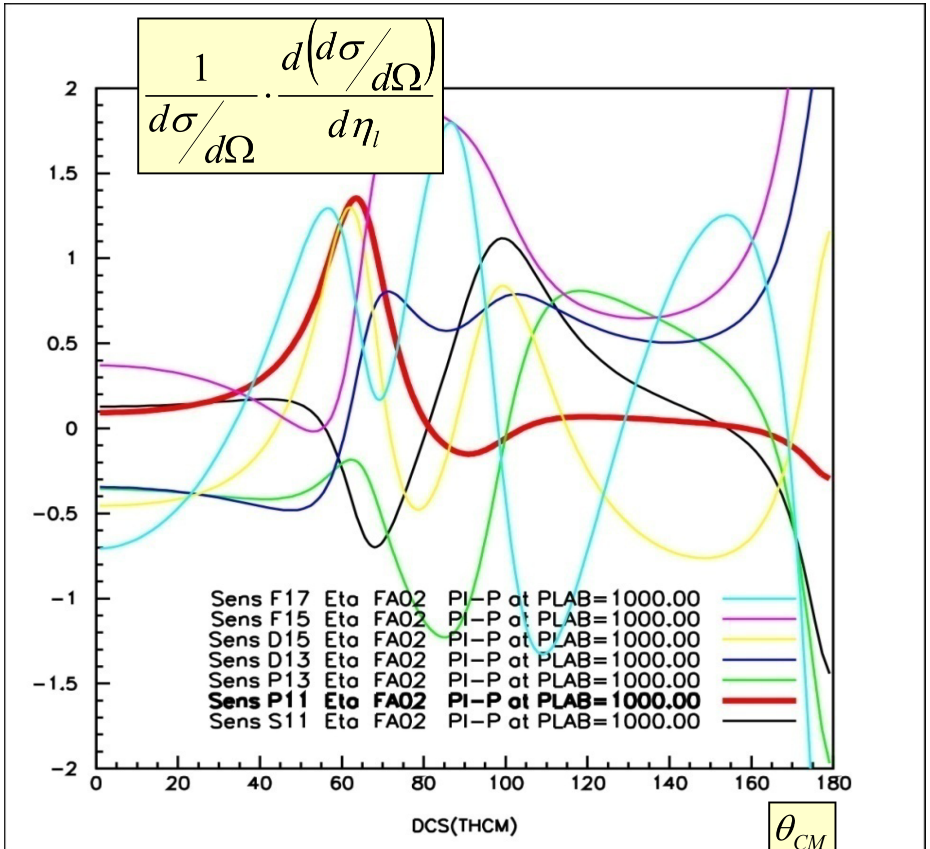
$$\Delta\eta_l \approx 2 \cdot \left(\Gamma_{EL}/\Gamma\right)$$

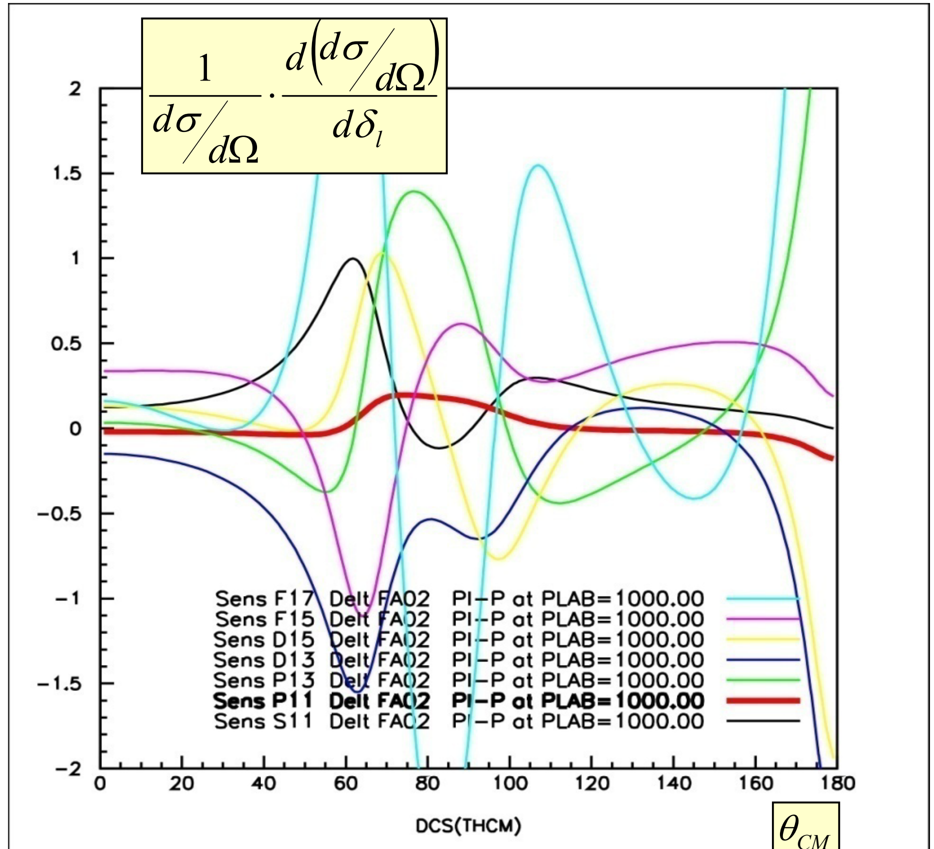
- Change of phase δ in the resonance:

$$\Delta\delta_l \approx \frac{1}{\eta_{lB}} \cdot \left(\Gamma_{EL}/\Gamma\right)$$



Sensitivity in the elastic channel



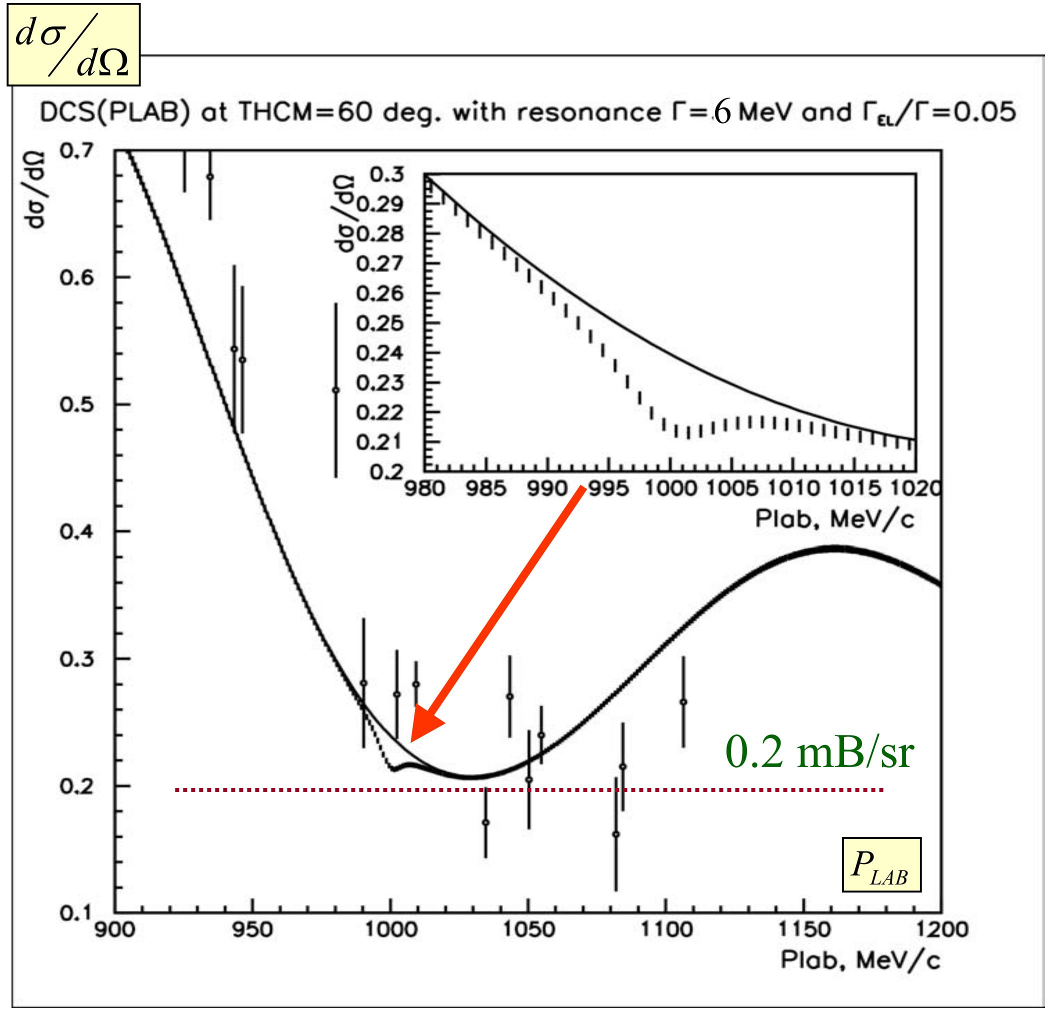


- Sensitivity of the differential cross section to elasticity is good: $\Delta\eta\,(P_{11}) \approx 1.5$, that is for $\Gamma_{EL}/\Gamma \approx 5\%$ change in the differential cross section will be 7--15%
- Sensitivity to the phase is small: $\Delta\delta\,(P_{11}) \approx 0.2$, that means that change in the phase of P_{11} doesn't contribute to the differential cross section

Expected effect

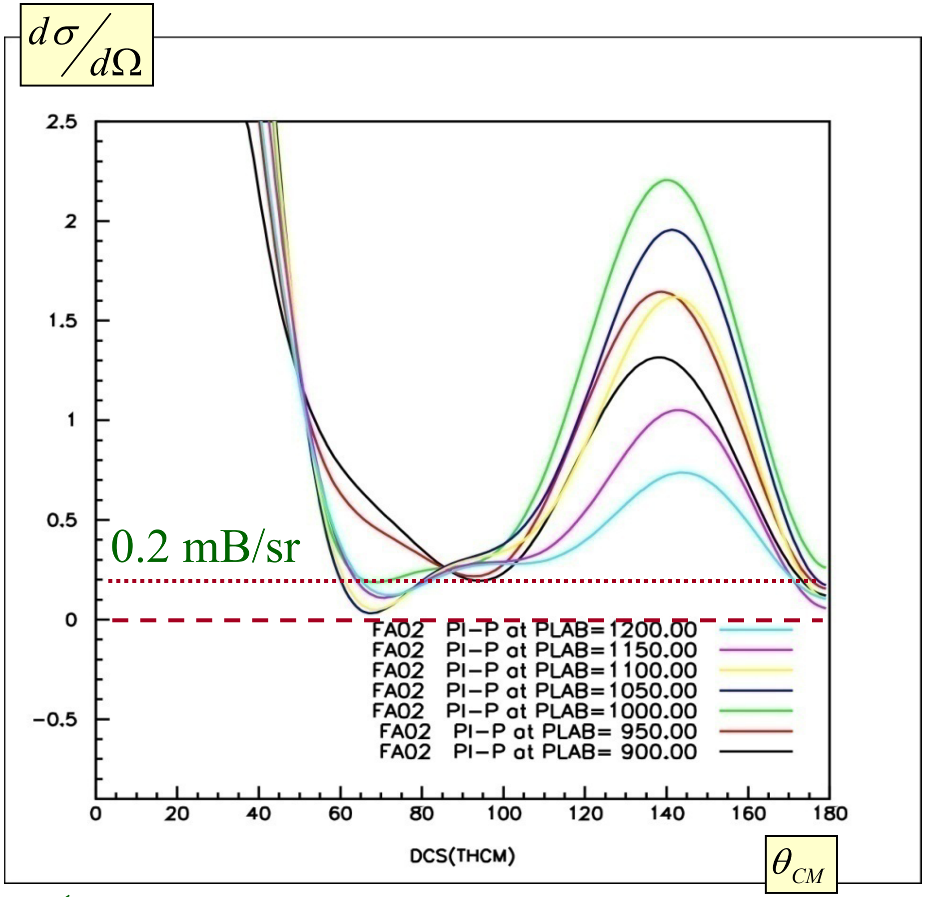
Differential cross section of the $\pi^- p \to \pi^- p$ elastic scattering

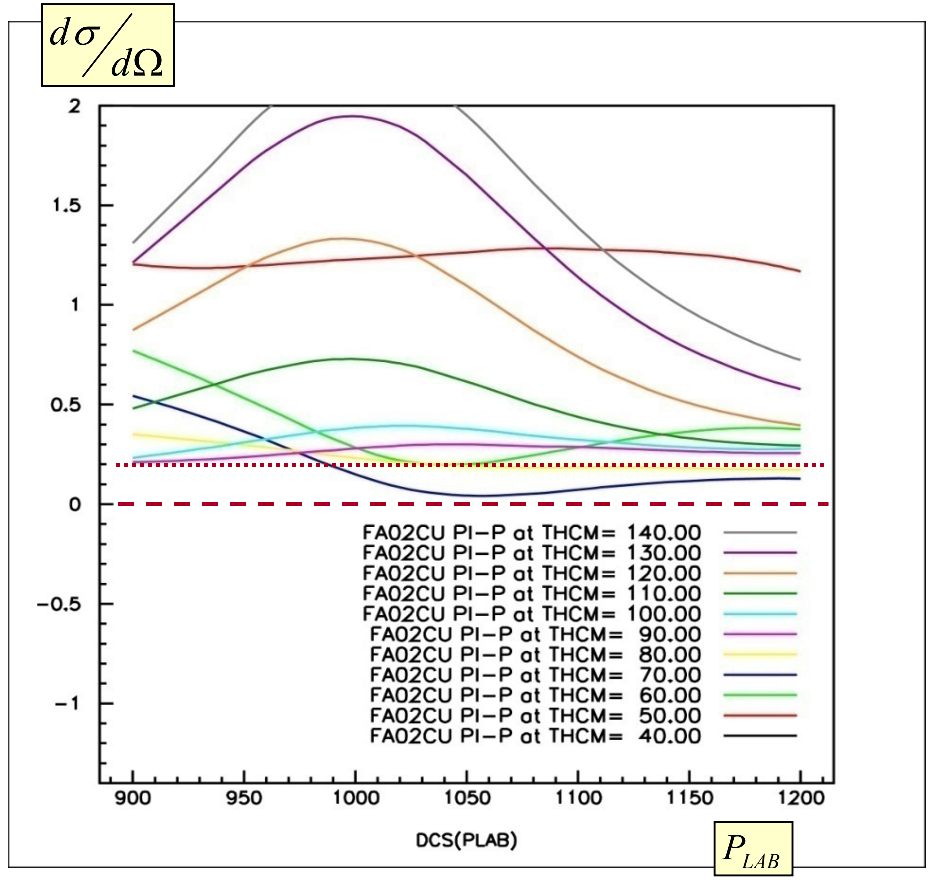
- Existing data doesn't allow to find a narrow structure
- Our idea is to measure differential elastic cross section with the statistical error 0.5% and step in the invariant mass 0.6 MeV
- We will cover angle range 30—120° in the center of mass frame and momentum range 900—1200 MeV/c (M_R=1610--1770 MeV)
- With fixed beam line settings we can cover about 30 MeV in the invariant mass. Then we can go in 15 MeV overlapping steps



Experimental conditions

Differential cross section $\pi^- p \to \pi^- p$





- ☑ Expected statistics was estimated to the differential cross section of 0.2 mB/sr.
- ☑ The energy dependence is smooth compare to the sharp a few MeV resonances under the question.

Expected results

Resonance parameters within safe reach by the experiment:

	Elastic scattering	*$K\Lambda$-production*
Width	(2-20) MeV	(2-20) MeV
Elastic width, Γ_{el}	>0.1 MeV	>0.02 MeV
Elasticity, X	>0.05	>0.01

This provides a good coverage of both theoretical and experimental expectations.

<u>Important note for the setup to be created</u>

The event selection in our magnetless spectrometer is based on the angular correlations of relatively low energy particles. This requires to have the smallest possible multiple scattering on the paths of all particles. ⇒ We needed light chambers with small amount of matter. Drift chambers with hexagonal structure were selected.

Setup for elastic scattering

⊙ Proportional chambers with 1mm pitch and 40 um aluminum foil potential electrode in the first focus (PC1-3) and in front of the target (PC4-6).

⊙ Liquid hydrogen target with beryllium outer shell and mylar hydrogen container. The target diameter is 40 mm and the length along the beam ~250 mm.

⊙ 8 modules of drift chambers with hexagonal structure to measure tracks of particles produced.

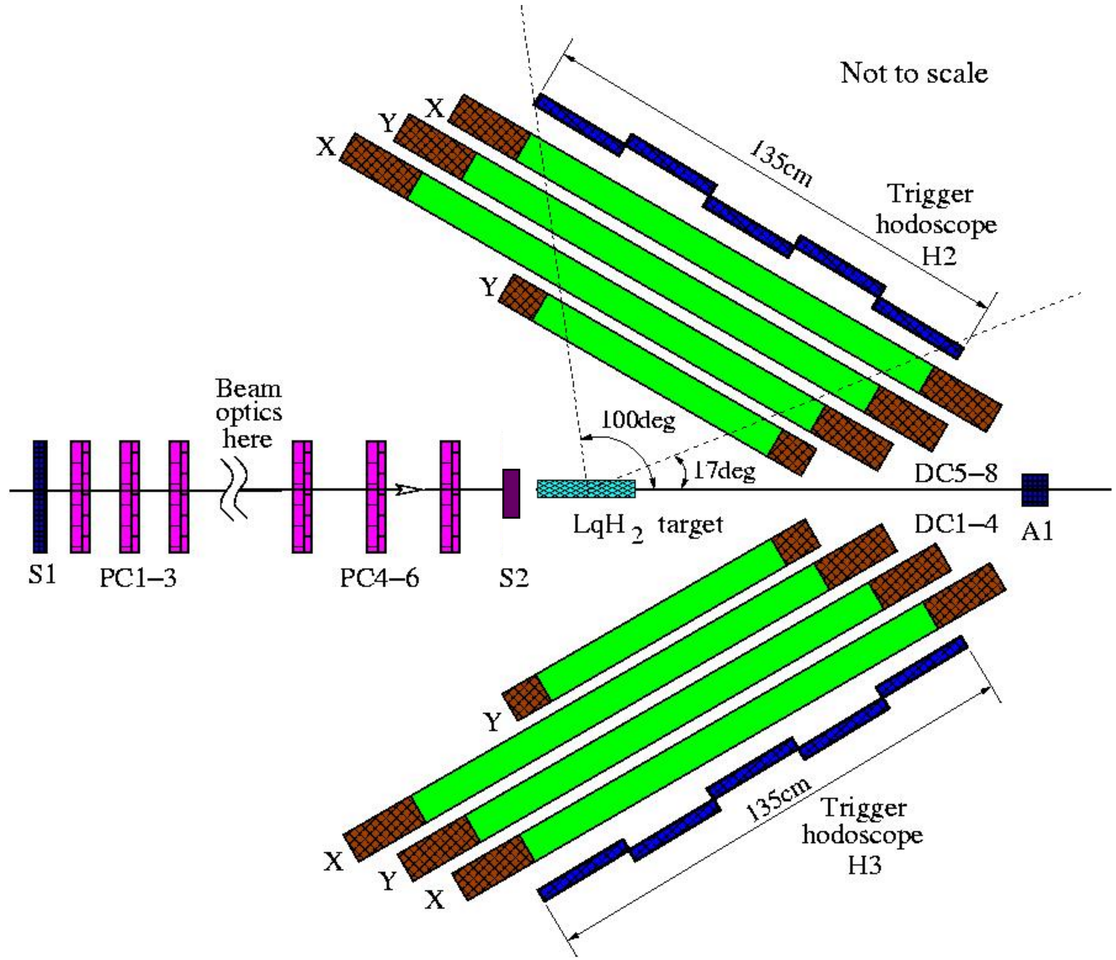
⊙ Trigger scintillation counters S1, S2, A1 and hodoscopes H2, H3.

⊙ NMR system for measurement field in the magneto-optic channel dipoles with precision better 0.1%.

⊙ Time-of-flight difference between beam pions and antiprotons measurement to control average momentum in each bin.

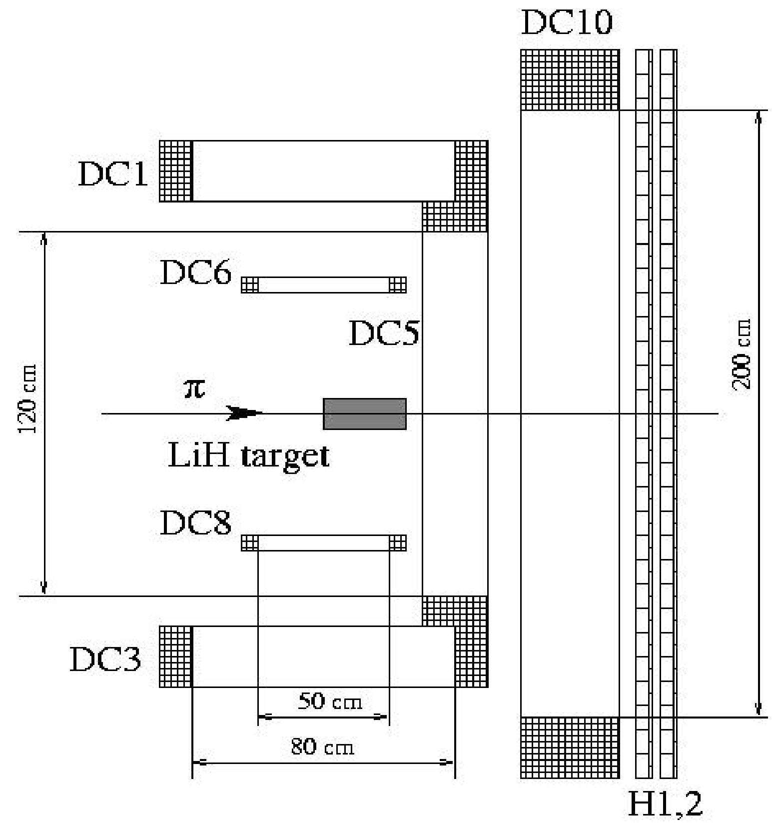
⊙ $2{\cdot}10^7$ elastic events in 2-3 weeks

$\pi^- p \rightarrow \pi^- p$



Setup for $\pi^- p \rightarrow K^0_S \Lambda \rightarrow \pi^+ \pi^- \pi^- p$

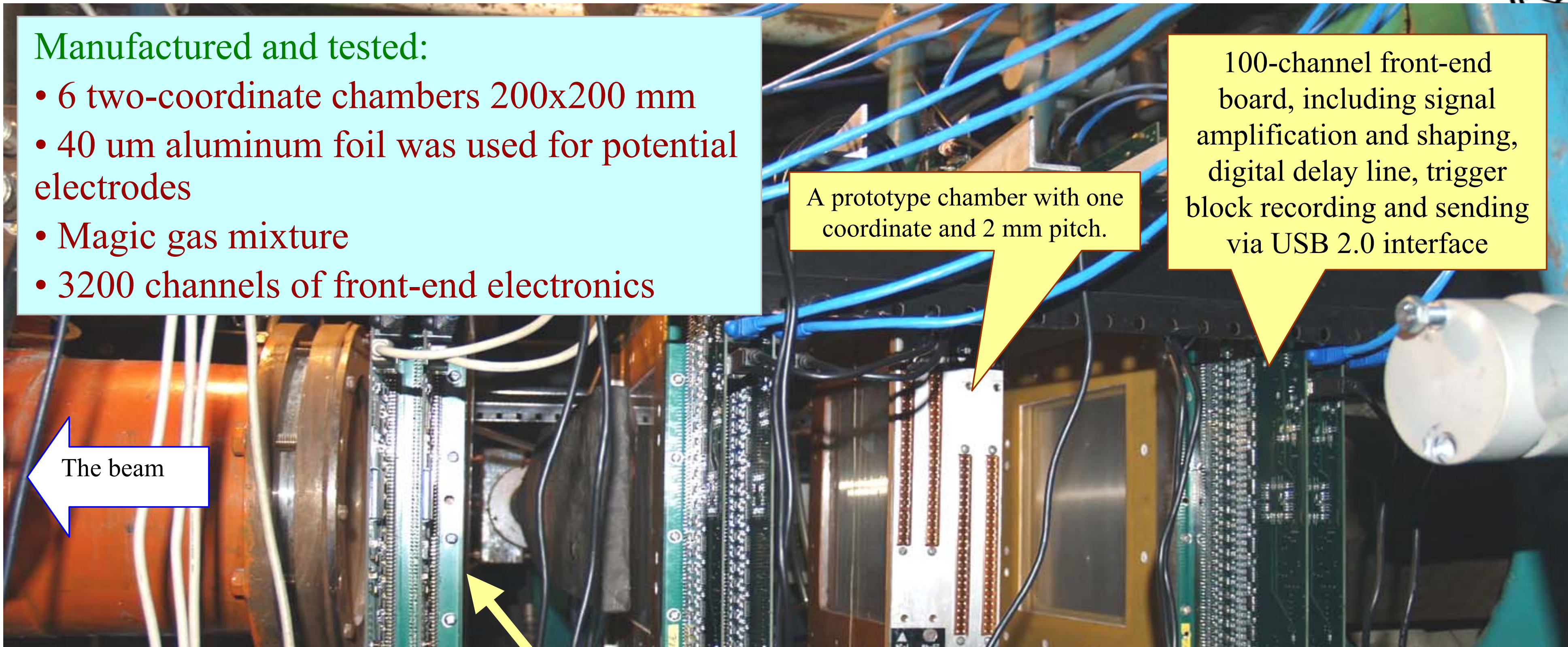
- The same:
  1. The beam line.
  2. Beam proportional chambers.
  3. The liquid hydrogen target.
  4. Drift chambers DC1-5 with sencitive volume 800x1200 mm^2
- To get reasonable 15-20% acceptance we need nearly 4π setup
- Internal drift chambers DC6—DC9 (500x700 mm^2)
- Large drift chamber DC10 (1400x2000 мм^2)
- Double layer trigger and TOF hodoscope H1,2 with 100x100 mm^2 granularity
- $3 \cdot 10^6$ events in 4-5 weeks.

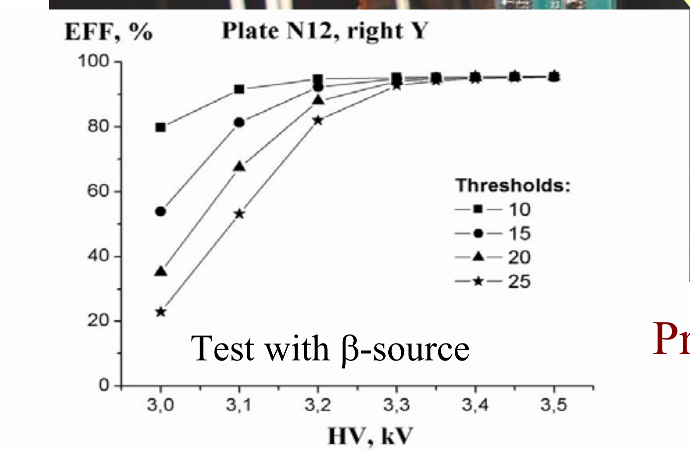


Most of the events have either all 4 particles going forward or 3 particles including the proton going forward and one pion going in some other direction

Proportional chambers with 1 mm pitch

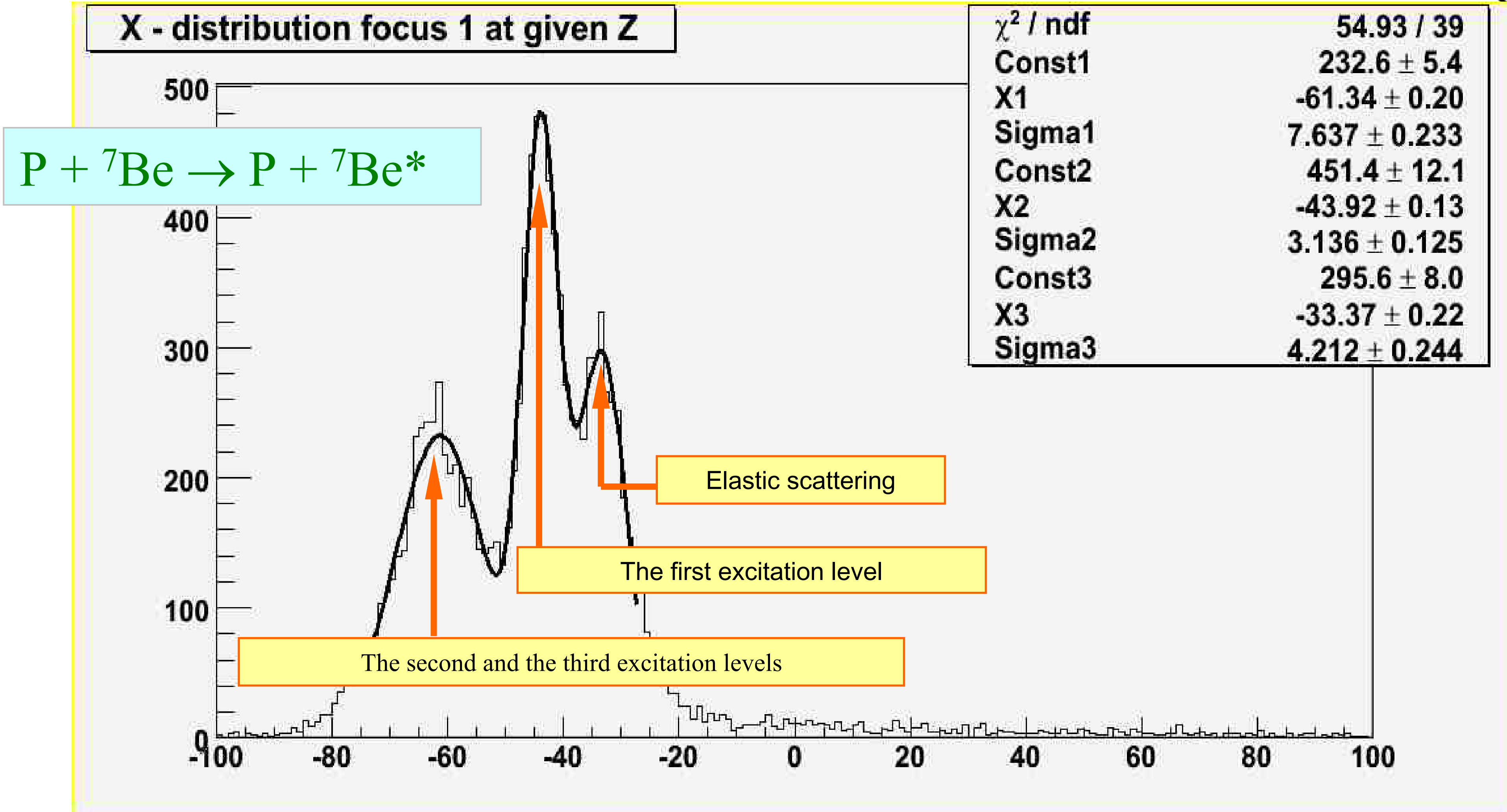
Manufactured and tested:
- 6 two-coordinate chambers 200x200 mm
- 40 um aluminum foil was used for potential electrodes
- Magic gas mixture
- 3200 channels of front-end electronics





Proportional chambers in the first focus of the magneto-optic channel

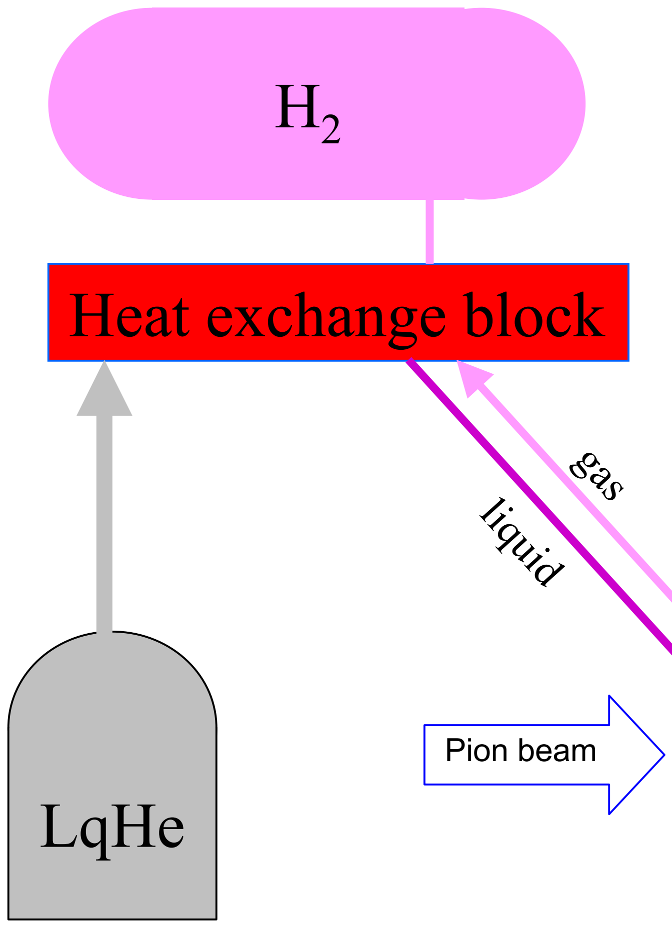
Measurement of the beam momentum resolution



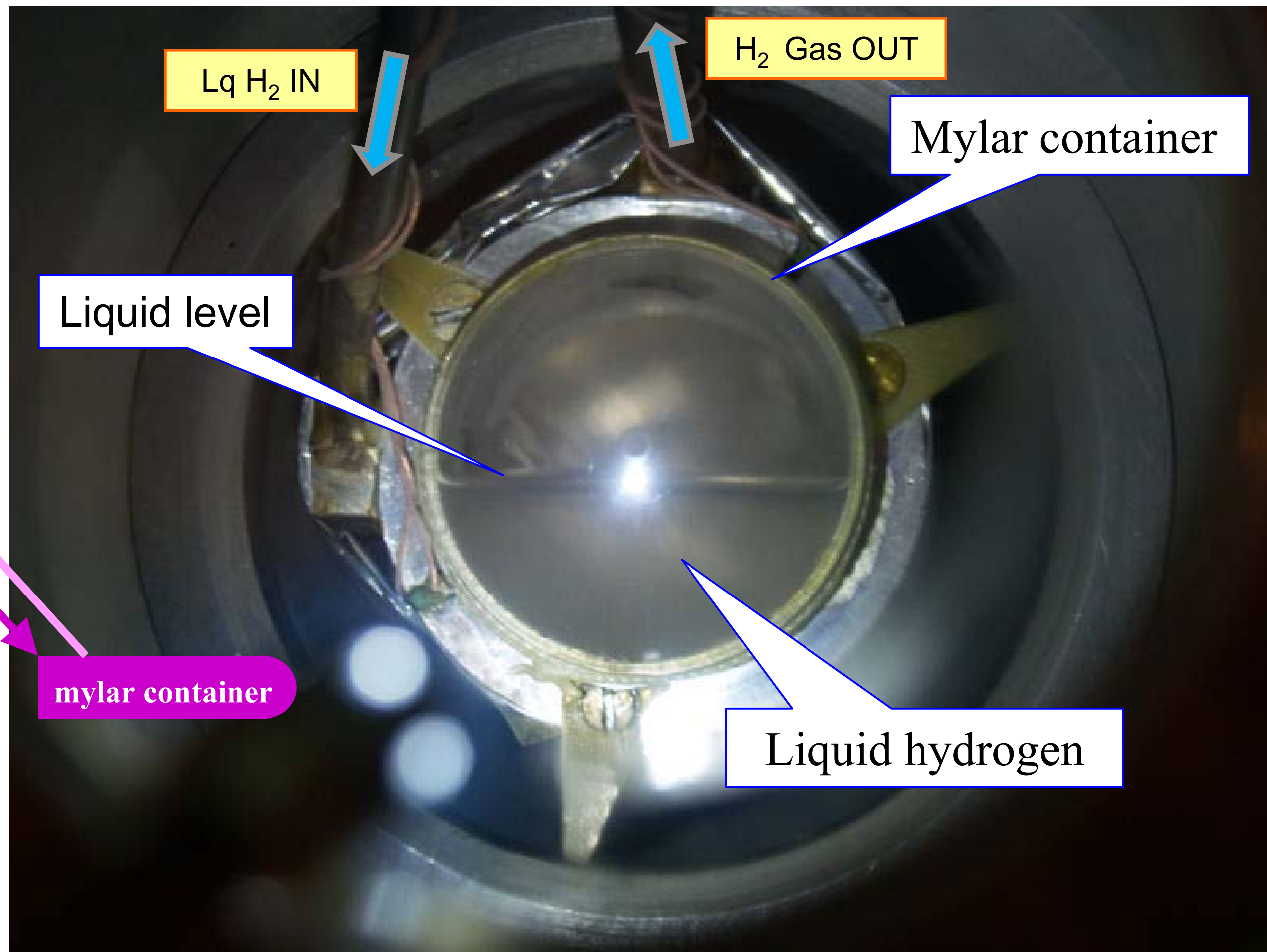
Horizontal coordinate distribution of events of internal accelerator beam scattering on the thin beryllium target. Events were collected at the beginning of spill. This picture corresponds to the momentum resolution 0.06%.

Liquid hydrogen target

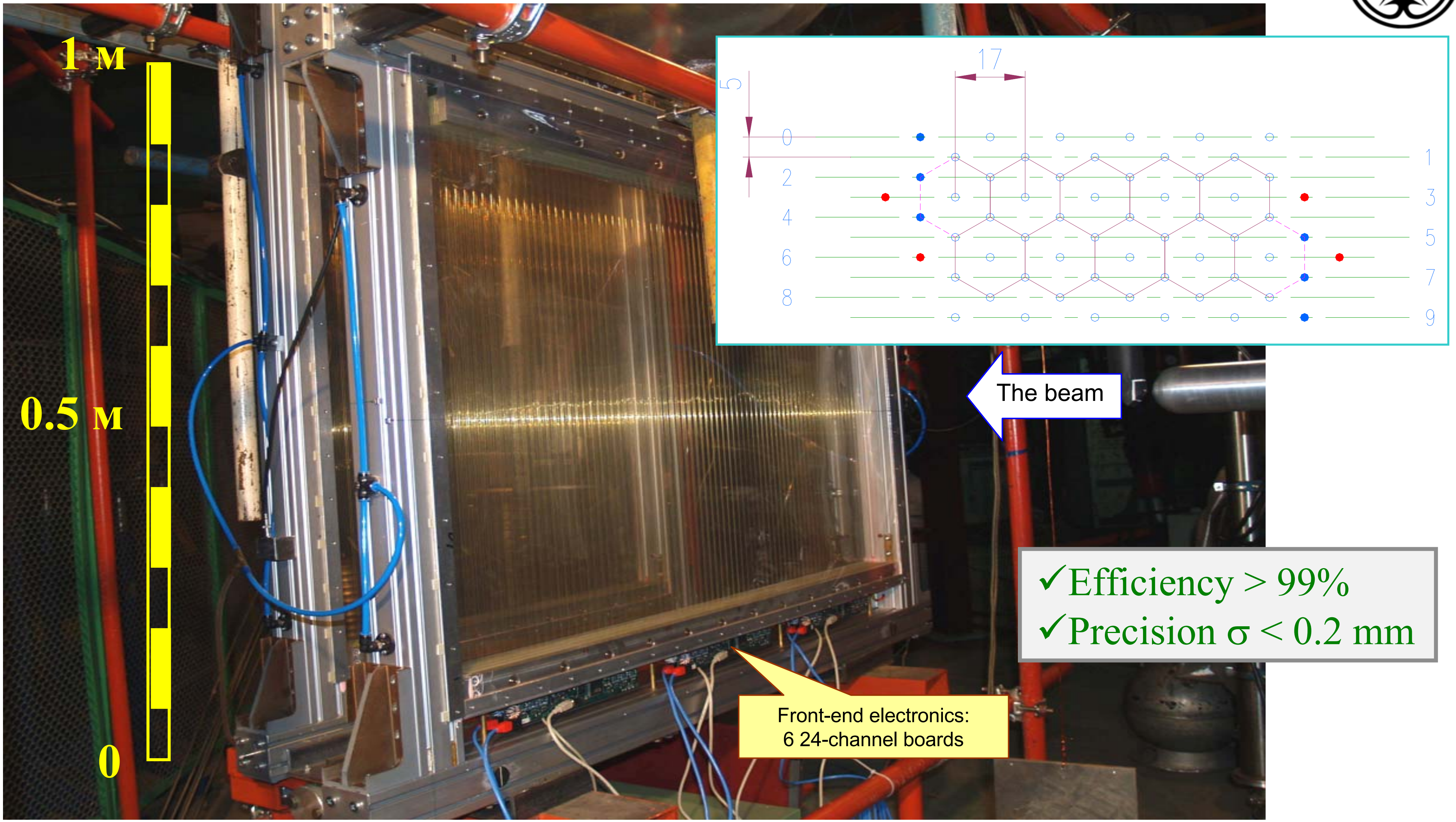
- The mylar container L=25 cm, ∅40 mm.
- Beryllium outer shell
- Tested with liquid neon and hydrogen.



While filling with hydrogen



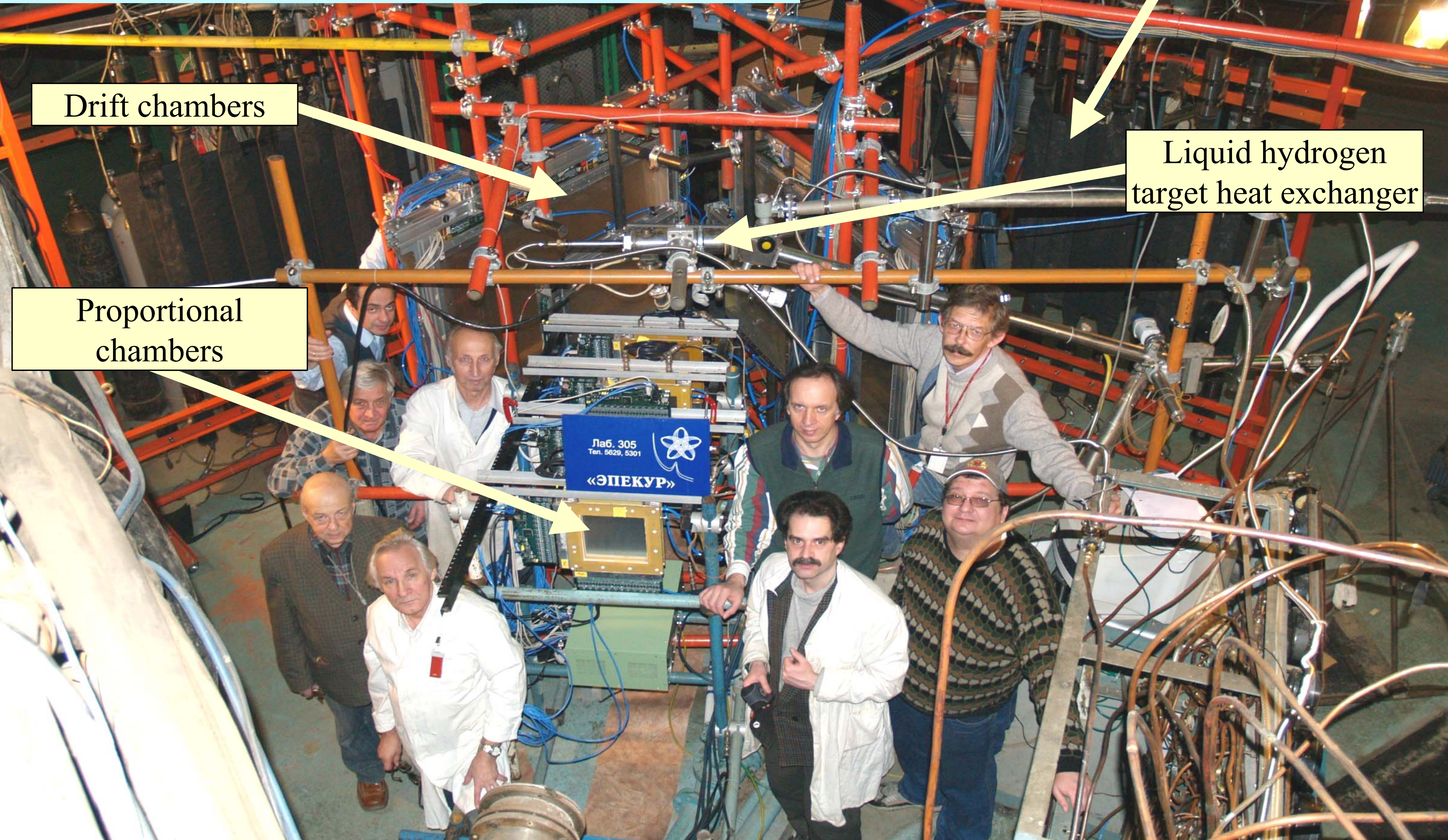
Drift chambers with hexagonal structure



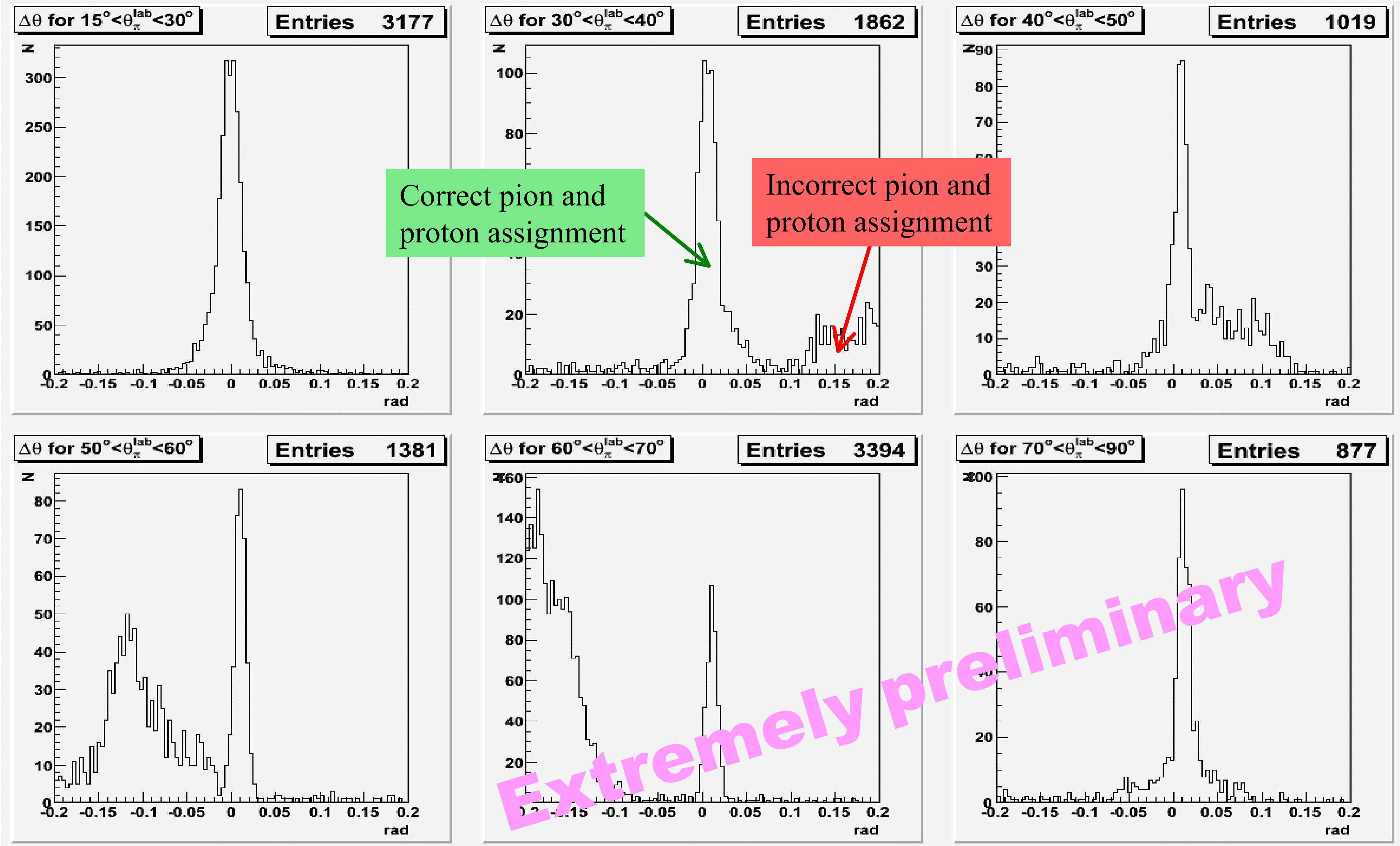
Drift chamber module “X” (wires along the short side) under test at ITEP accelerator. A “Y” module could be seen behind the “X” module.

Engineering run (December 2008)

7 millions of triggers were written with the liquid hydrogen target



Elastic events selection



The first physics run - spring 2009

- ✓ 2 weeks of beam time with pion beam
- ✓ 1st week – setup
- ✓ 2nd week – acquire statistics
- ✓ >500 millions triggers written ⇒ ~4-5 millions elastic events
- ✓ Pion beam momentum range 940 – 1135 MeV/c ⇒ invariant mass range 1640 – 1745 MeV

As a conclusion:

Elastic scattering:

- We have started taking data.
- We will have a calibration run this June.
- We may have another physics run in October-November.

We need for KΛ-production:

- Trigger hodoscope with time-of-flight capability.
- ADC and TDC for this hodoscope.
- Large (~2400×1600 mm^2) drift chambers.

New collaborators are WELCOME !