First results from the FINUDA experiment

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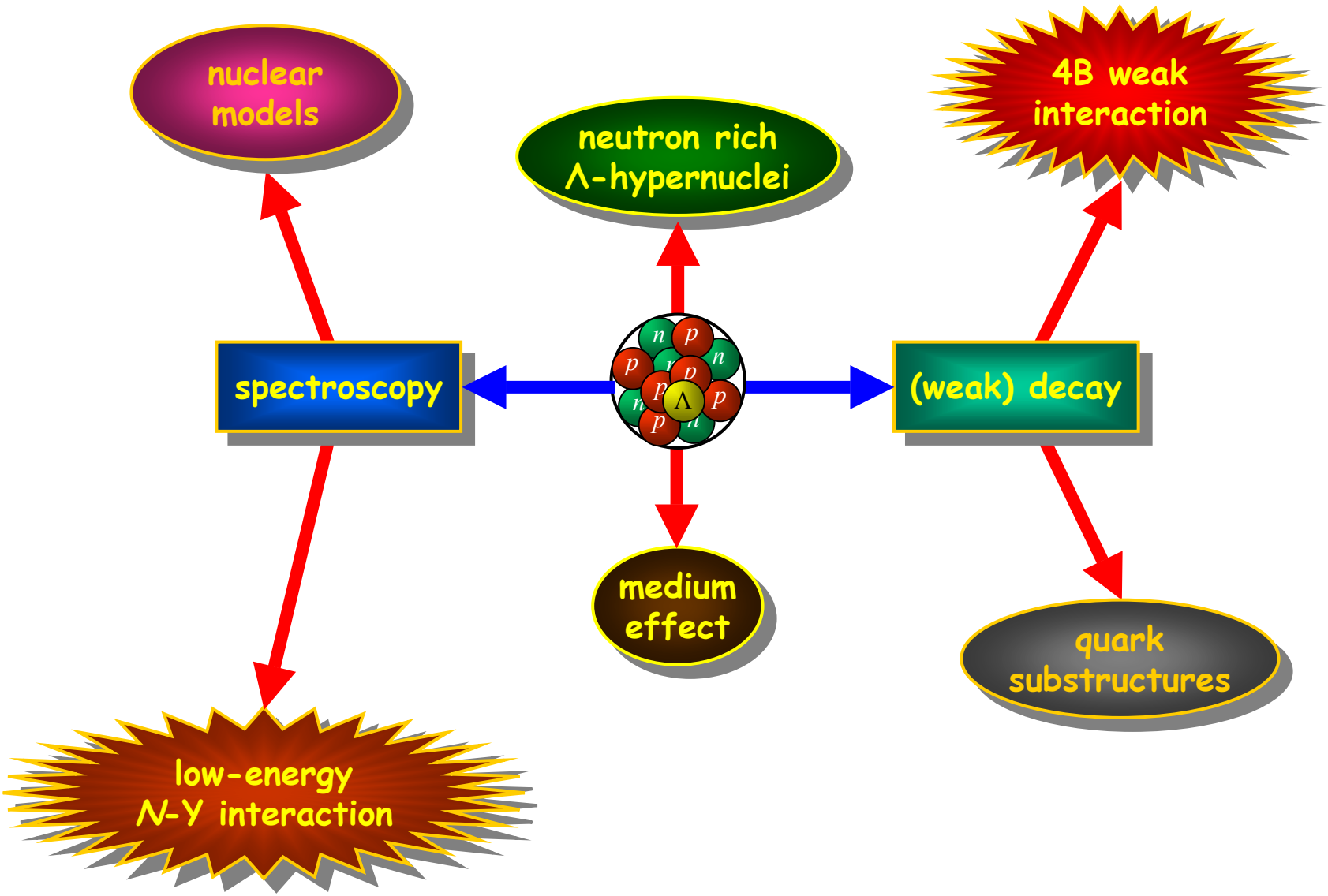
on behalf of the FINUDA Collaboration

Outline

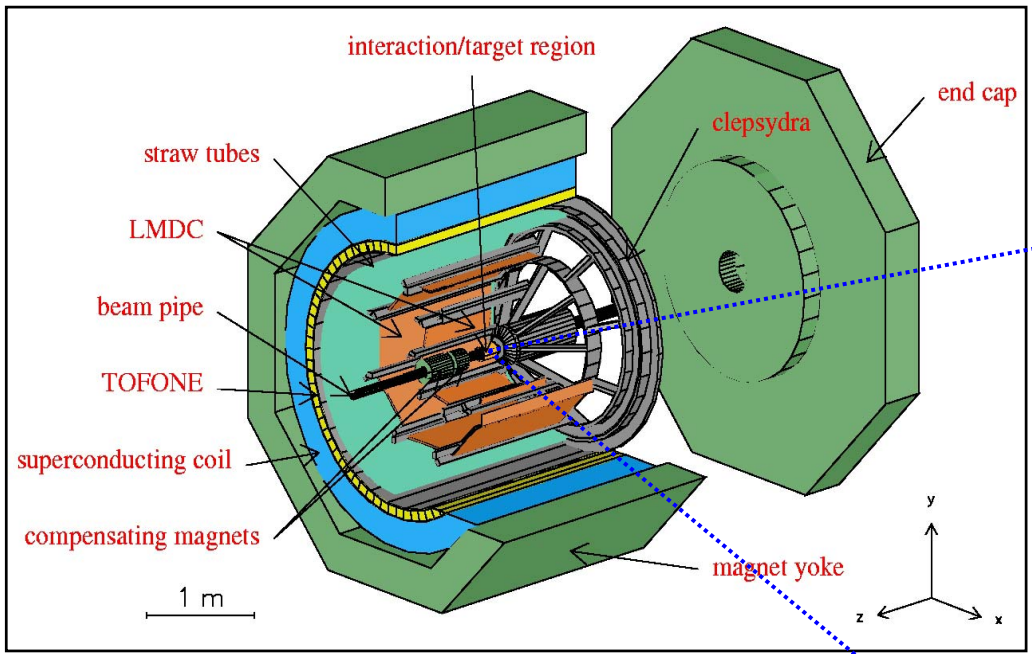
1) the FINUDA experiment
   - the physics program
   - the apparatus

2) the results
   - hypernuclear spectroscopy
   - search for neutron-rich hypernuclei
   - hypernucleus (rare) decays

Physics output (S=-1)

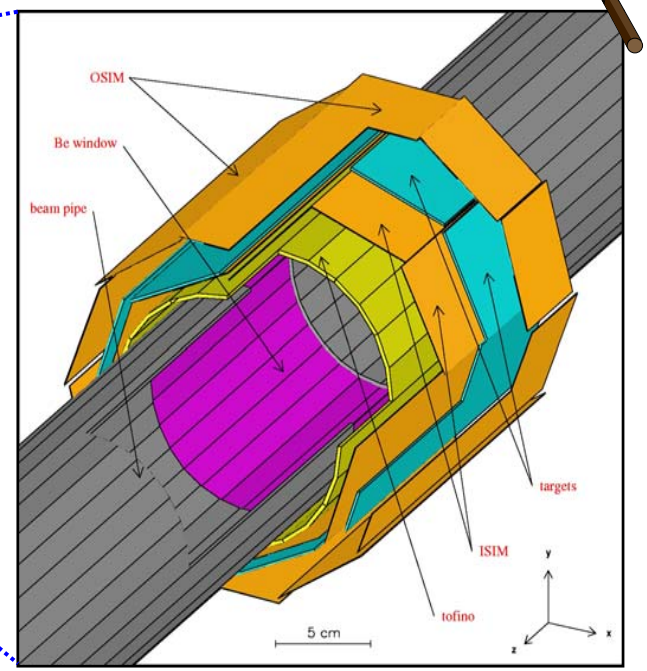


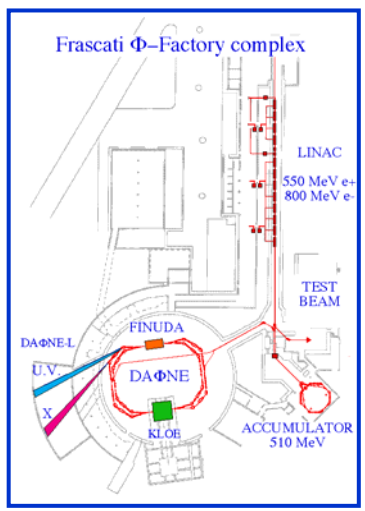
FINUDA @ DAΦNE



$$e^- + e^+ \rightarrow \phi \rightarrow K^- K^+$$

$$K^-_{stop} + {}^{A}Z \rightarrow {}^{A}_{\Lambda}Z + \pi^-$$





energy	510 MeV
luminosity	5 10^{32} cm^{-2} s^{-1}
σ_x (rms)	2.11 mm
σ_y (rms)	0.021 mm
σ_z (rms)	35 mm
bunch length	30 mm
crossing angle	12.5 mrad
frequency (max)	368.25 MHz
bunch/ring	up to 120
part./bunch	8.9 10^{10}
current/ring	5.2 A (max)

$$ {}^{A}_{\Lambda}Z \rightarrow \begin{cases} {}^{A}(Z+1) + \pi^- \\ {}^{(A-2)}(Z-1) + p + n \\ {}^{(A-2)}Z + n + n \end{cases} $$

FINUDA key features

- very thin nuclear targets (0.1 ÷ 0.3 g/cm^2)

  → high resolution spectroscopy

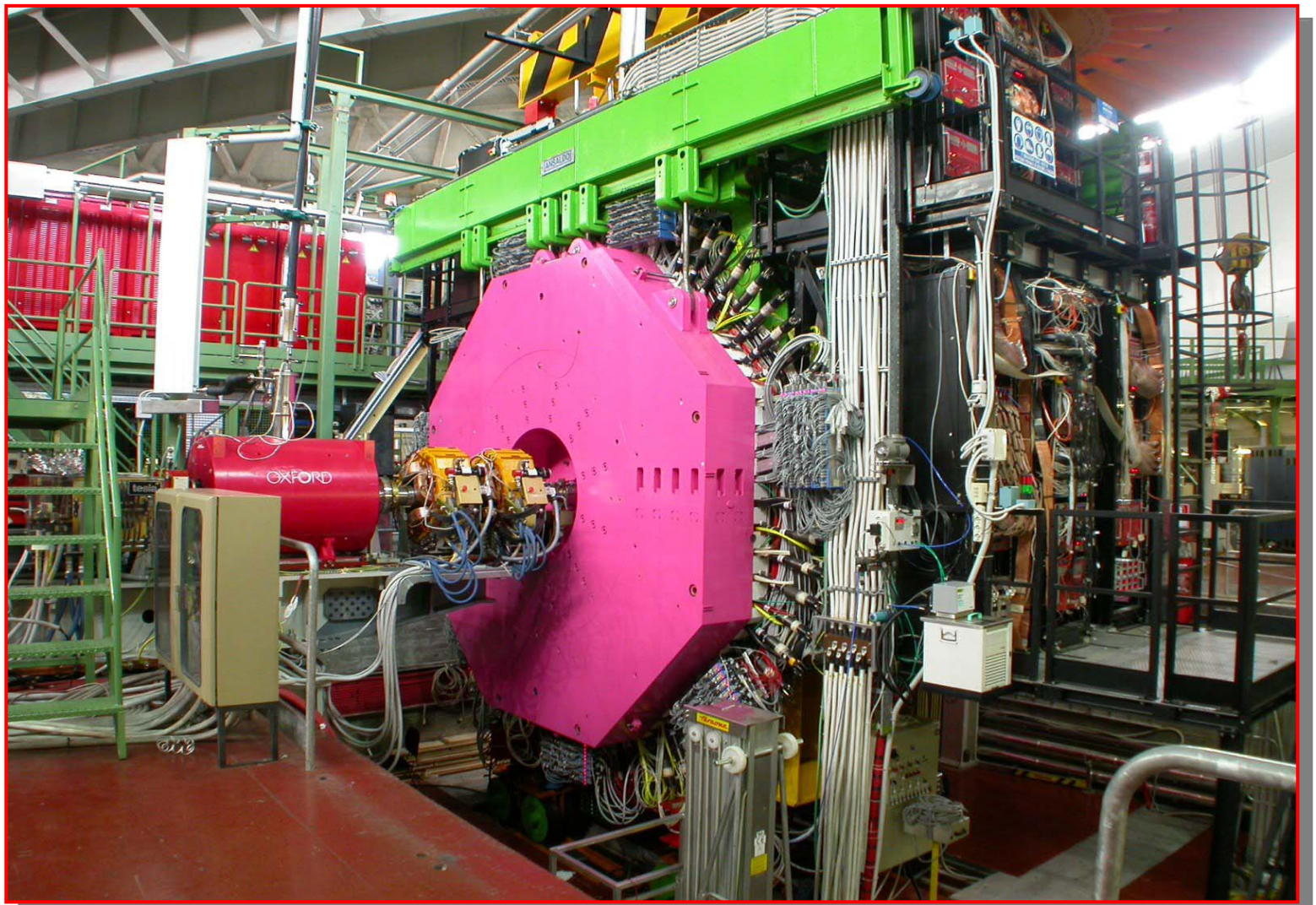
- coincidence measurement with large acceptance

  → decay mode study

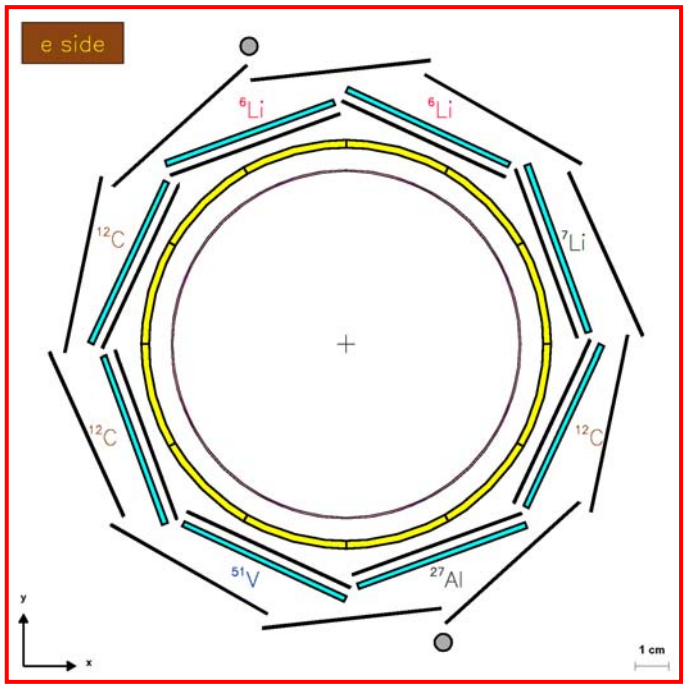
- irradiation of different targets in the same run

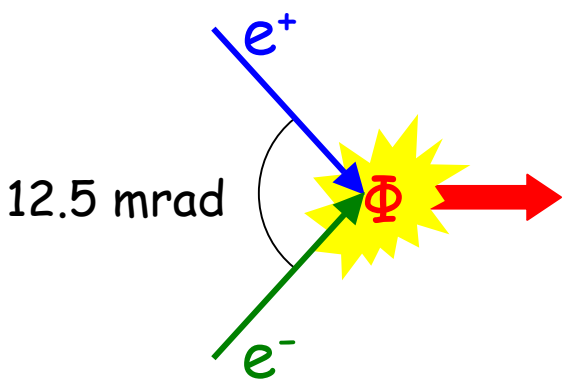
  → high degree of flexibility

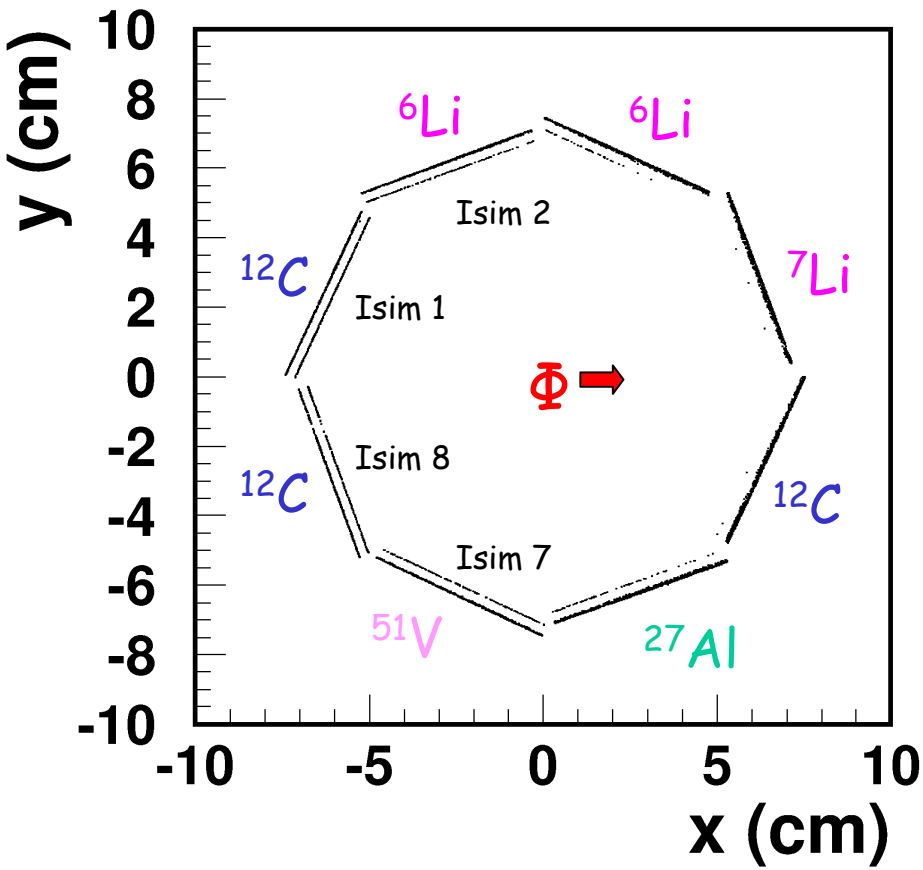
FINUDA @ DAΦNE



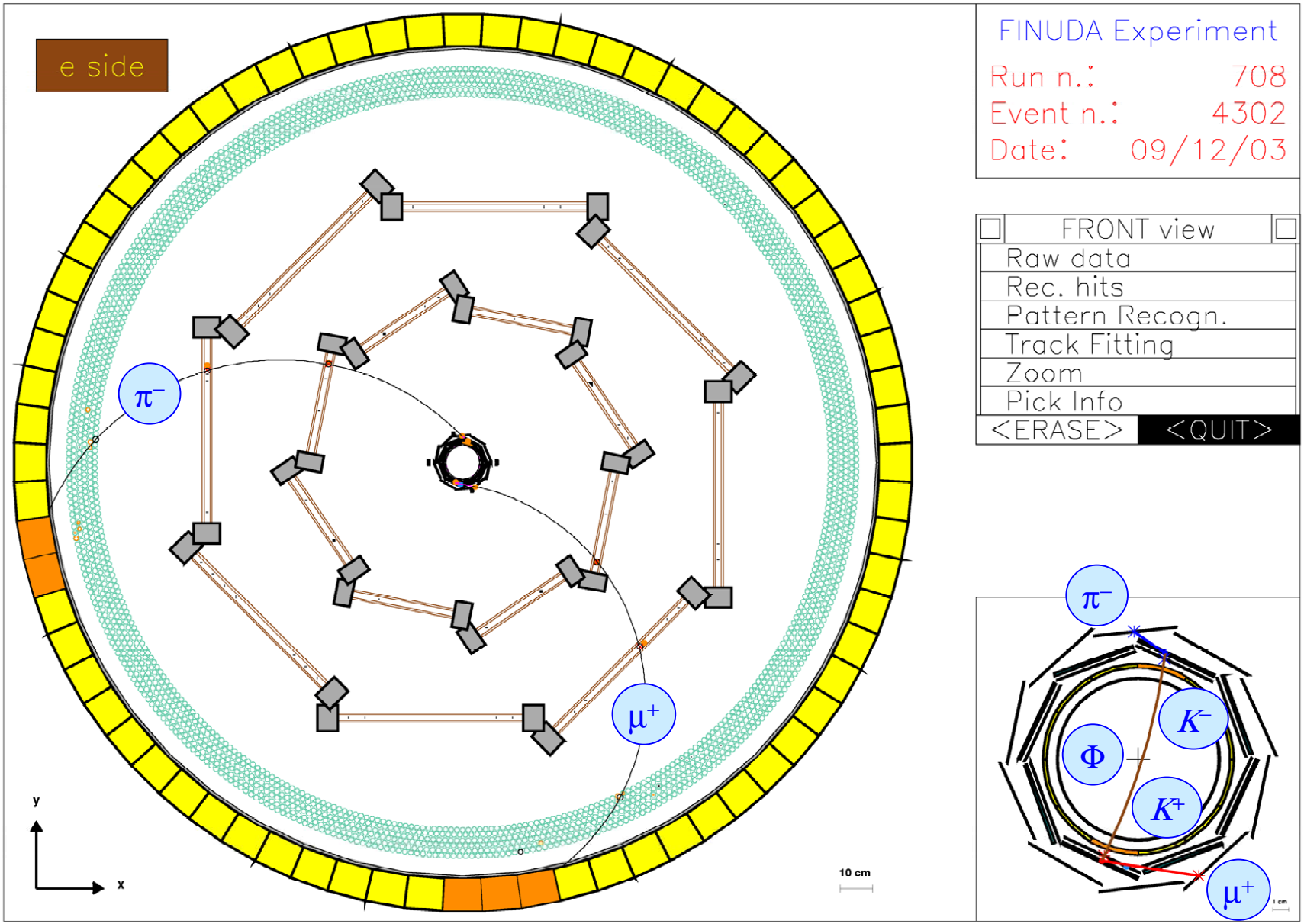
Target envelope by K⁻ stopping points







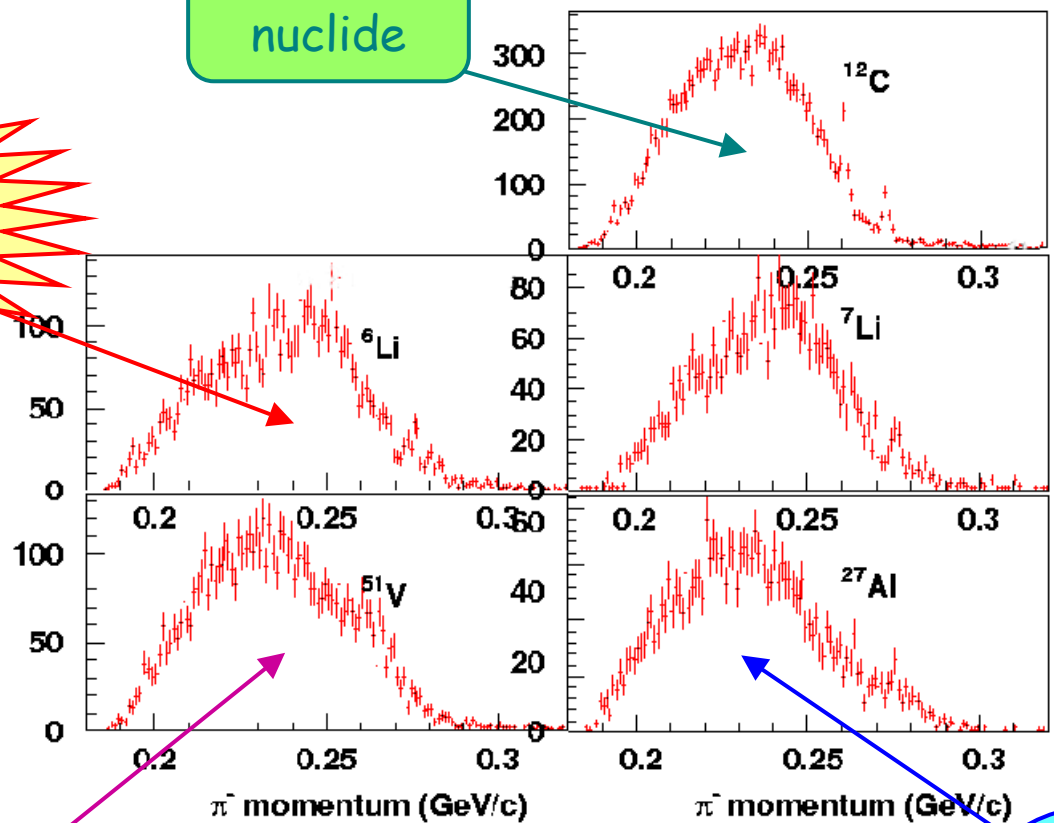
The typical event



Spectroscopy

reference nuclide

doorway for light systems
(${}^{4}_{\Lambda}H$, ${}^{4}_{\Lambda}He$, ${}^{5}_{\Lambda}He$)

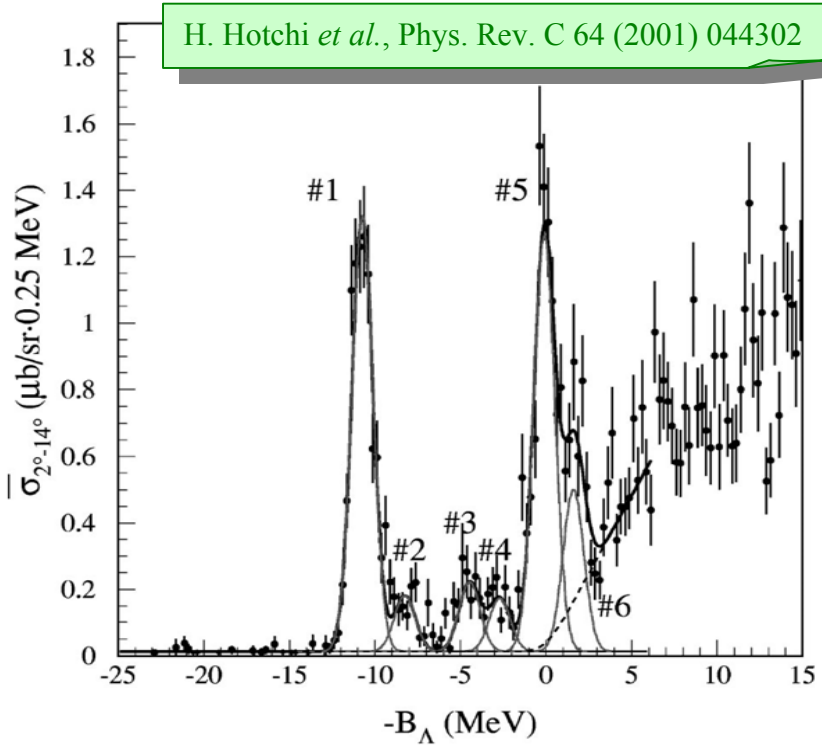


medium-A systems
(~ terra incognita)

never studied before

FINUDA vs. KEK-E369

H. Hotchi *et al.*, Phys. Rev. C 64 (2001) 044302

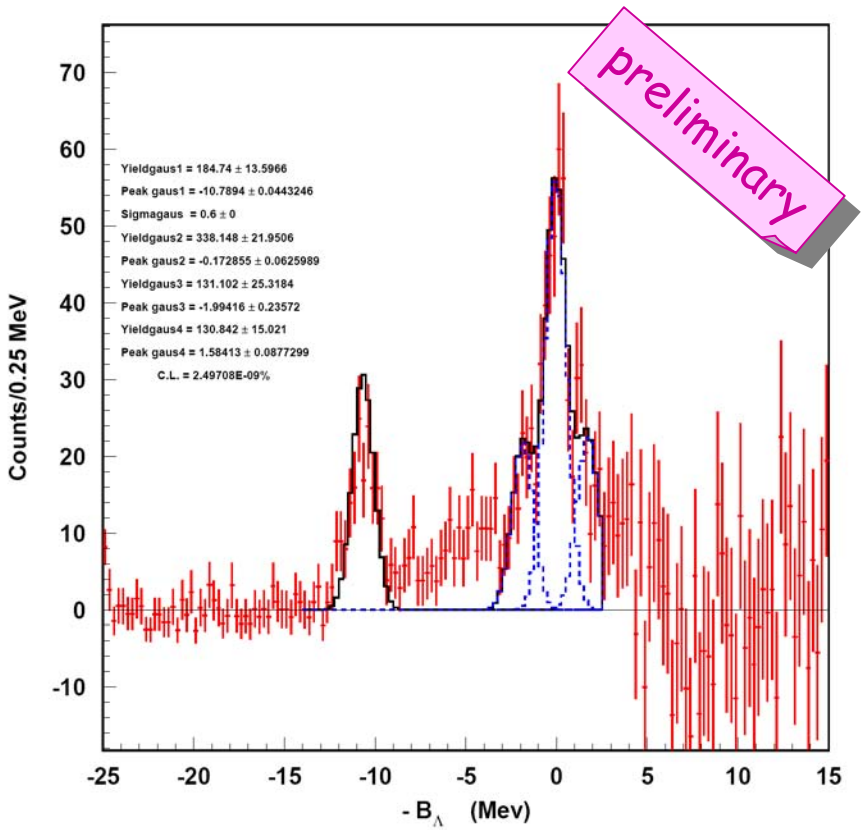


$^{12}C(\pi^+,K^+)^{12}_{\Lambda}C$

ΔE ~ 1.5 MeV FWHM

$^{12}C(K^-_{stop},\pi^-)^{12}_{\Lambda}C$

ΔE ~ 1.4 MeV FWHM



neutron-rich hypernuclei

2 production mechanisms:

1) strangeness + double charge exchange

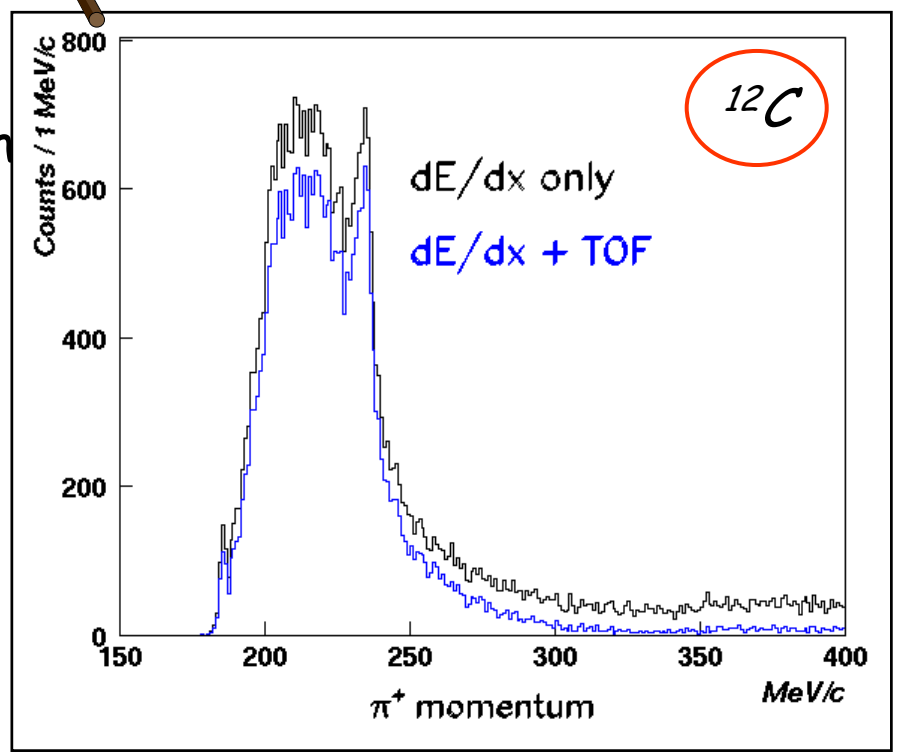
$$K^- + p \rightarrow \Lambda + \pi^0$$
$$\hookrightarrow \pi^0 + p \rightarrow n + \pi^+$$

$$\pi^- + p \rightarrow \pi^0 + n$$
$$\hookrightarrow \pi^0 + p \rightarrow K^+ + \Lambda$$

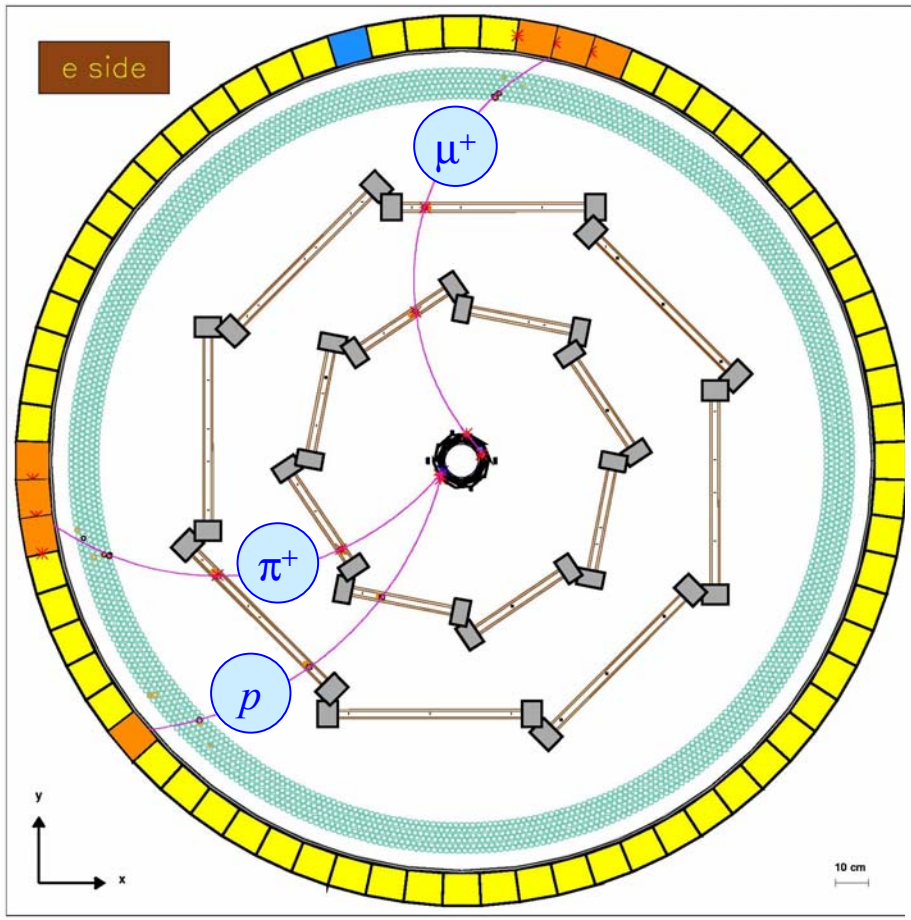
2) Strangeness exchange with

$$K^- + p \rightarrow \Sigma^- + \pi^+$$
$$\hookrightarrow \Sigma^- + p \rightarrow \Lambda + n$$

$$\pi^- + p \rightarrow \Sigma^- + K^+$$
$$\hookrightarrow \Sigma^- + p \rightarrow \Lambda + n$$

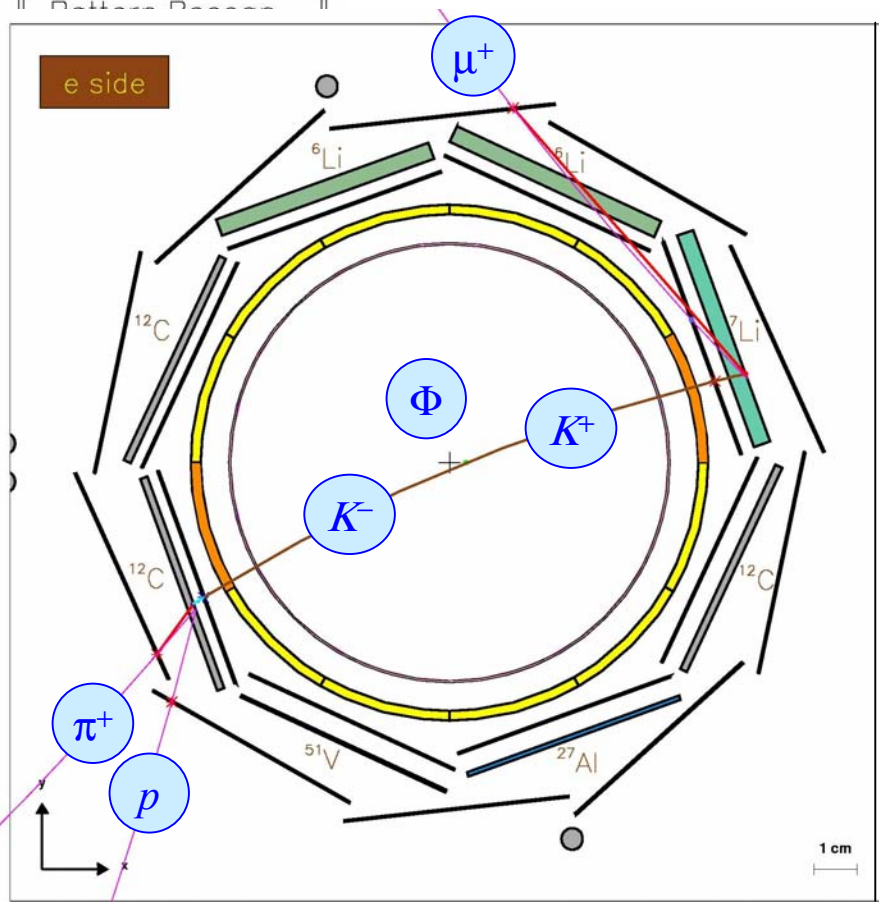


neutron-rich hypernuclei

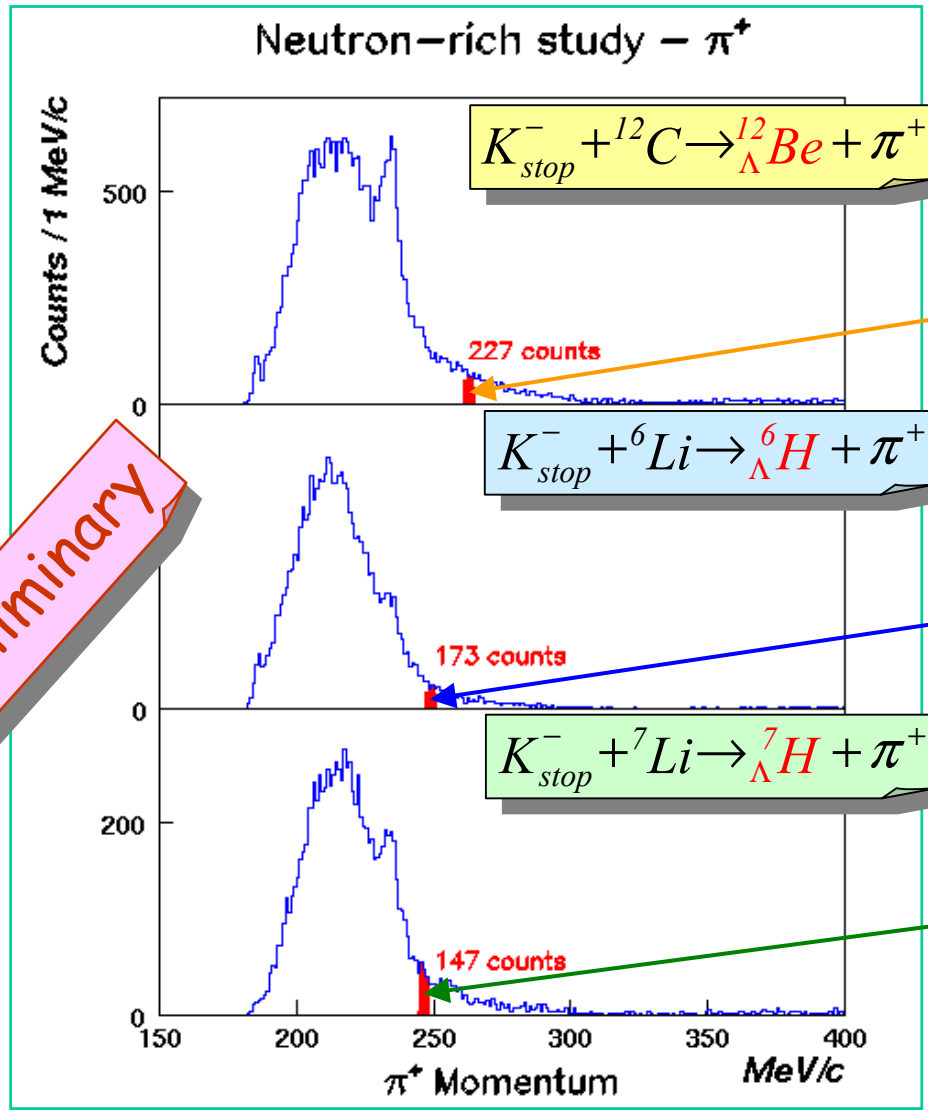


FINUDA Experiment
Run n.: 1
Event n.: 764
Date: DD/MM/YY

FRONT view
Raw data
Rec. hits



neutron-rich hypernuclei



$K^-_{stop} + {}^{12}C \rightarrow {}^{12}_{\Lambda}Be + \pi^+$

$K^-_{stop} + {}^{6}Li \rightarrow {}^{6}_{\Lambda}H + \pi^+$

$K^-_{stop} + {}^{7}Li \rightarrow {}^{7}_{\Lambda}H + \pi^+$

preliminary

$p_{\pi^+} = 262.9 \text{ MeV}/c \pm 2\sigma_{p_{\pi^+}}$

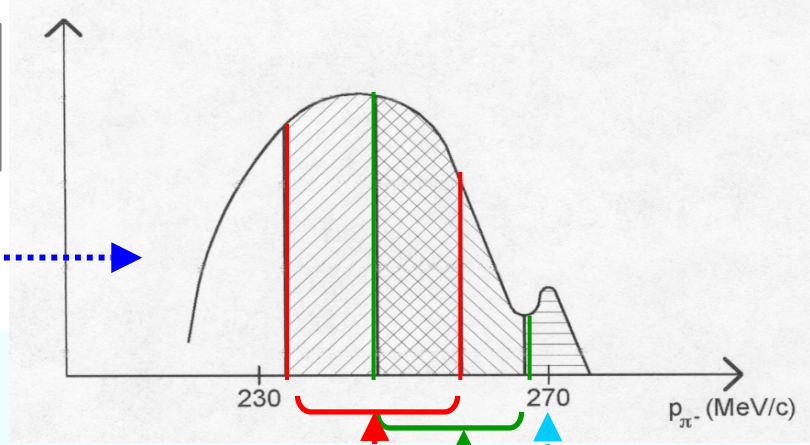
$p_{\pi^+} = 249.1 \text{ MeV}/c \pm 2\sigma_{p_{\pi^+}}$

$p_{\pi^+} = 246.4 \text{ MeV}/c \pm 2\sigma_{p_{\pi^+}}$

neutron-rich hypernuclei

P_{NRH} upper limit ($\times 10^{-5}$)	90% C.L.		2 σ C.L.		3 σ C.L.		
	dE/dx PID	*dE/dx* + TOF PID	*dE/dx* PID	*dE/dx* + TOF PID	*dE/dx* PID	*dE/dx* + TOF PID	
present momentum resolution (9‰)	2.6	2.1	3.2	2.6	4.9	4.0	$^{12}_{\Lambda}Be$
	3.5	2.9	4.3	3.6	6.6	5.6	$^{6}_{\Lambda}H$
	4.9	4.3	6.1	5.3	9.4	8.3	$^{7}_{\Lambda}H$
nominal momentum resolution (3.5‰)	1.6	1.3	2.0	1.6	3.1	2.5	$^{12}_{\Lambda}Be$
	2.1	1.8	2.6	2.2	4.1	3.5	$^{6}_{\Lambda}H$
	3.3	2.8	4.1	3.5	6.5	5.6	$^{7}_{\Lambda}H$

${}^{4}_{\Lambda}$He (rare) decay



Spectroscopized

$K^- + {}^6Li \rightarrow \pi^- + \ldots$

${}^{5}_{\Lambda}He + p$

- τ
- Γ_p (in coinc.) about 10/pb^{-1}
- Γ_n (in coinc.) a few/pb^{-1}
- $\Gamma_{\pi-}$ about 10^2/pb^{-1}

${}^{4}_{\Lambda}He + p + n$

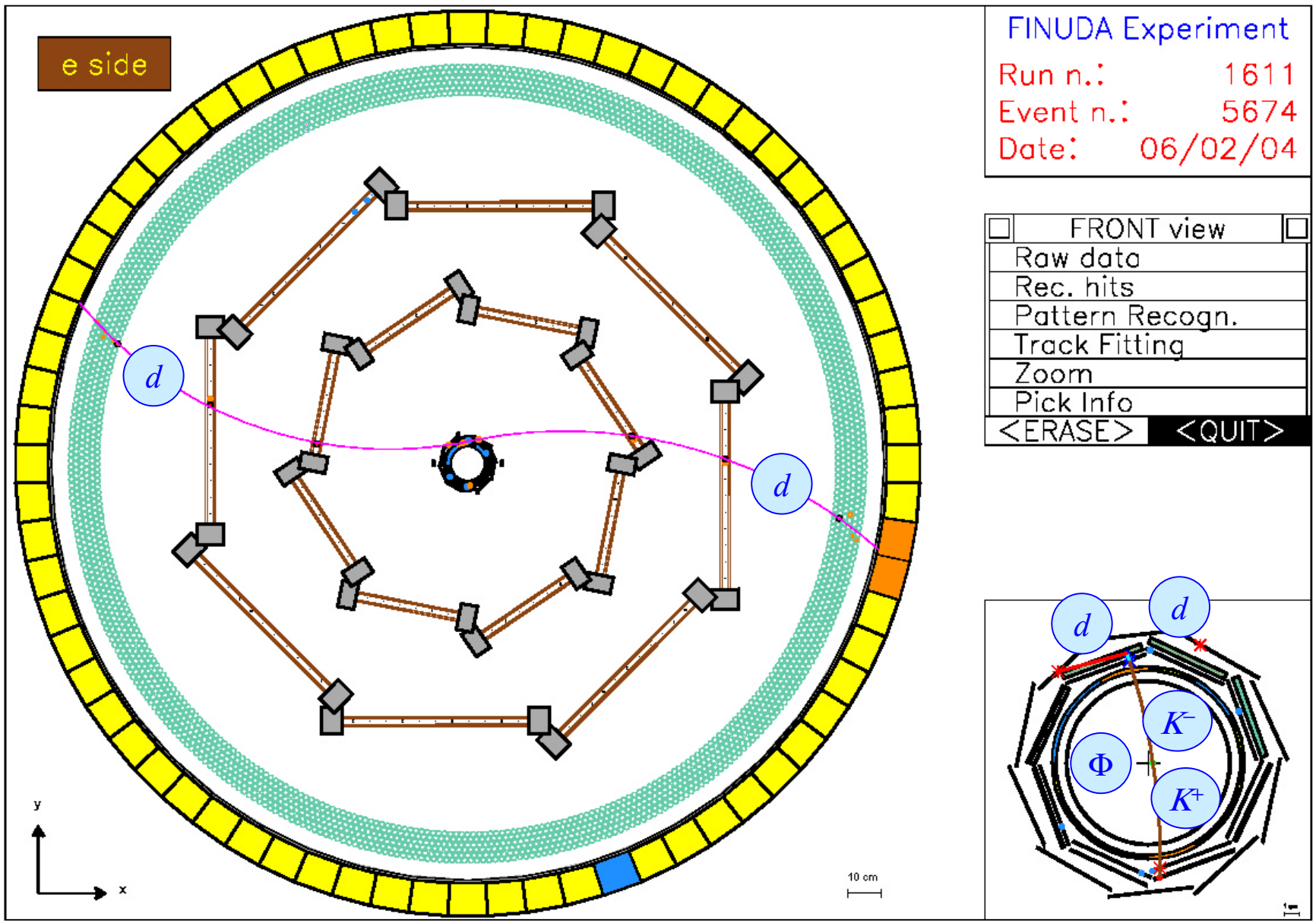
- $d + d$ spectr. (~0.3/pb^{-1} if B.R. ~10^{-3})
- $p + {}^3H$ spectr. (0.2/ pb^{-1} if B.R. ~10^{-3})
- $\pi^+ + n + {}^3H$ many events (~ 10^2/pb^{-1})

how distinguishable?

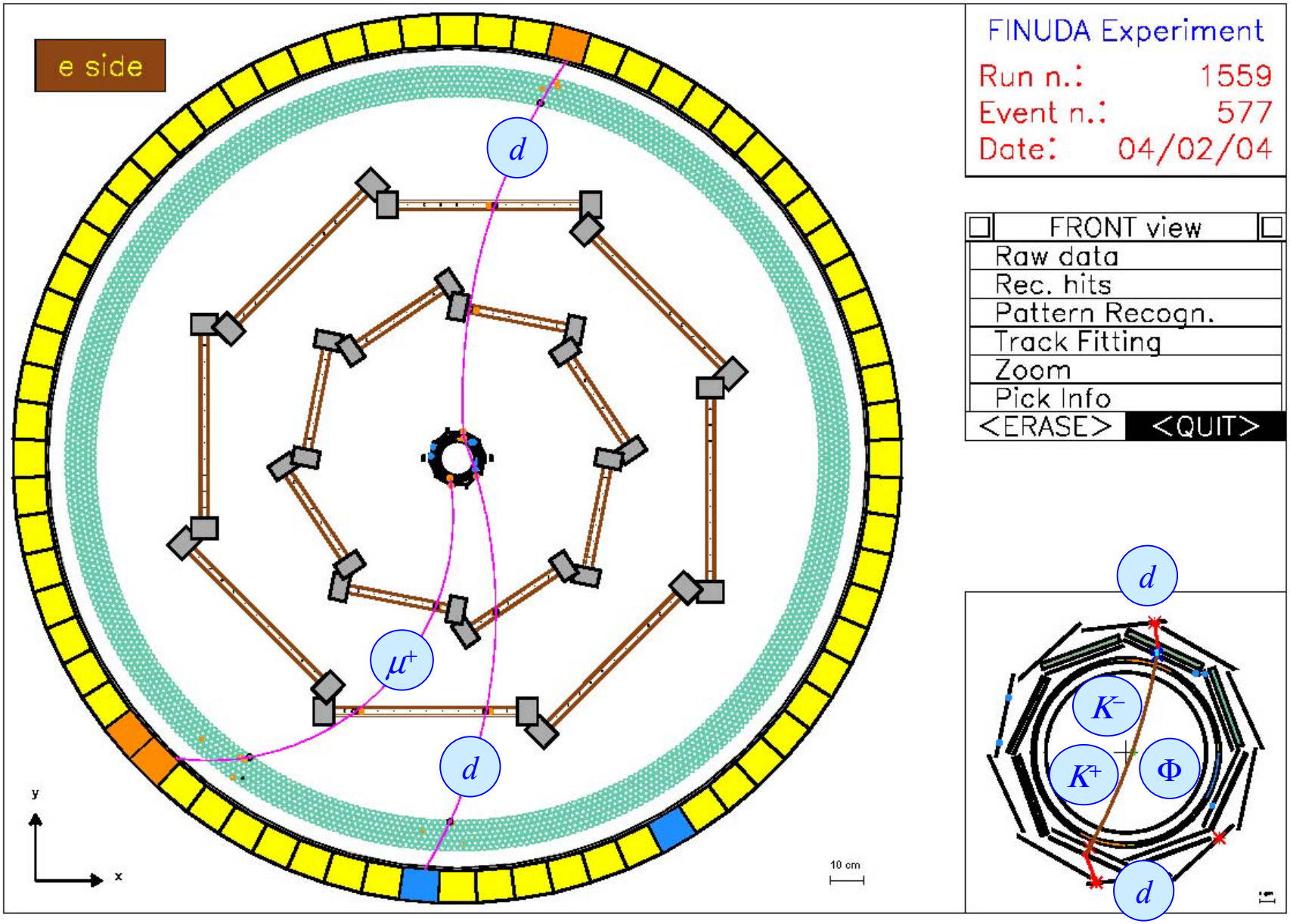
${}^{4}_{\Lambda}H + p + p$

- ${}^4He + \pi^-$ spectr. (10^2/pb^{-1}) calibration

${}^{4}_{\Lambda}He \rightarrow d + d$ (rare) decay



${}^{4}_{\Lambda}He \rightarrow d + d$ (rare) decay



Summary

- First data taking period successfully carried out (30×10^6 events on tape)
- Preliminary and partial results on spectroscopy are competitive with world published data
- Experimental upper limit for the *NRH* production:
  - ✔ better than published one for ${}^{12}_{\Lambda}Be$
  - ✔ measured for the first time for ${}^{6}_{\Lambda}H$ and ${}^{7}_{\Lambda}H$
- First observation of ${}^{4}_{\Lambda}He$ non mesonic (rare) decay

The FINUDA Collaboration

- Bari University and I.N.F.N. Bari
- Brescia University and I.N.F.N. Pavia
- KEK
- L.N.F. / I.N.F.N. Frascati
- Pavia University and I.N.F.N. Pavia
- Seoul National University
- Teheran Shahid Beheshty University
- Torino University and I.N.F.N. Torino
- Torino Polytechnic and I.N.F.N. Torino
- Trieste University and I.N.F.N. Trieste
- TRIUMF

Short term plans

- Next data-taking period scheduled in the 2nd half of 2005

  options:

  - effort focused on light targets (^{6}Li, ^{7}Li, ^{9}Be)
  - move to the high A region (^{89}Y, ^{139}La, ^{209}Bi, ...)

- Increase by a factor 4 of the DAQ rate

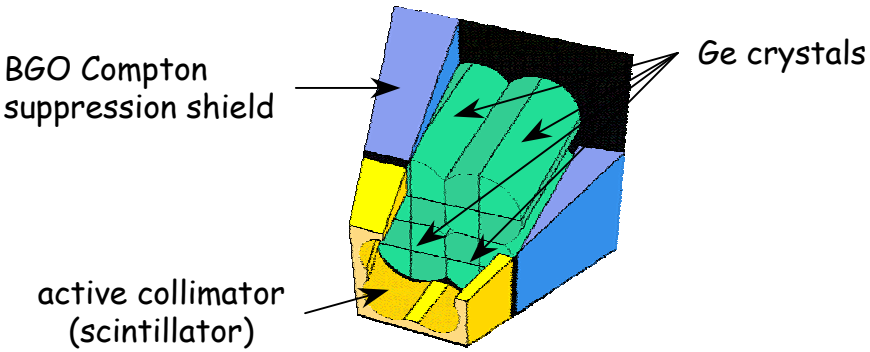
- Replacement of the internal TOF detector

- Improvement of the reconstruction program

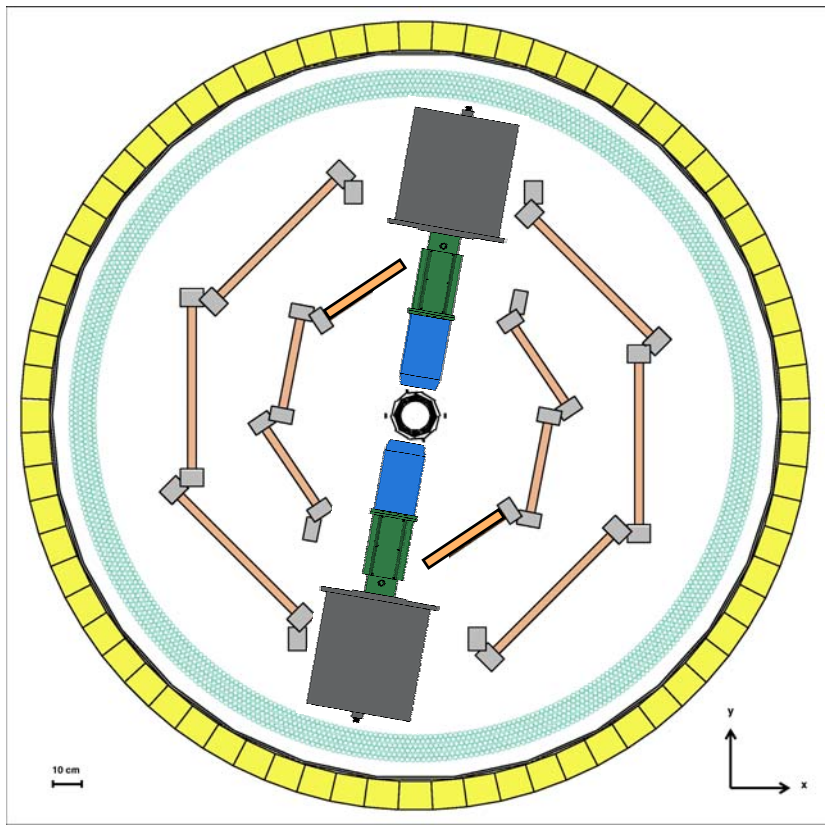
  - geometrical alignment
  - detector calibration
  - pattern recognition strategy
  - selection criteria

Long term plans

The Segmented Clover Detector



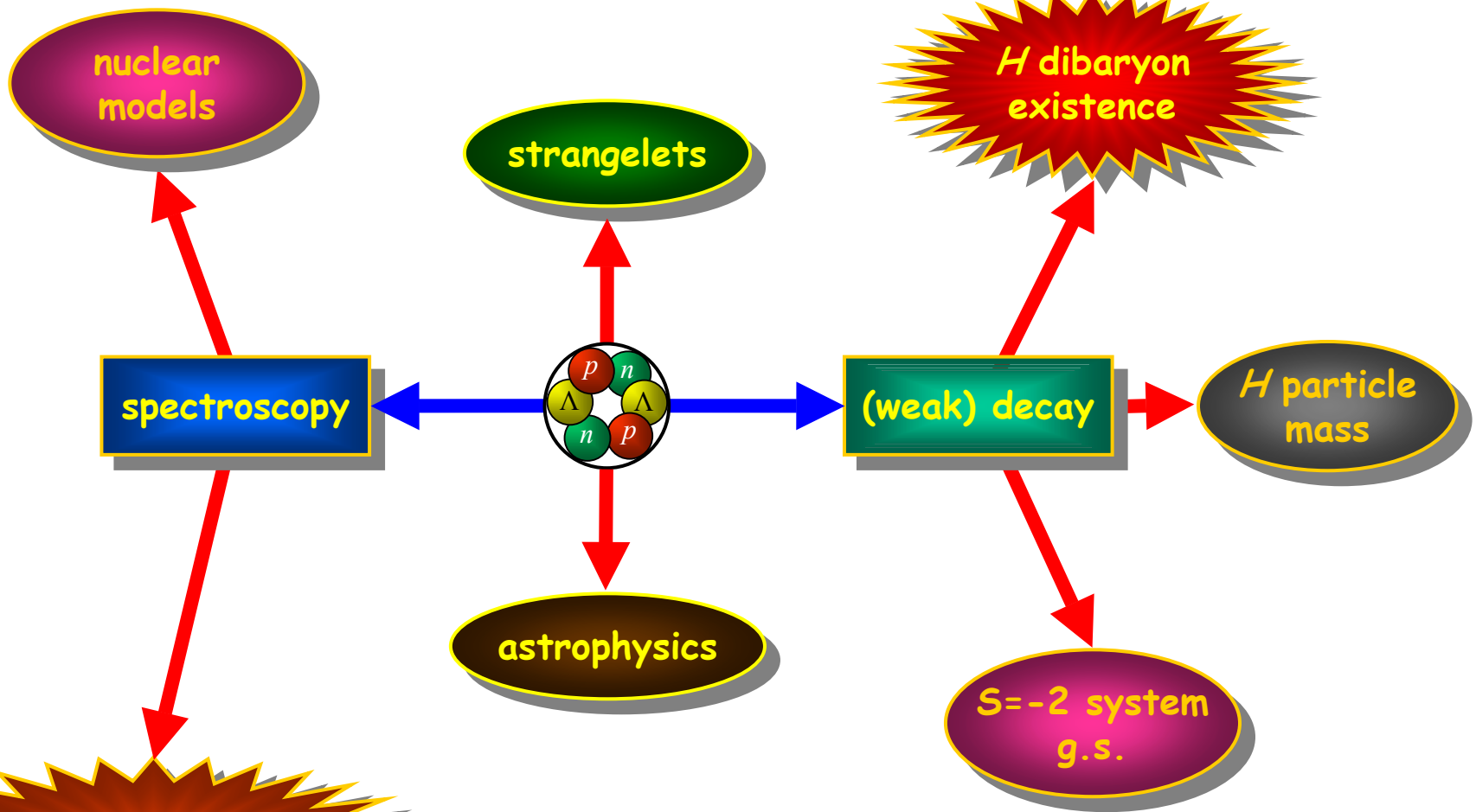
$\mathcal{L} \approx 10^{34}\ cm^{-2}s^{-1}$



Geometrical acceptance
reduced to 72%

Additional slides

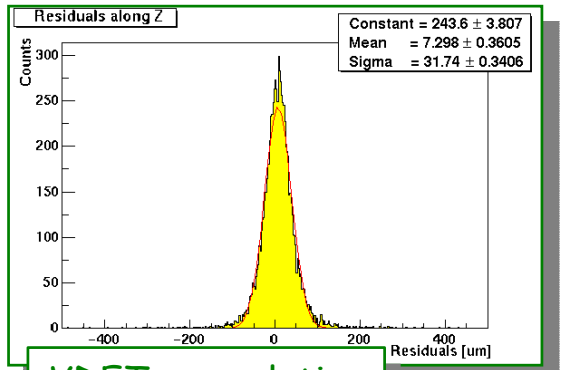
Physics output (S=-2)



FINUDA detectors performances

- s.c. solenoid: B = 1.0 T; field homogeneity within 2%
- interaction/target region: K^+/K^- identification, hypernucleus production and detection

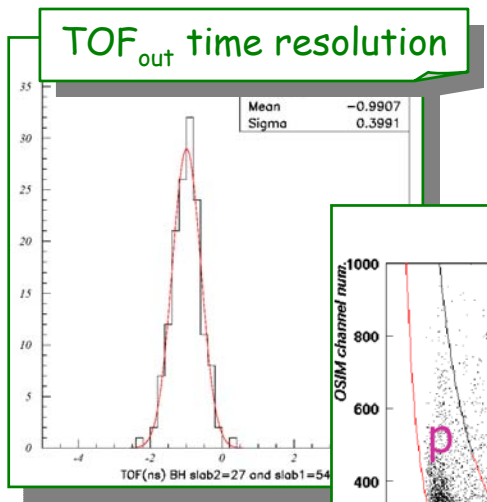
  ISIM/OSIM: σ_z = 30 μm; ΔE = 20% FWHM
  TOF_{in}: σ_t = 250 ps



VDET z resolution

- tracking devices: measurement of trajectories and momenta of charged particles (Δp/p 3.5‰)

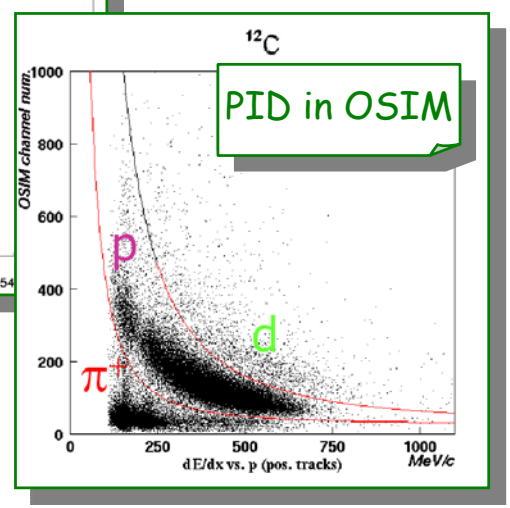
  LMDC: σ(ρ, φ) = 150 μm; $\sigma_z \leq$ 1% wire length
  STB: σ(ρ, φ) = 150 μm; σ_z 500 μm



TOF_{out} time resolution

- external scintillator barrel: trigger and neutron detection

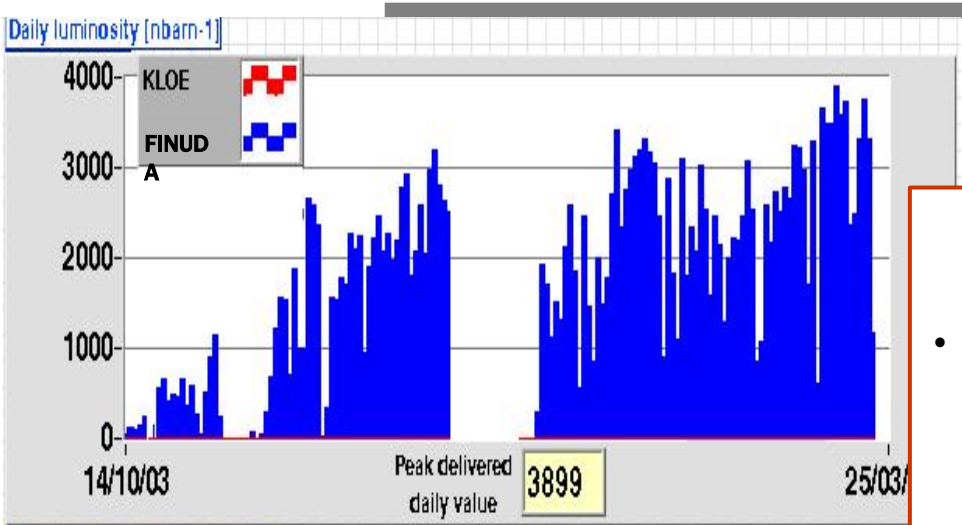
  TOF_{out}: σ_t = 500 ps FWHM
  efficiency ≥ 10%; ΔE = 8 MeV

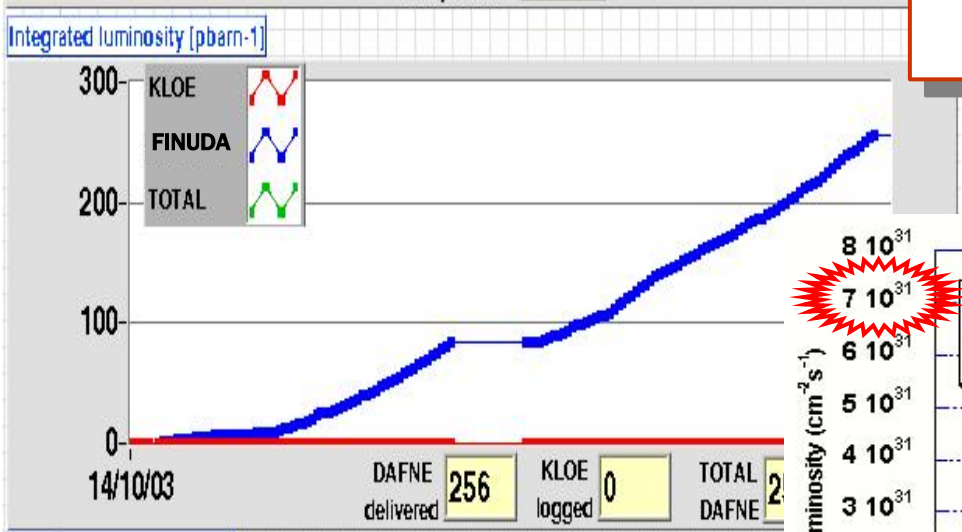


- He chamber: minimization of particle multiple scattering

  Δp/p: He atmosphere = 3.5‰
  air = 2%

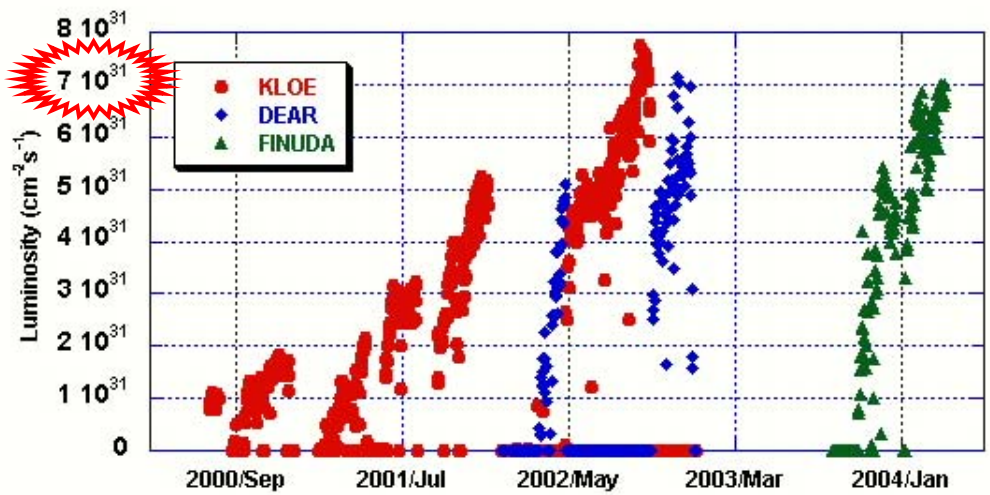
FINUDA first run



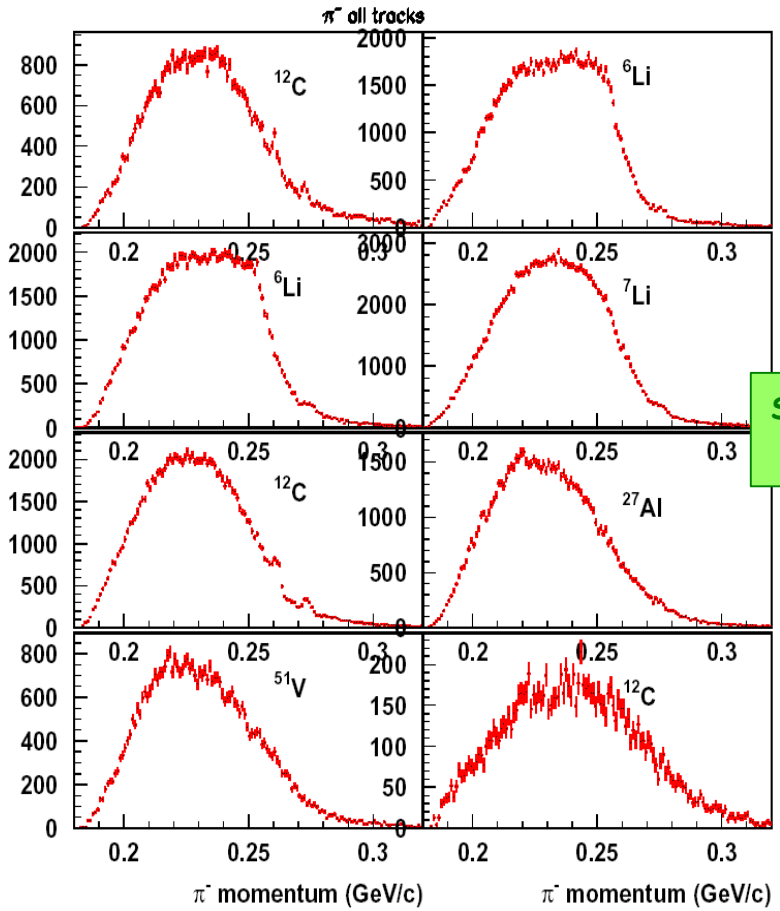


14-Oct-2003 to 22-Mar-2004:

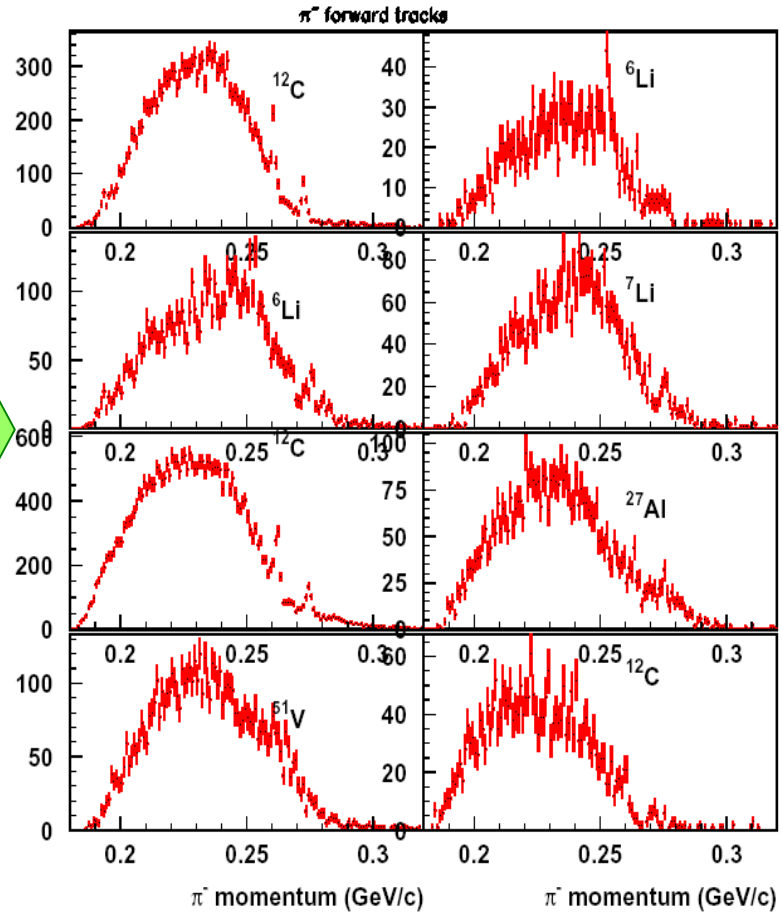
- 250 pb^{-1} delivered to IP2
  - 33 pb^{-1} machine tuning
  - 10 pb^{-1} FINUDA debugging
  - 190 pb^{-1} useful data taking



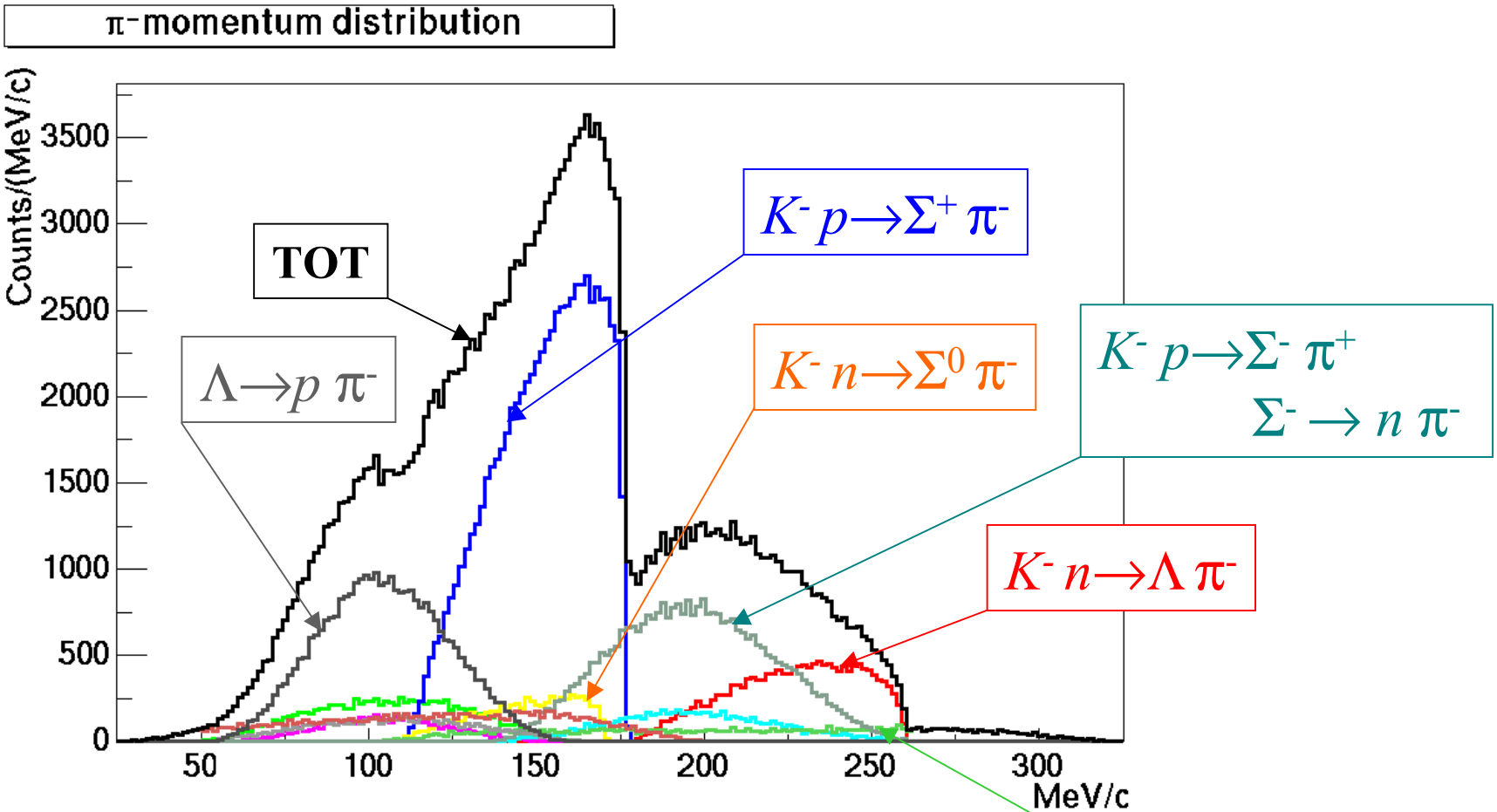
Spectroscopy



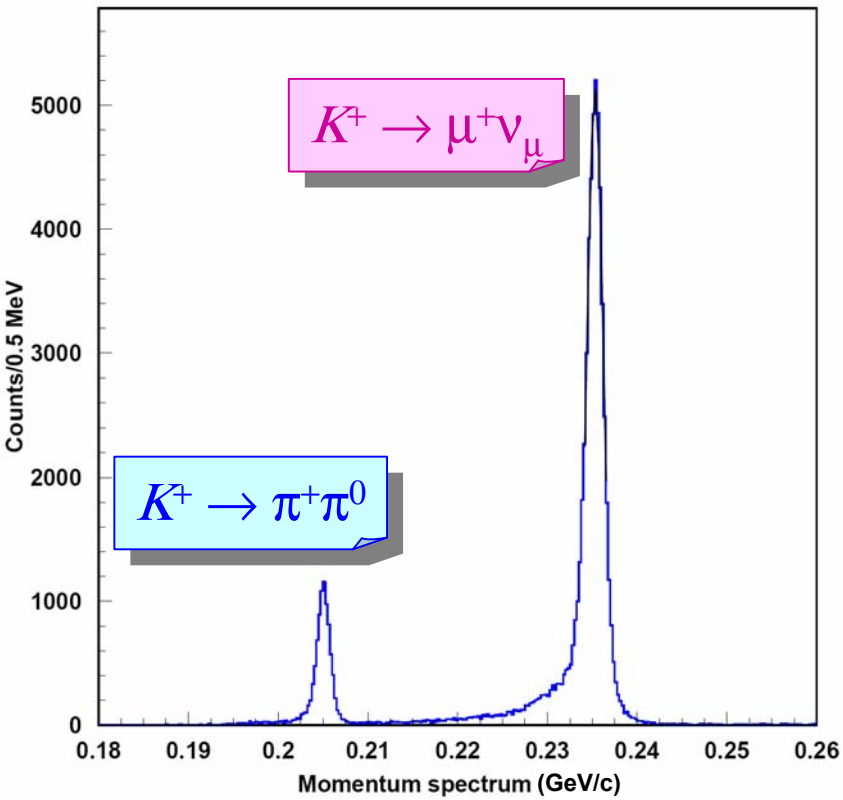
selection cuts



Background reactions: π^- spectrum

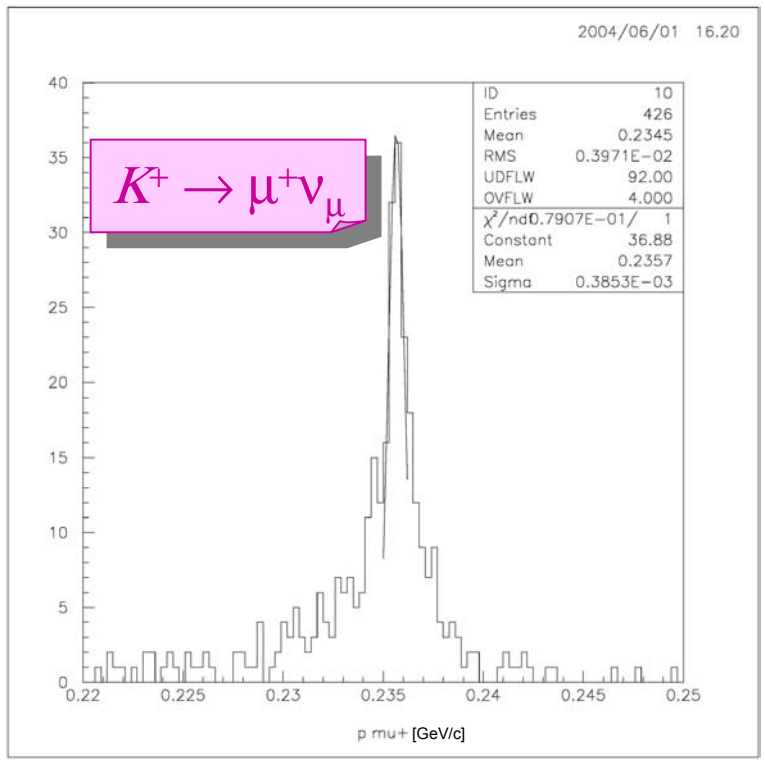


Improvement in momentum resolution

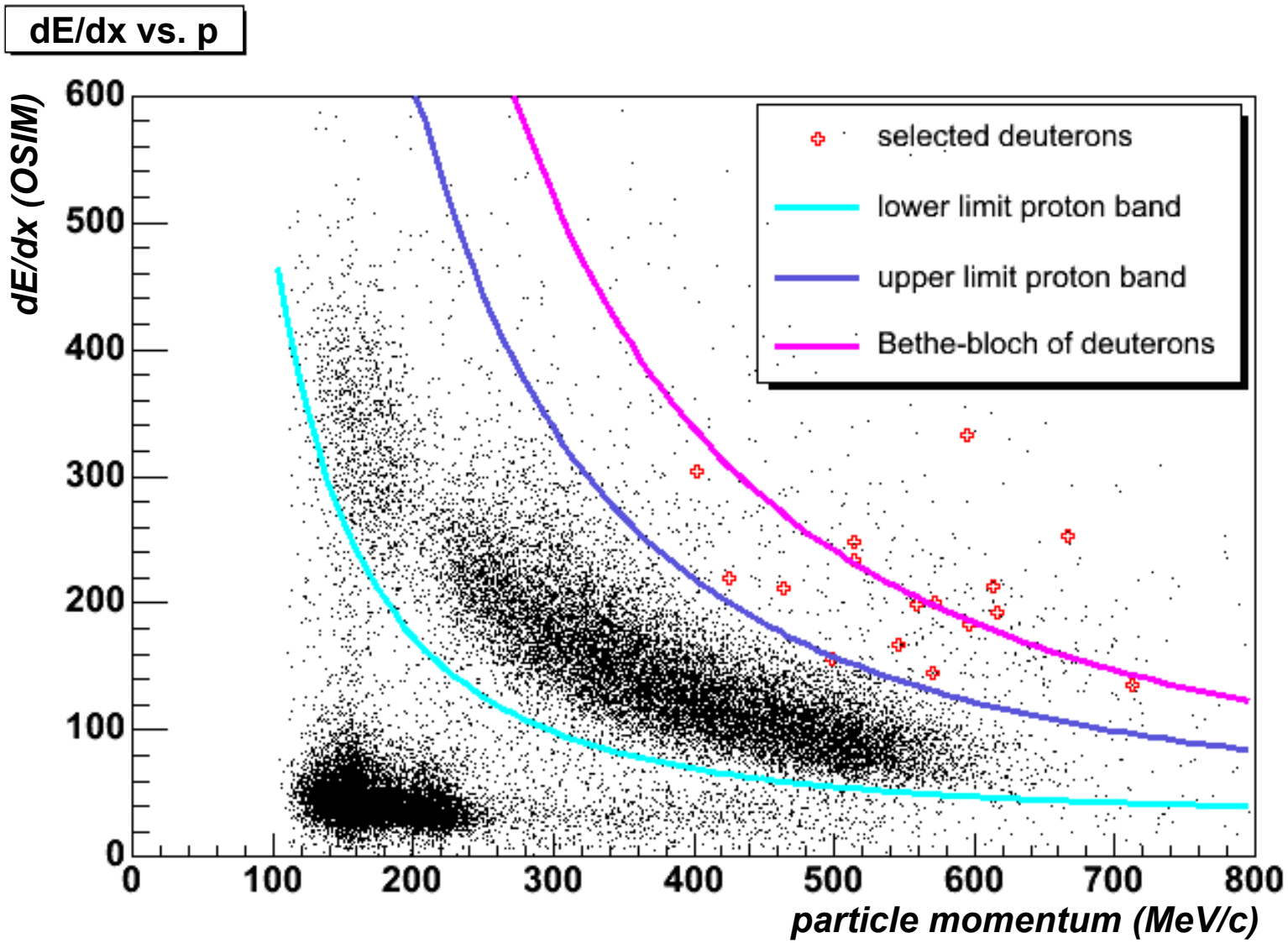


$\Delta p/p \sim 0.4\%$

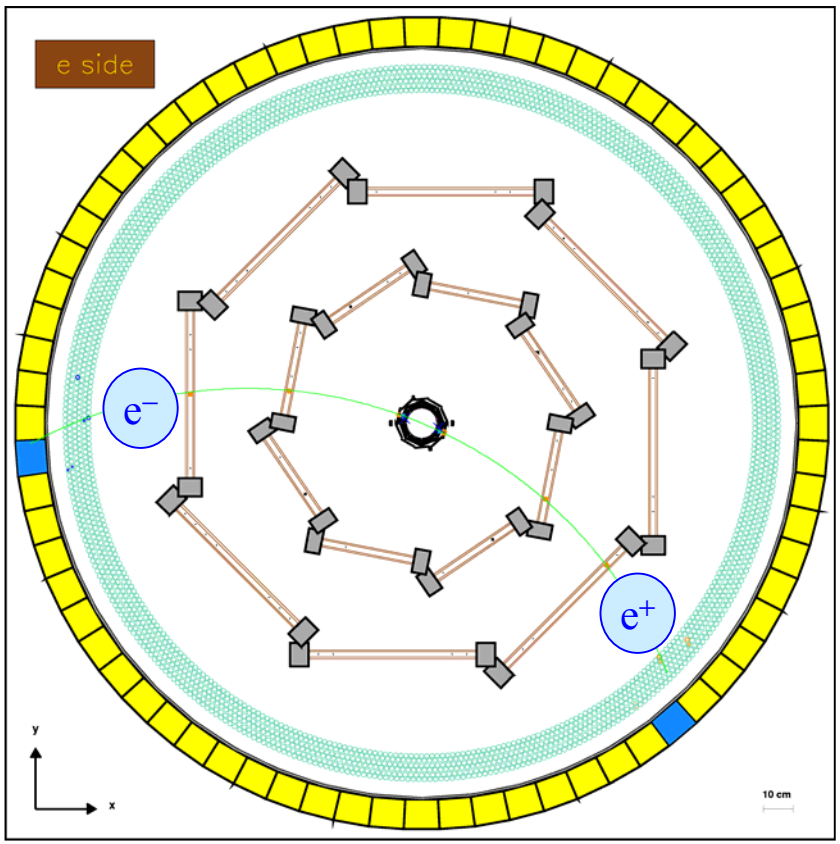
$\Delta p/p \sim 0.9\%$

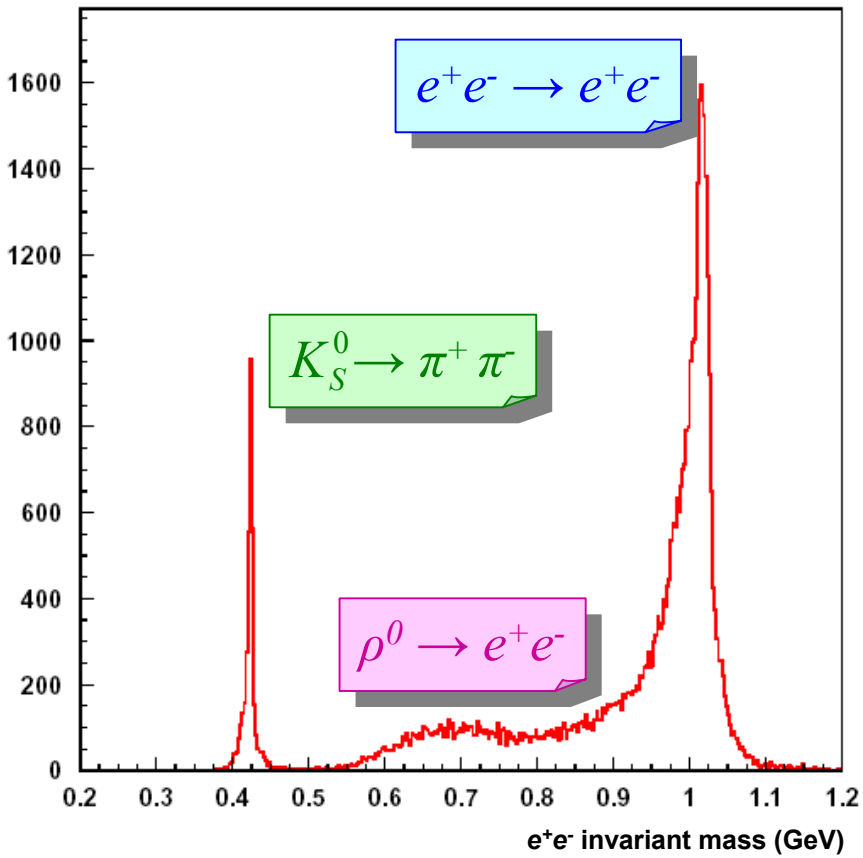


PID (dE/dx in vertex detectors)

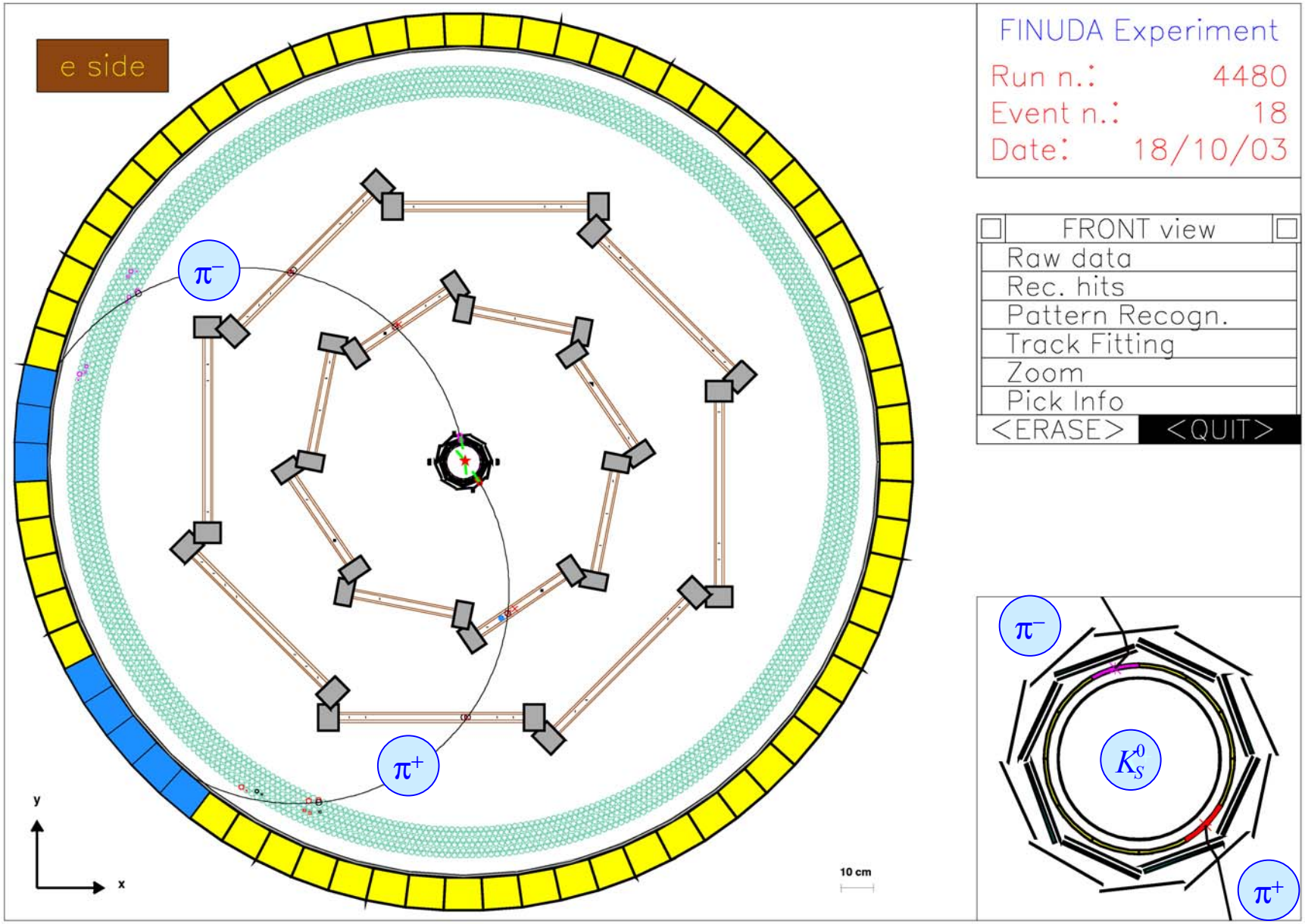


Bhabha event

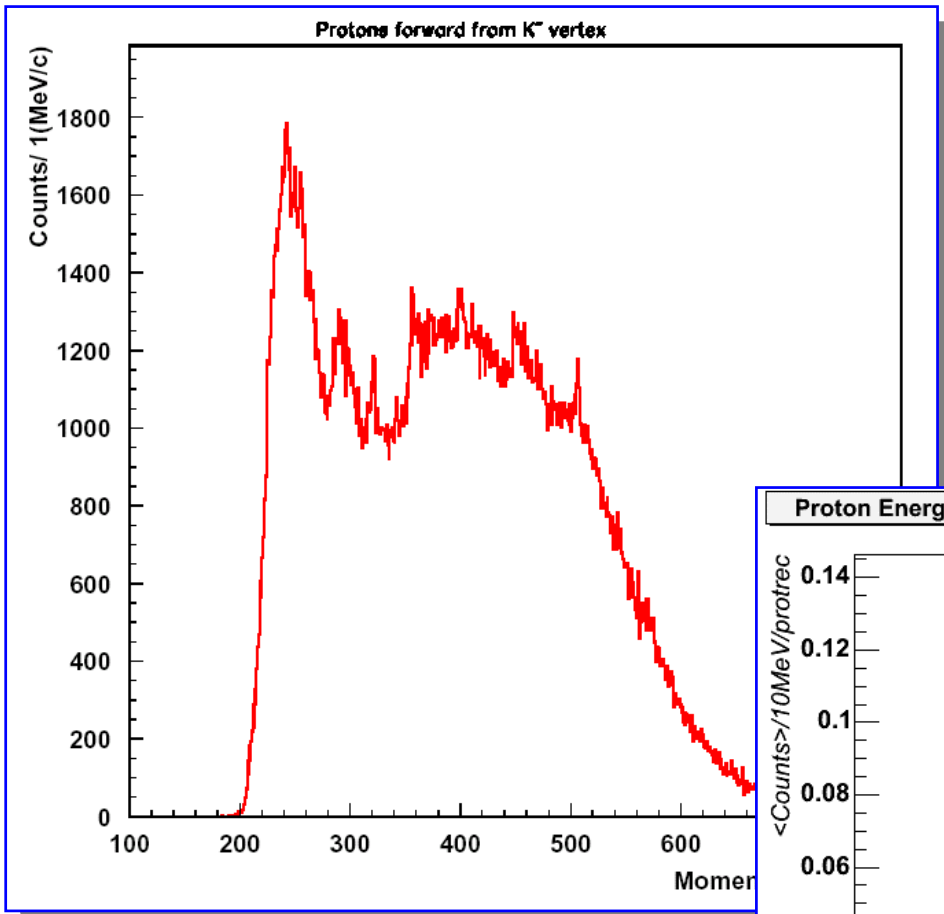




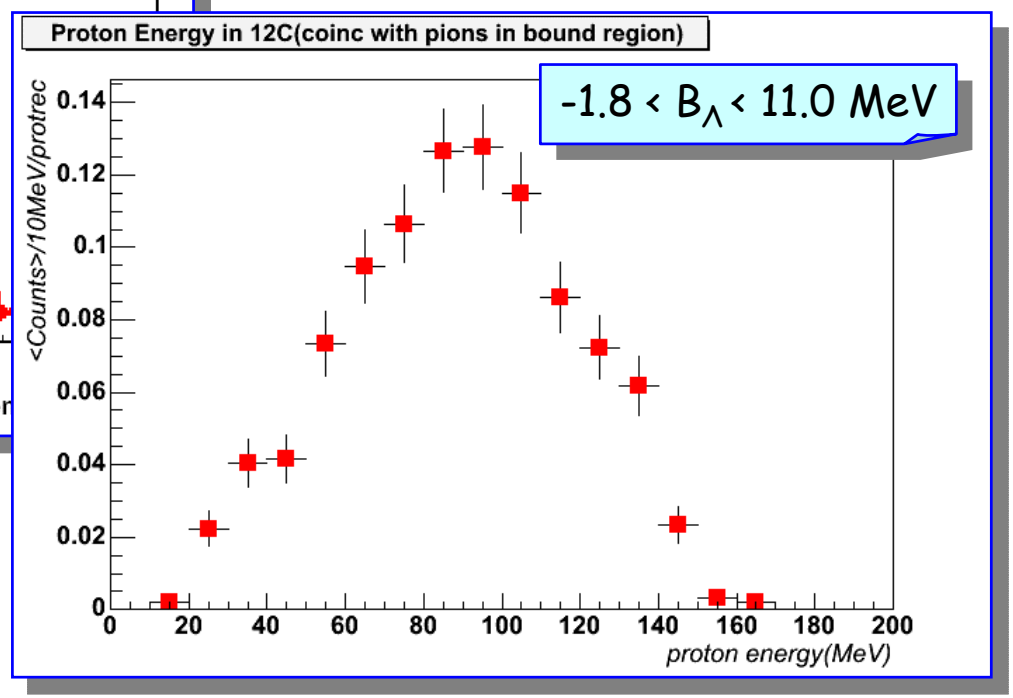
$K^0_S \rightarrow \pi^+\pi^-$ event



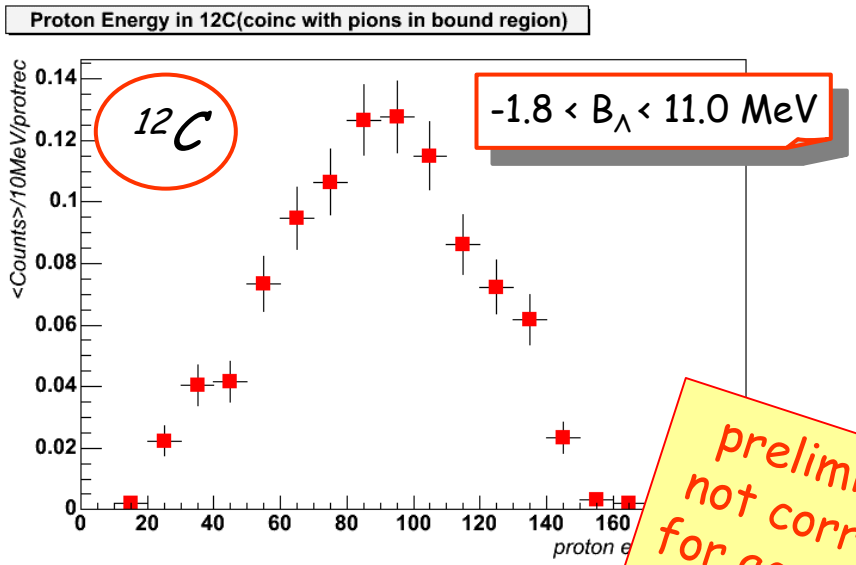
NM proton stimulated decay

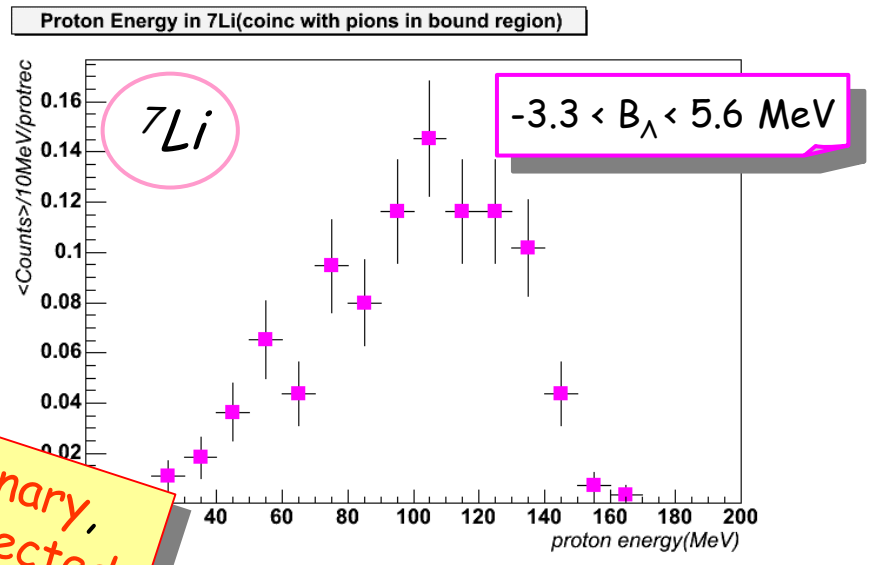


^{12}C target

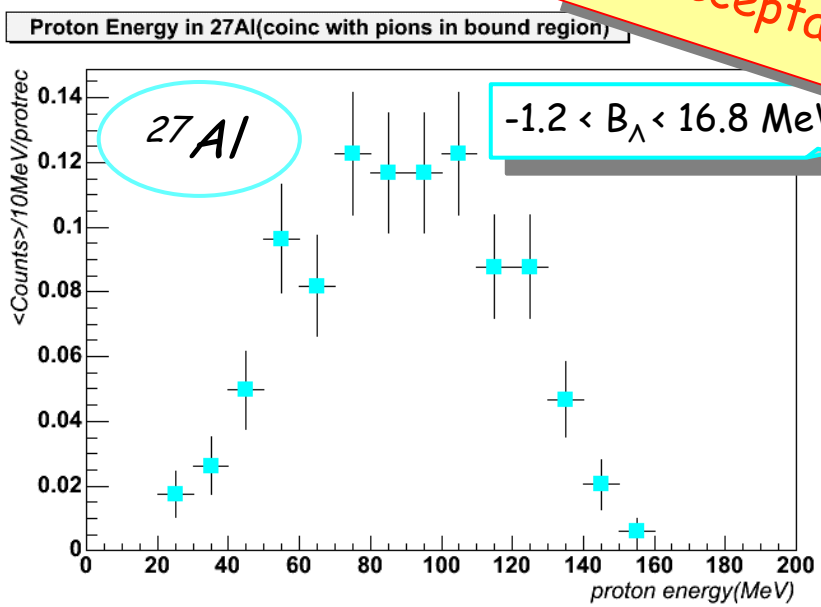


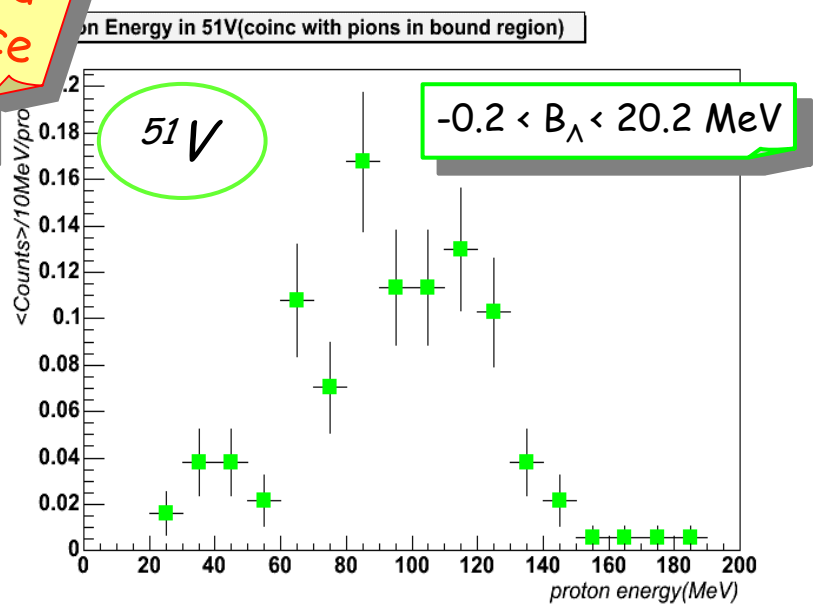
NM proton stimulated decay



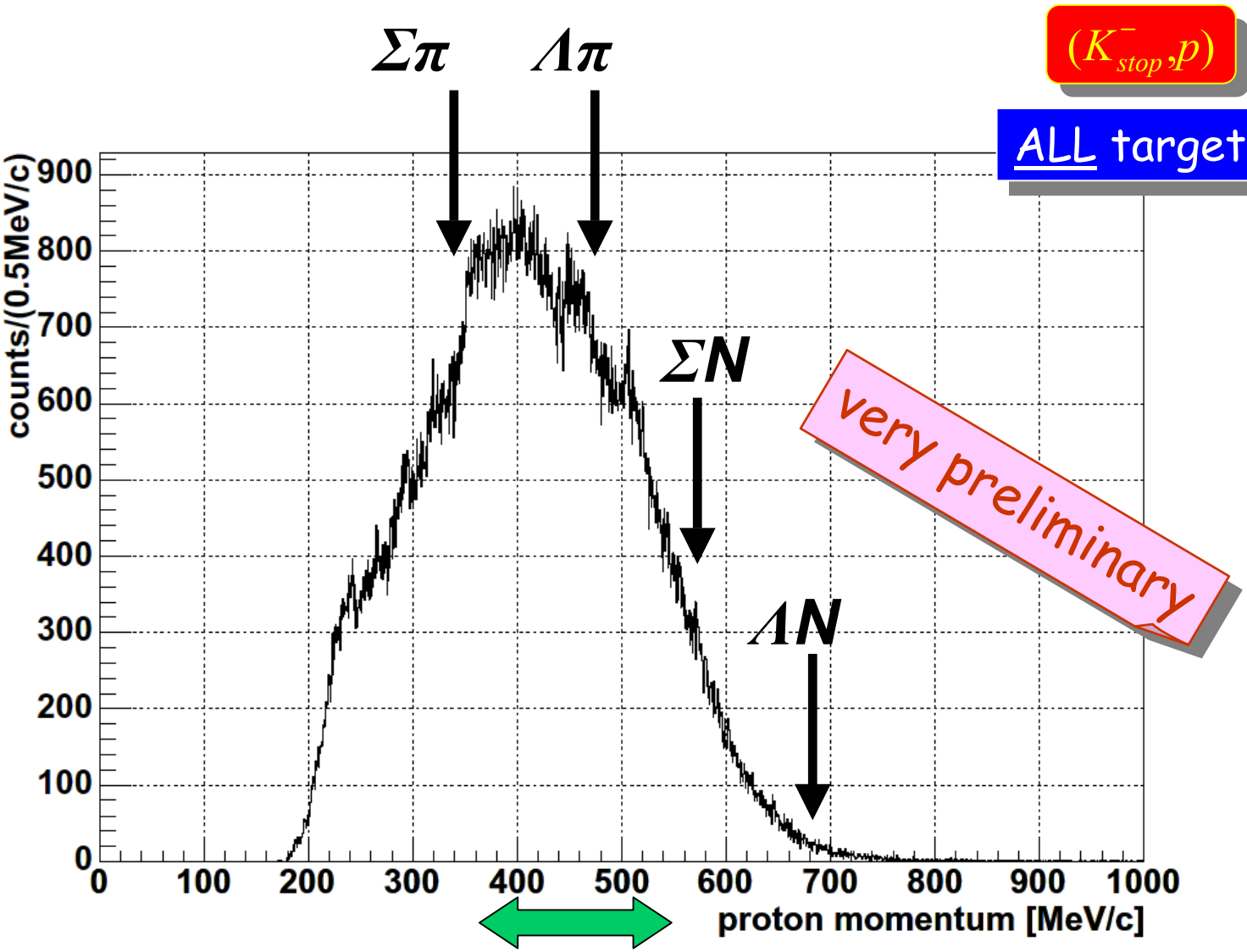


preliminary, not corrected for acceptance





Deeply bound kaonic states



(K^-_{stop}, p)

ALL targets

very preliminary