(π^+, K^+)反応を用いたK中間子原子核の探索

Search for kaonic nuclei by the (π^+, K^+) reaction

藤岡　宏之　（京大理）

for the J-PARC E27 collaboration

“New Hadrons” Workshop 2010

J-PARC E27 Collaboration

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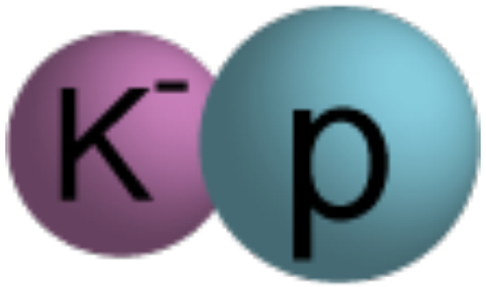
- Tohoku Univ.
  K. Hosomi, T. Koike, K. Miwa, K. Shirotori, H. Tamura

- JAEA
  K. Imai

antikaon-nuclear bound state

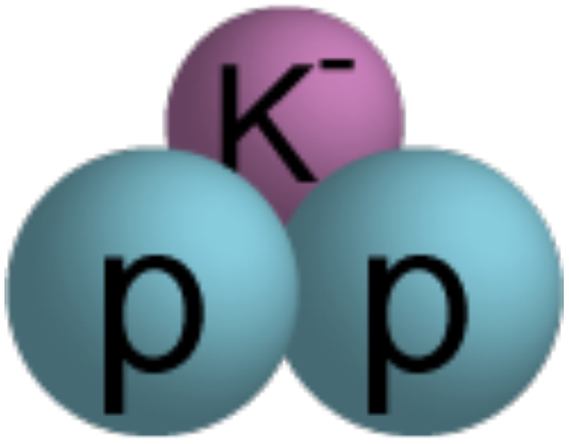


- three-quark state?
- $\bar{K}N$ bound state?
- superposition of two states ($\bar{K}N$, $\pi\Sigma$)?
- pentaquark state?

experimental investigation by LEPS, CLAS, J-PARC E31, HADES, ...

$\Lambda(1405)$

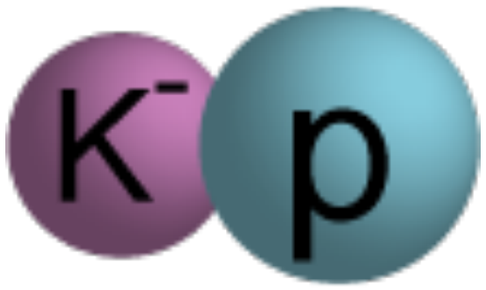
+proton



"K^-pp"

- will be bound due to strong attraction between isospin=0 $\bar{K}N$ pairs

antikaon-nuclear bound state



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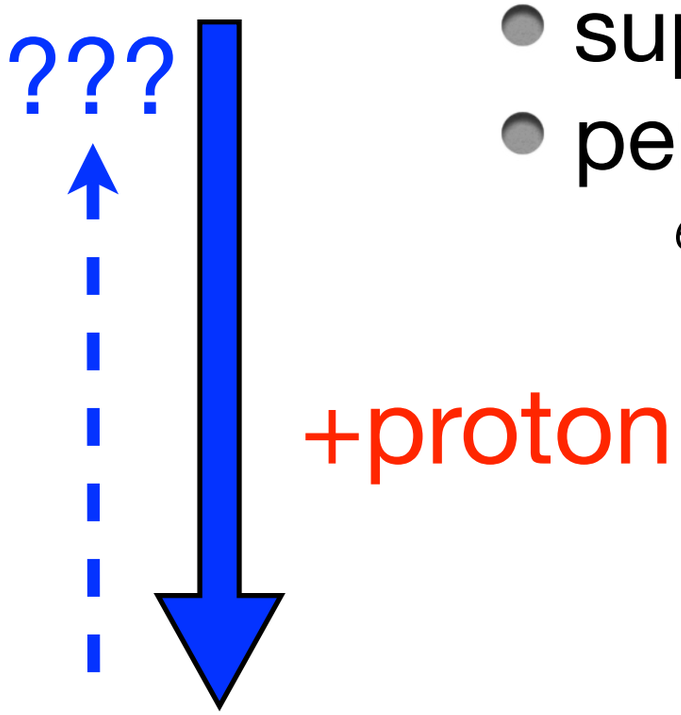
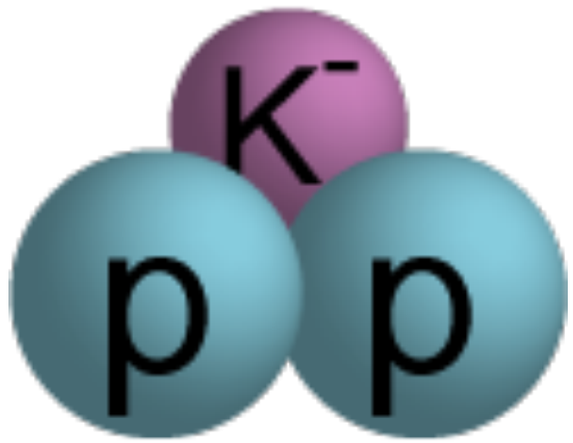
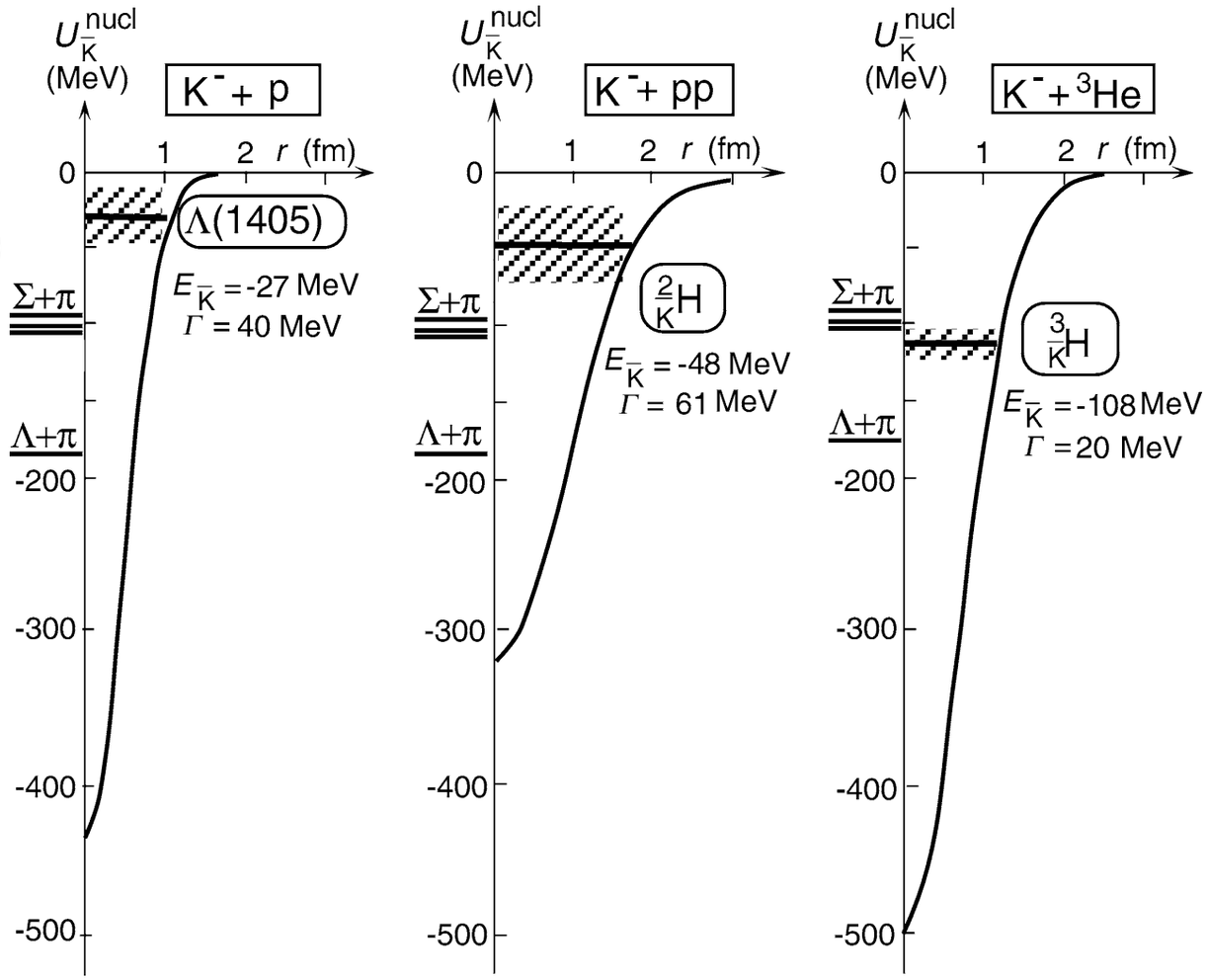




- will be bound due to strong attraction between isospin=0 $\bar{K}N$ pairs

$\bar{K}NN$ bound state

- $[\bar{K}(NN)_{T=1}]_{T=1/2}$: isospin mixing between K^-p and $\bar{K}^0n$
- Theoretical calculation by Akaishi and Yamazaki (2002)
- decay width can be small if B.E. is large enough



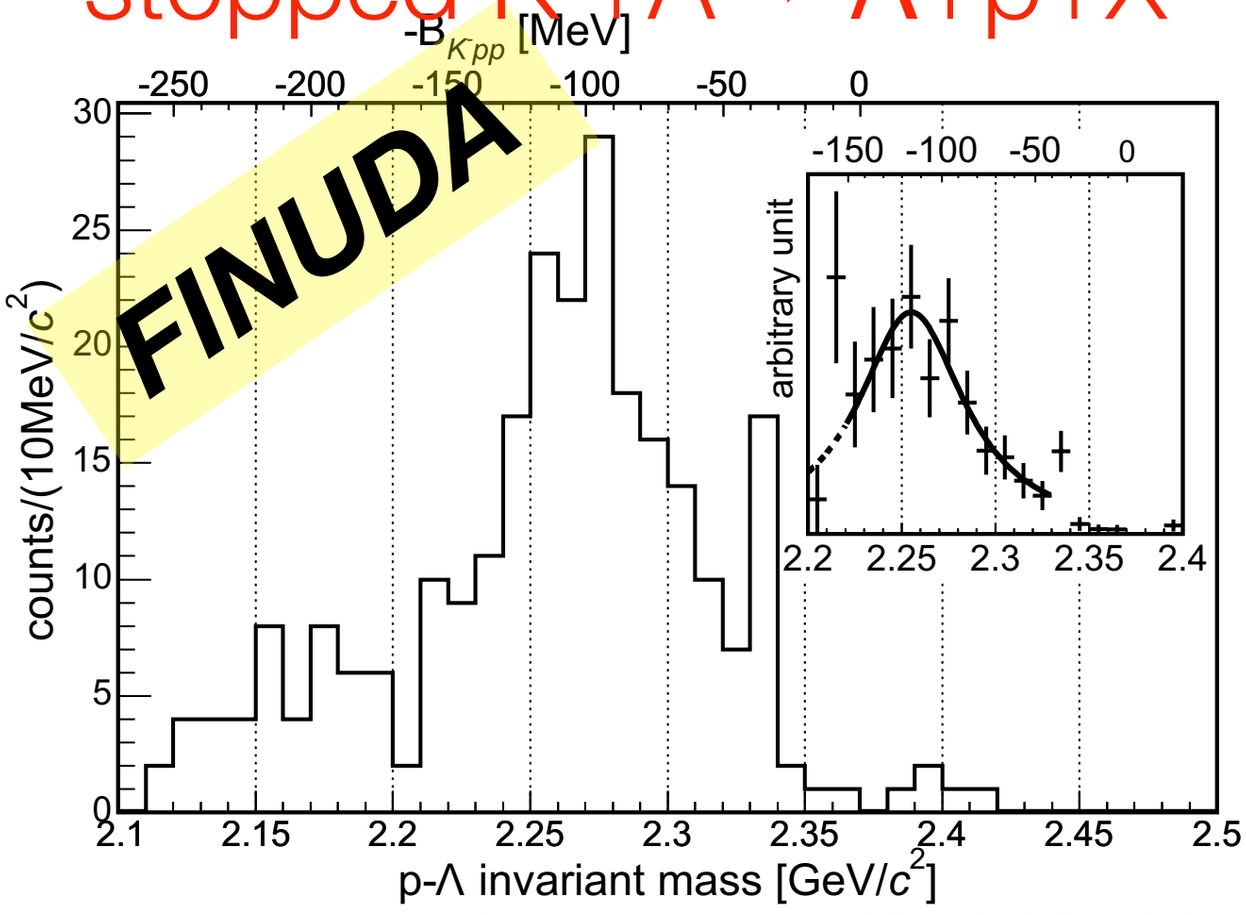
Y. Akaishi and T. Yamazaki, Phys. Rev. C 65, 044005 (2002)

Theoretical calculation on $\bar{K}NN$ state

	B (MeV)	Γ (MeV)
Akaishi, Yamazaki (ATMS variational) PLB535, 70 (2002)	48	61
Dote, Hyodo, Weise (variational) PRC79, 014003 (2009)	17-23	40-70
Shevchenko, Gal, Mares (Faddeev) PRC76, 044004 (2007)	50-70	90-110
Ikeda, Sato (Faddeev) PRC79, 035201 (2009)	60-95	45-80
Wycech, Green (variational) PRC79, 014001 (2009)	40-80	40-85

Experimental "observations" of $\bar{K}NN$ state

stopped $K^-+A \rightarrow \Lambda+p+X$

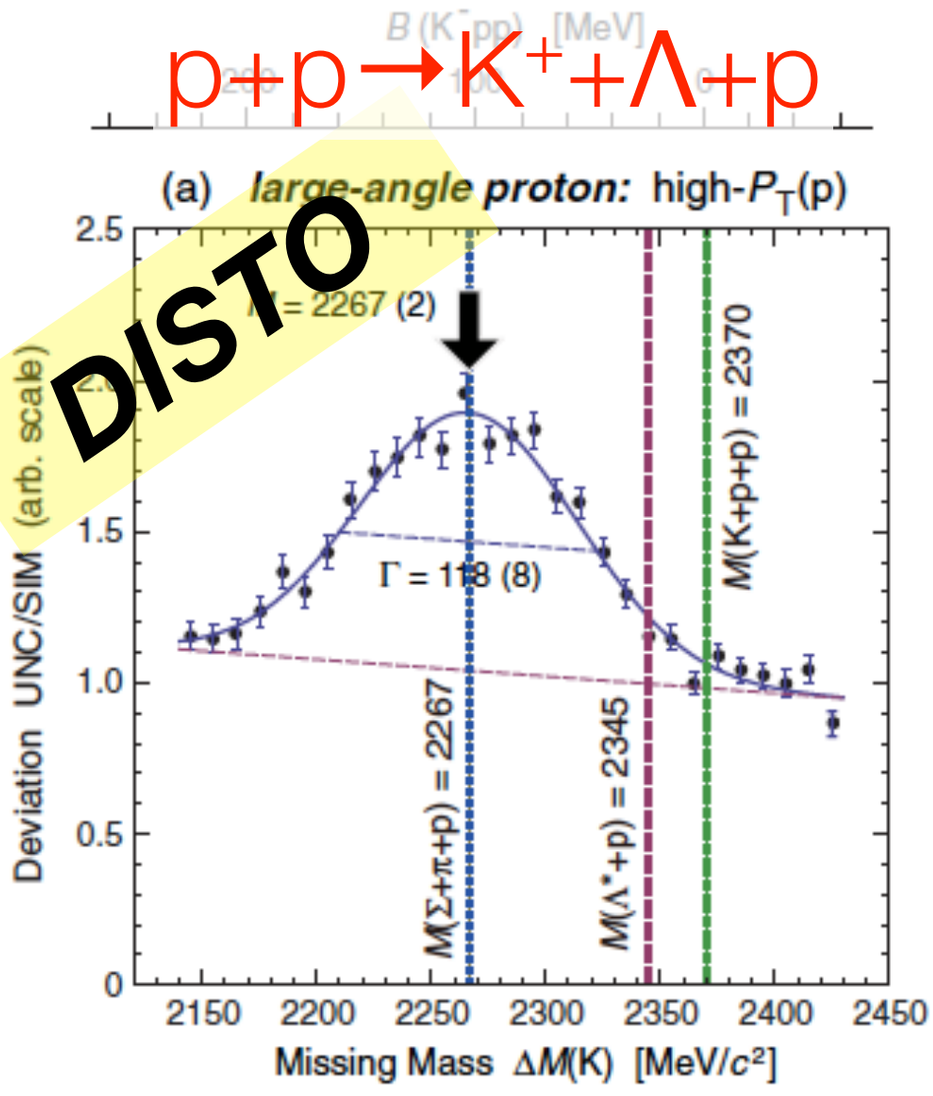


M. Agnello et al., Phys. Rev. Lett. 94, 212303 (2005)

$$B = 115^{+6+3}_{-5-4}\,\mathrm{MeV}$$

$$\Gamma = 67^{+14+2}_{-11-3}\,\mathrm{MeV}$$

$p+p \rightarrow K^+ + \Lambda + p$



T. Yamazaki et al., Phys. Rev. Lett. 104, 132502 (2010)

$$B = 103 \pm 3 \pm 5\,\mathrm{MeV}$$

$$\Gamma = 118 \pm 8 \pm 10\,\mathrm{MeV}$$

Forthcoming experiment

- FOPI @ GSI : $p+p \rightarrow K^{+}+\Lambda+p$
- J-PARC E15 : $^{3}He(K^{-}, n)K^{-}pp$, $K^{-}pp \rightarrow \Lambda+p$ / $\Sigma^{0}+p$
- J-PARC E27 : $d(\pi^{+}, K^{+})K^{-}pp$, $K^{-}pp \rightarrow \Lambda+p$ / $\Sigma^{0}+p$
- AMADEUS @ DAΦNE : stopped K^{-} + $^{3}He/^{4}He$

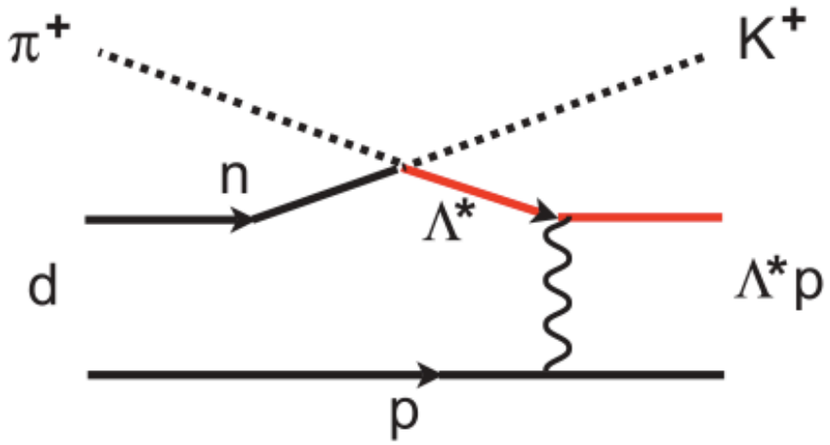
J-PARC E27 experiment
@ K1.8 beamline + SKS spectrometer

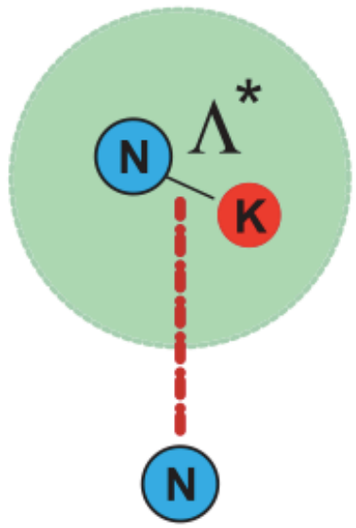
- d(π^+, K^+) reaction

π^+ + "n" --> "Λ^*" + K^+

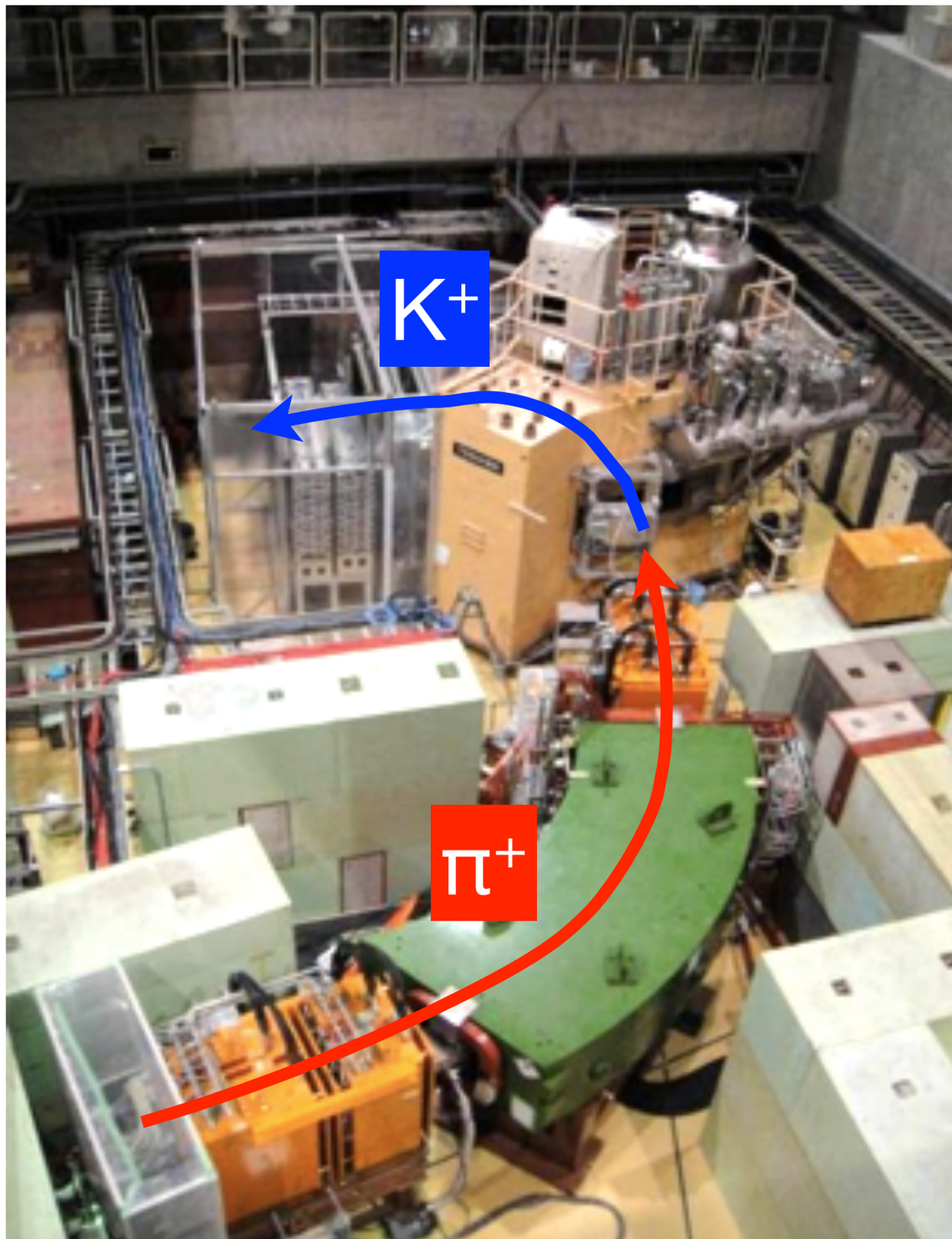
"Λ^*" + "p" --> bound K^-pp *minor*

--> quasi-free Λ^* *dominant*





T. Yamazaki and Y. Akaishi, Phys. Rev. C 76, 045201 (2007)



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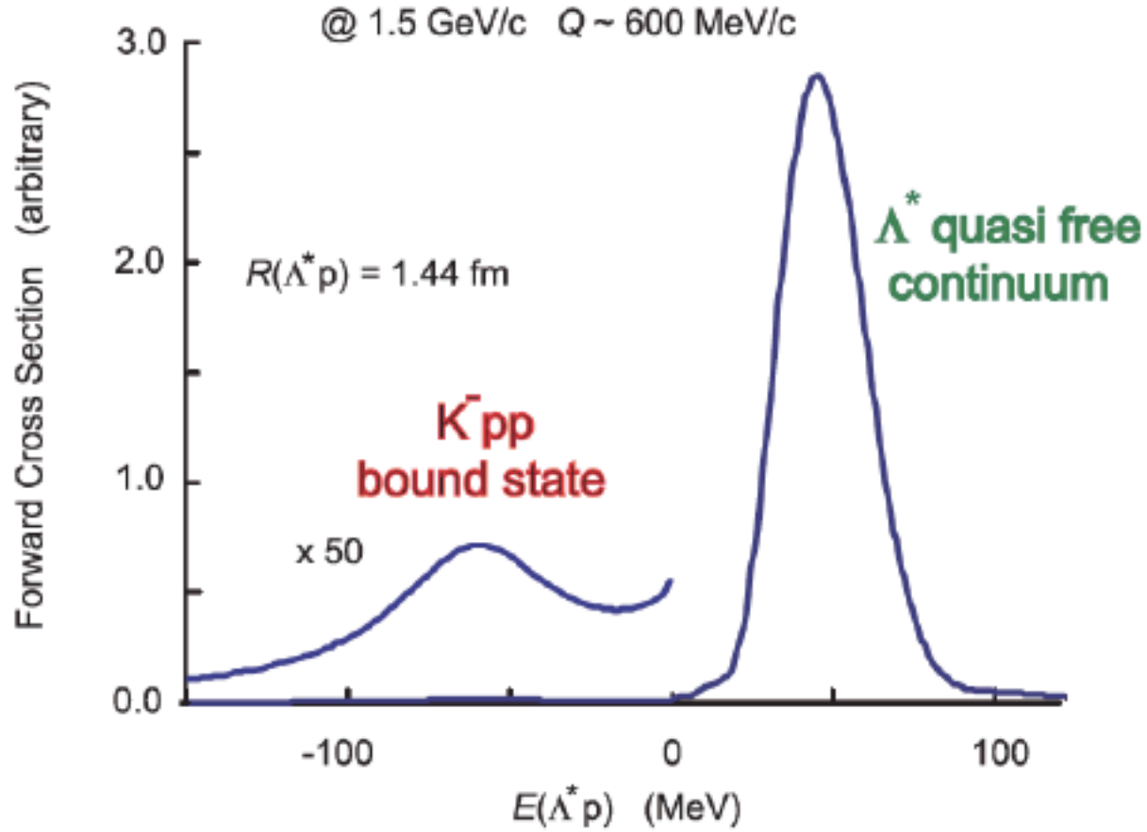

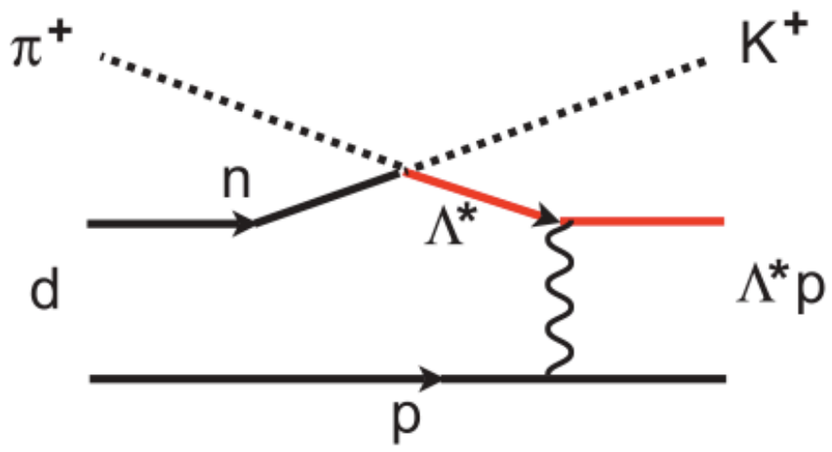

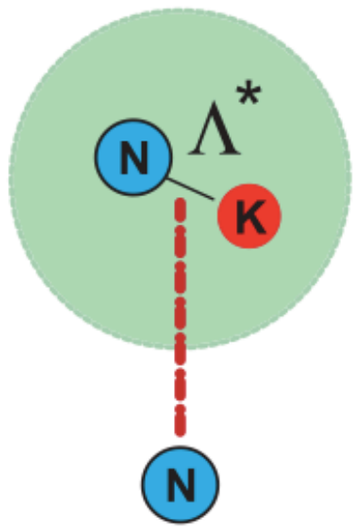

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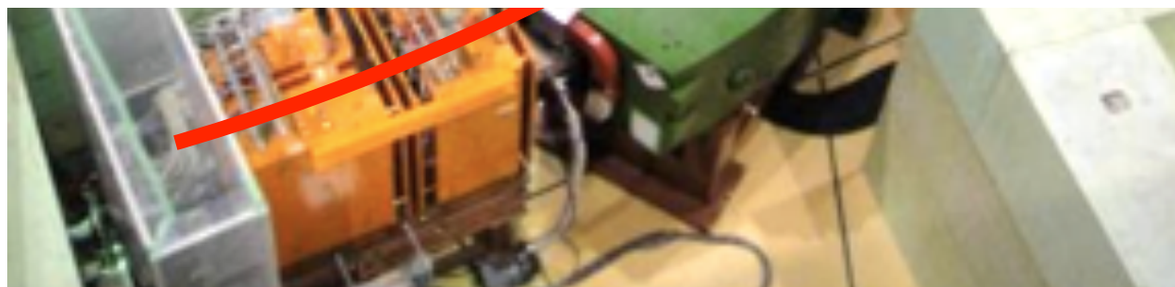
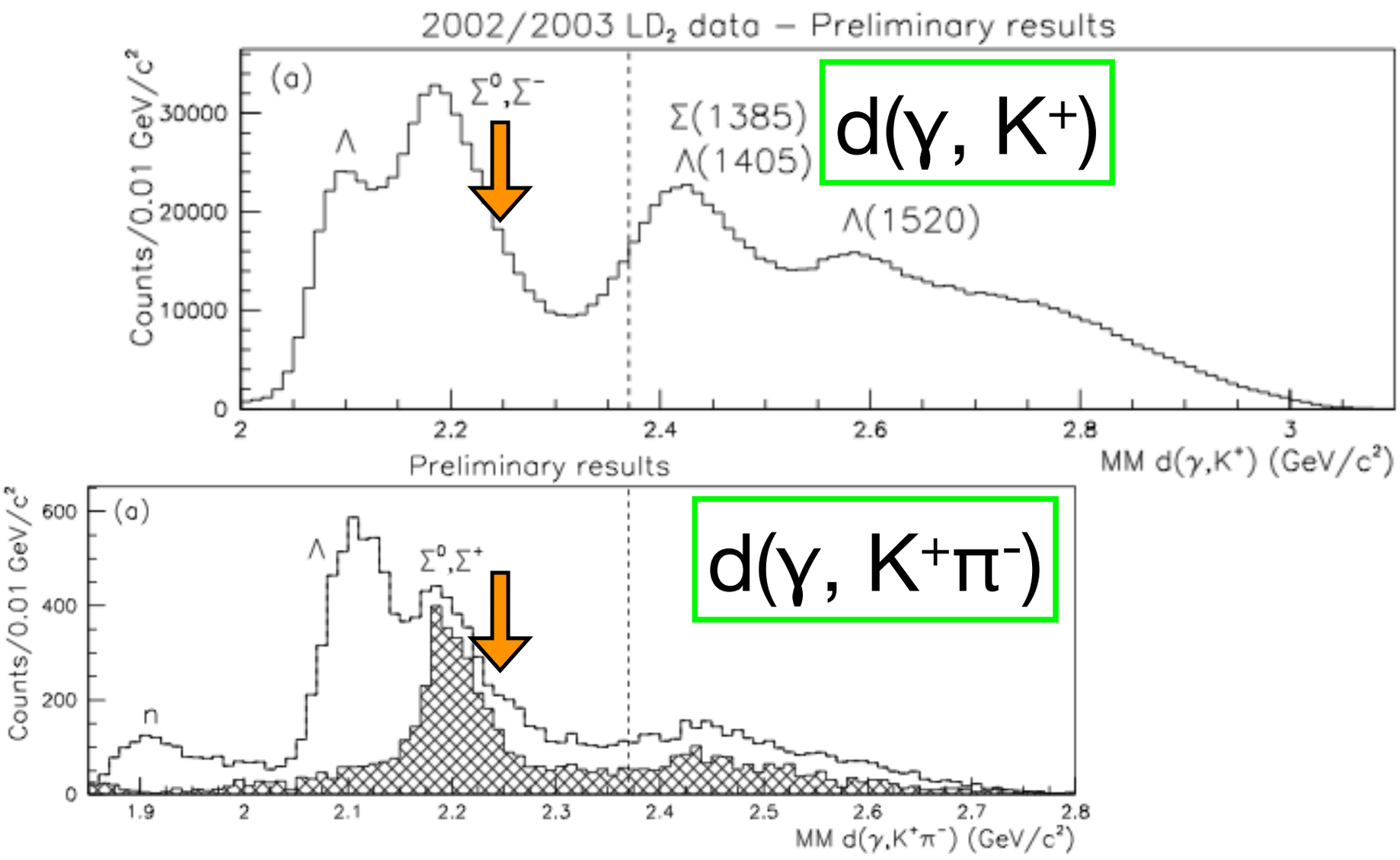


cf. d(γ, K^+)X^0, d(γ, $K^+\pi^-$)X^+ reactions @ LEPS

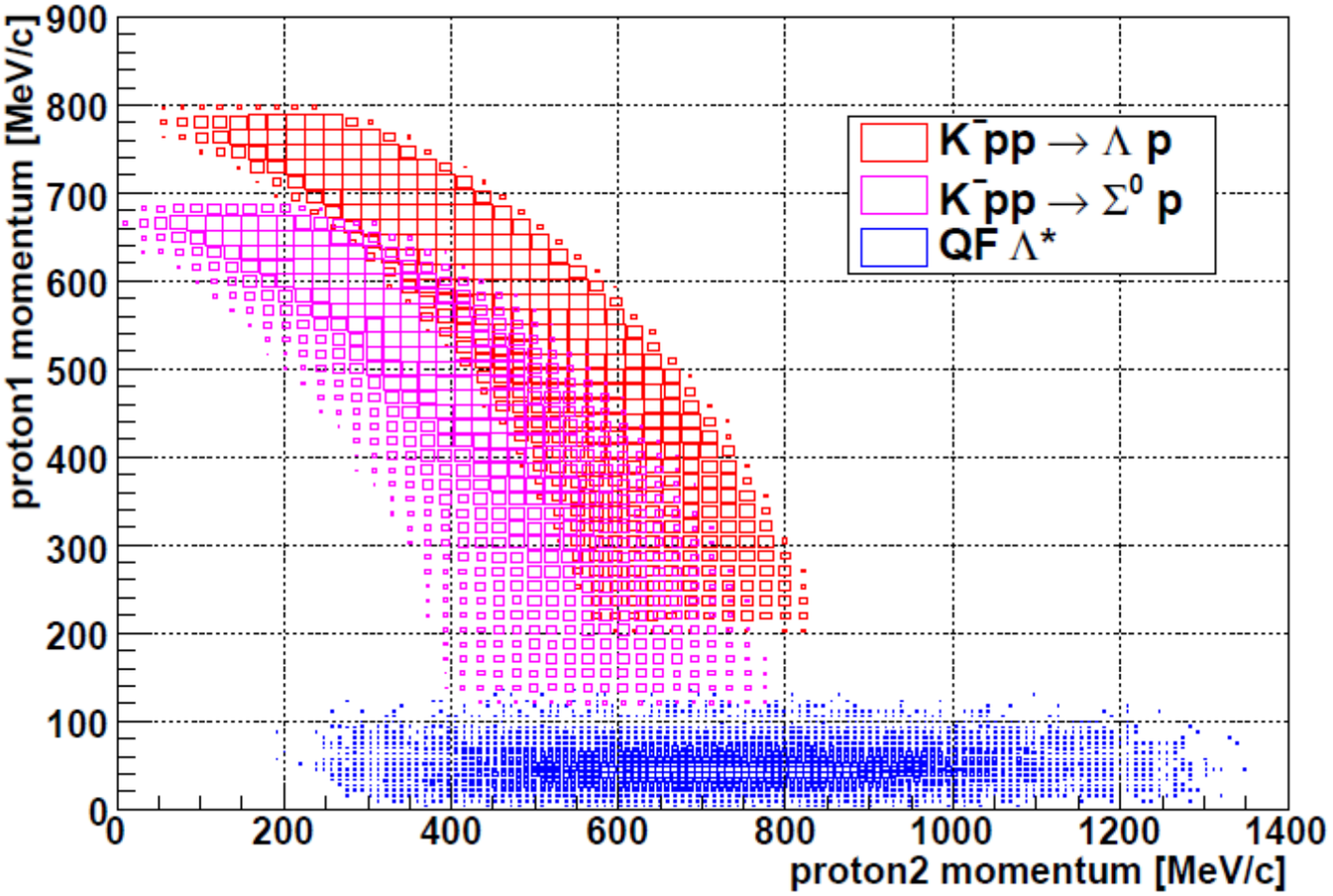


J. D. Parker for the LEPS collaboration, Mod. Phys. Lett. 23, 2544 (2008)

Background reduction by *two-proton tagging*

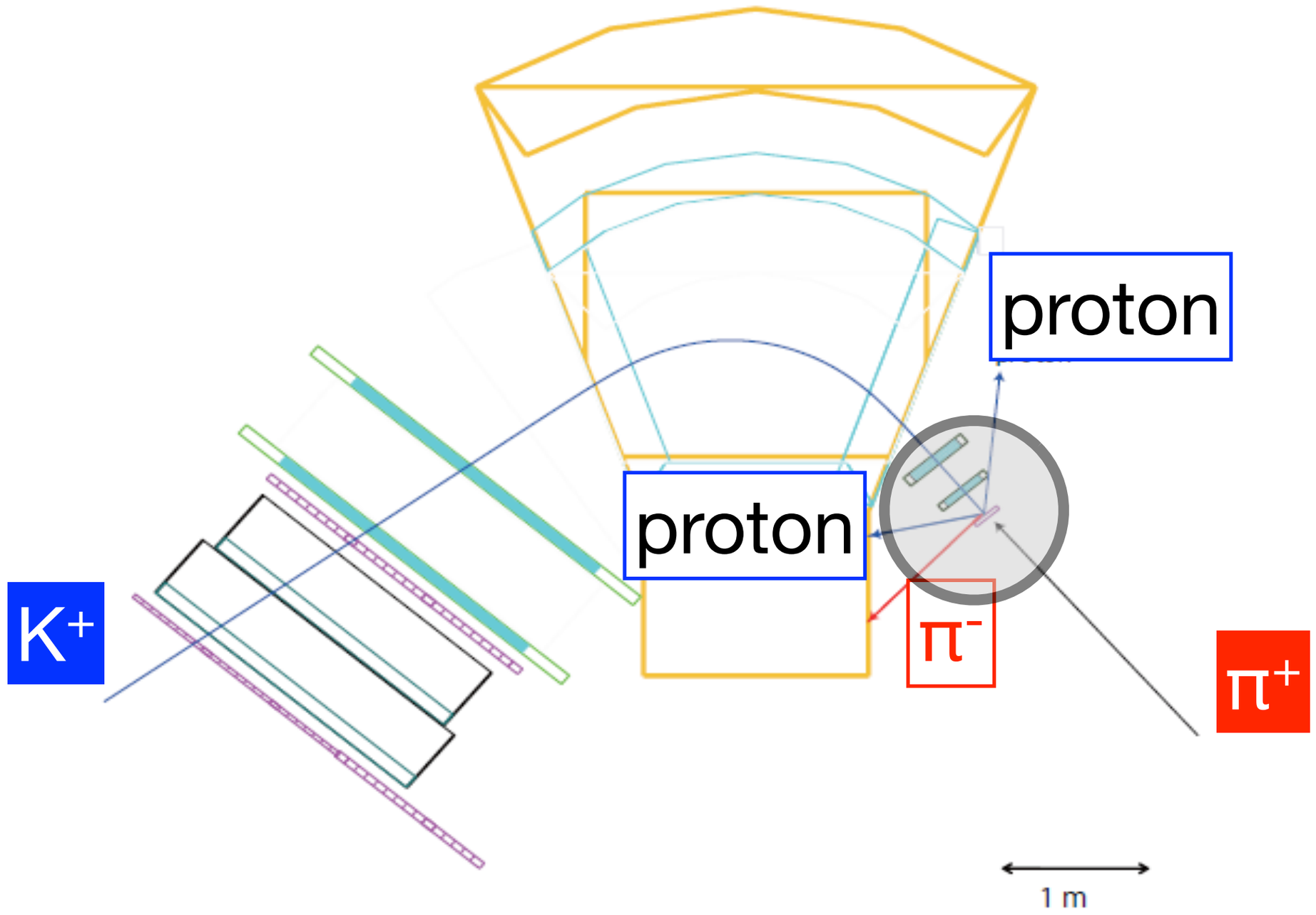
- Signal: $K^-pp \rightarrow \Lambda p \rightarrow (\mathbf{p}\pi^-)\mathbf{p}$, $\Sigma^0 p \rightarrow \Lambda\gamma p \rightarrow (\mathbf{p}\pi^-)\gamma\mathbf{p}$

- Background: quasi-free process (e.g. $\pi^+ d \rightarrow \Lambda^* K^+ \mathbf{p_s}$)



$\rightarrow \Sigma^+\pi^- \rightarrow \mathbf{p}\pi^0\pi^-$)

Experimental setup with Range Counter



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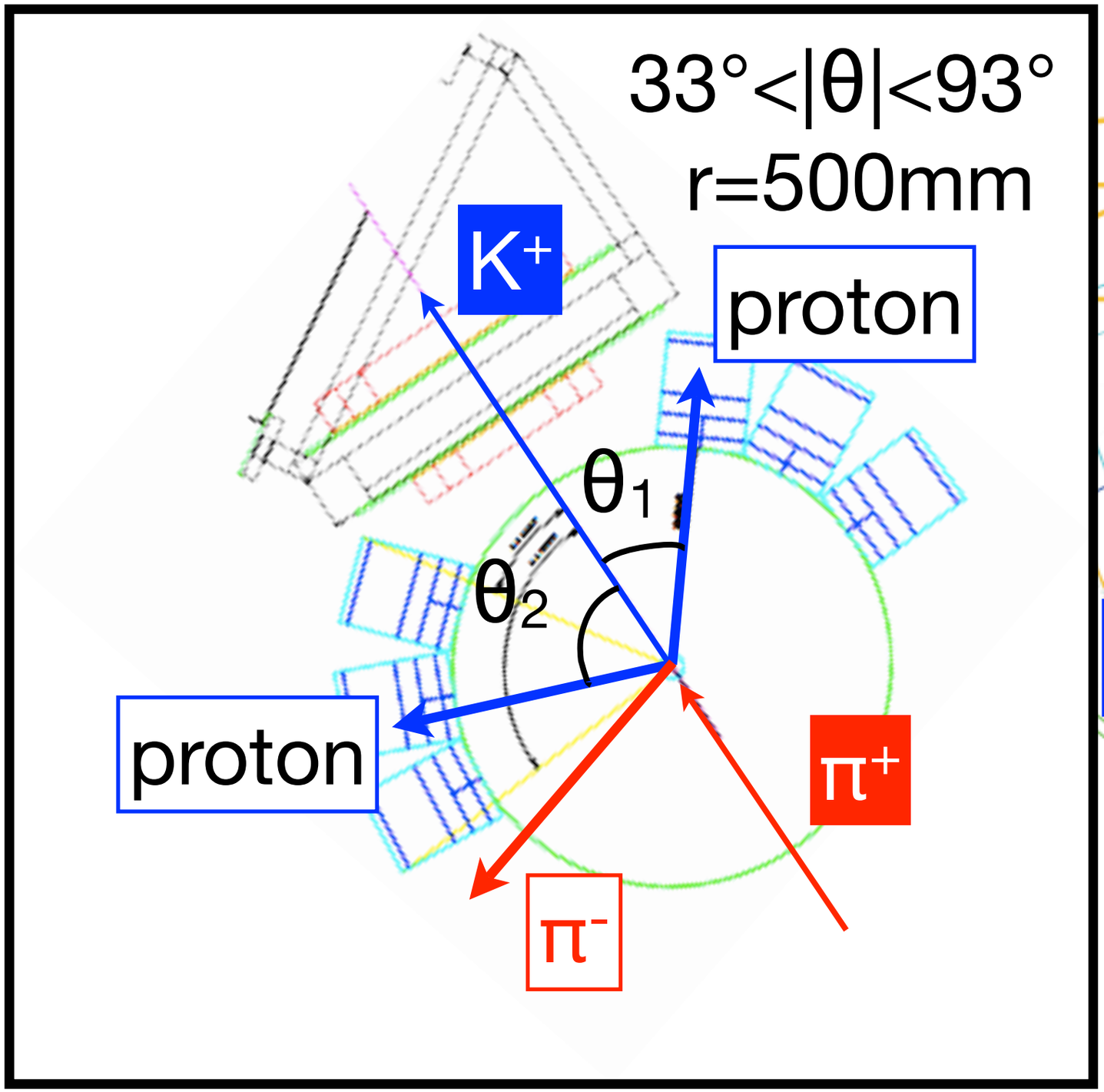

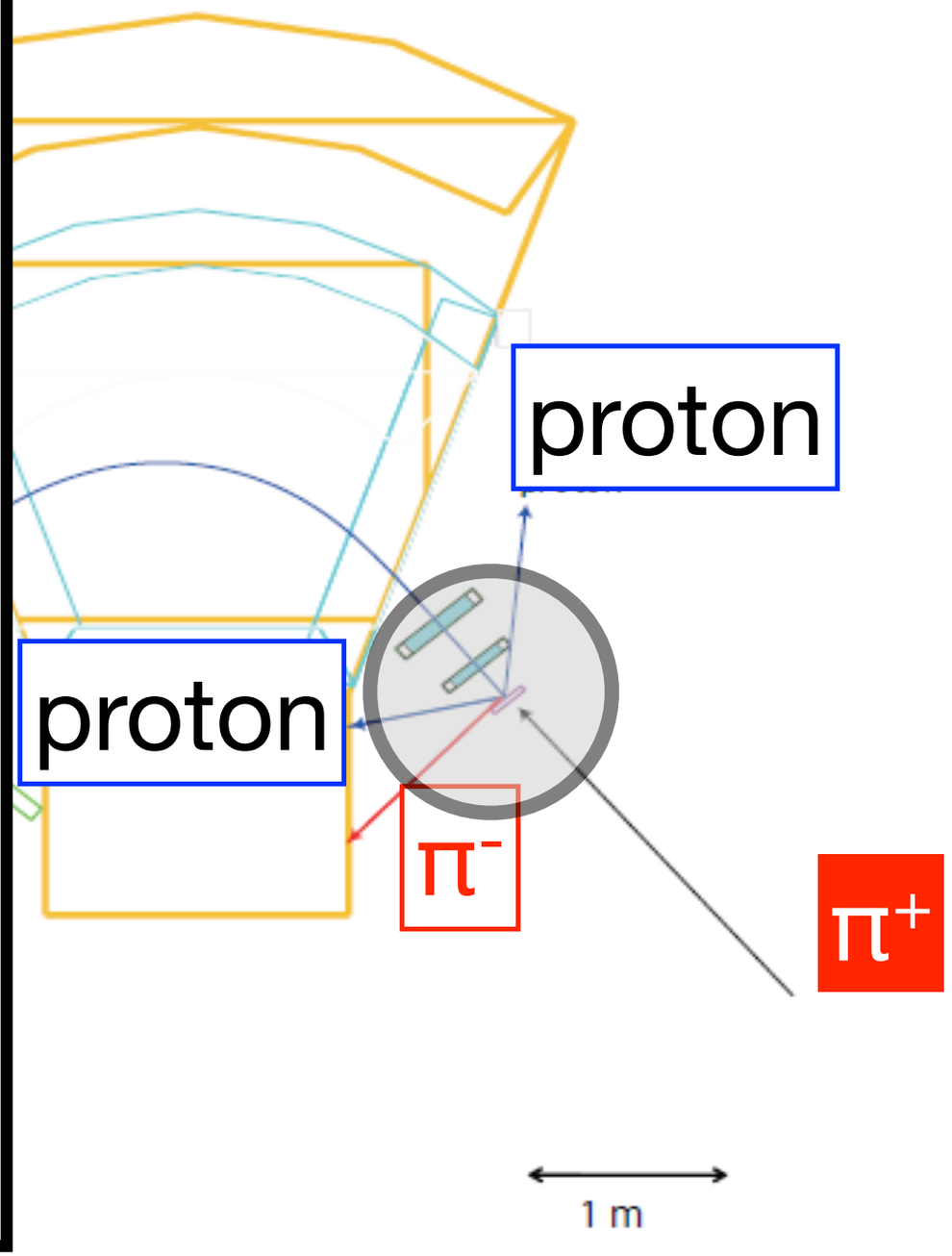

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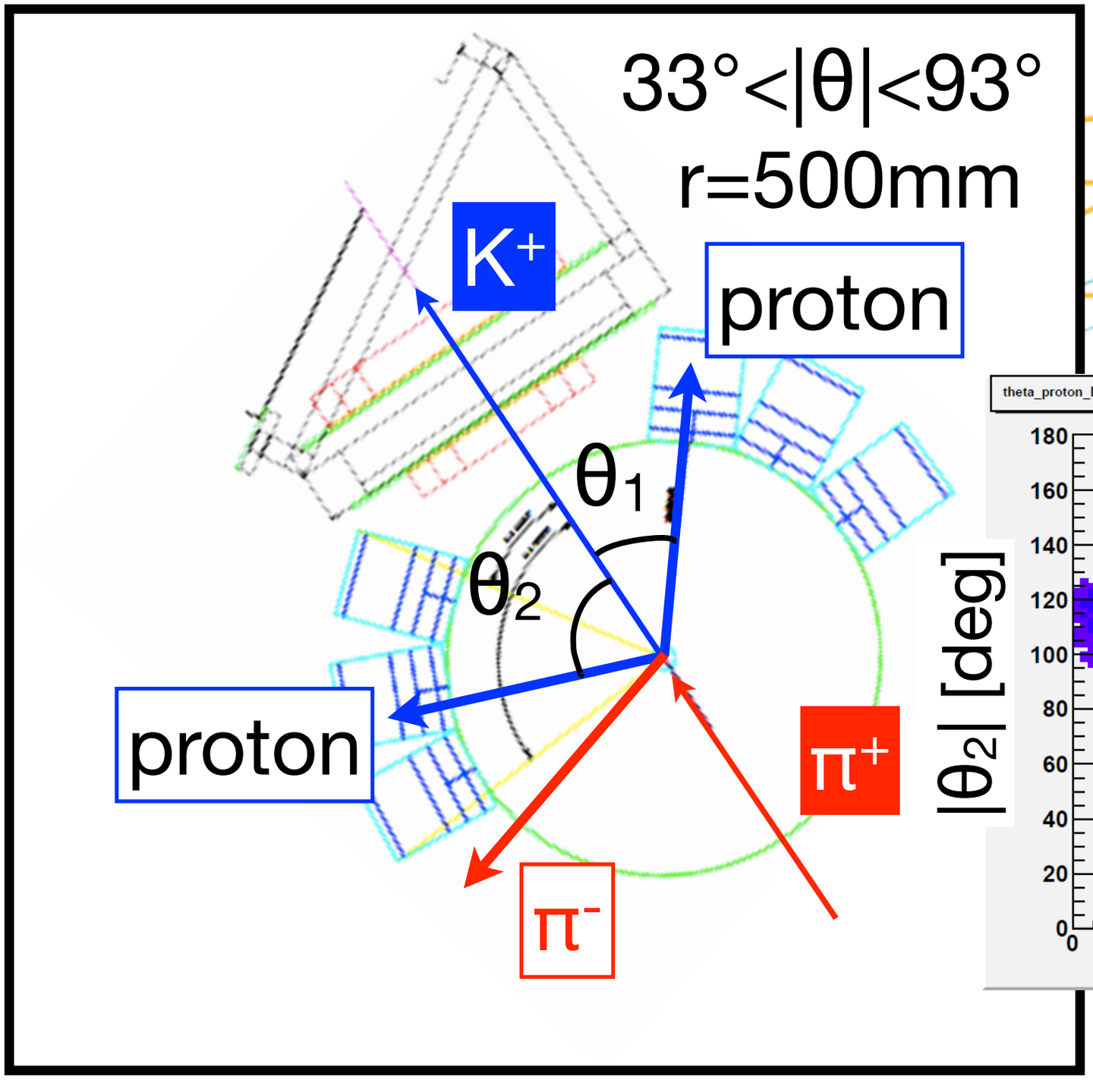
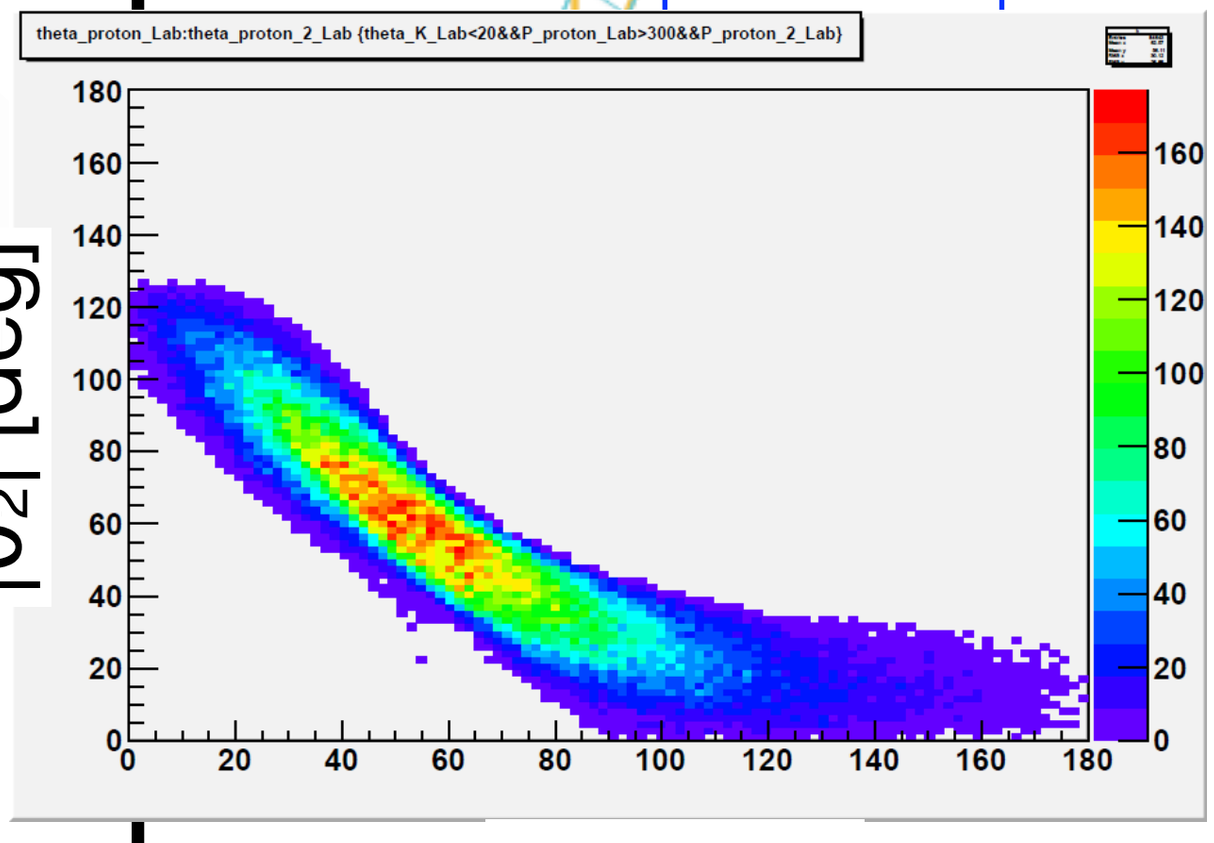
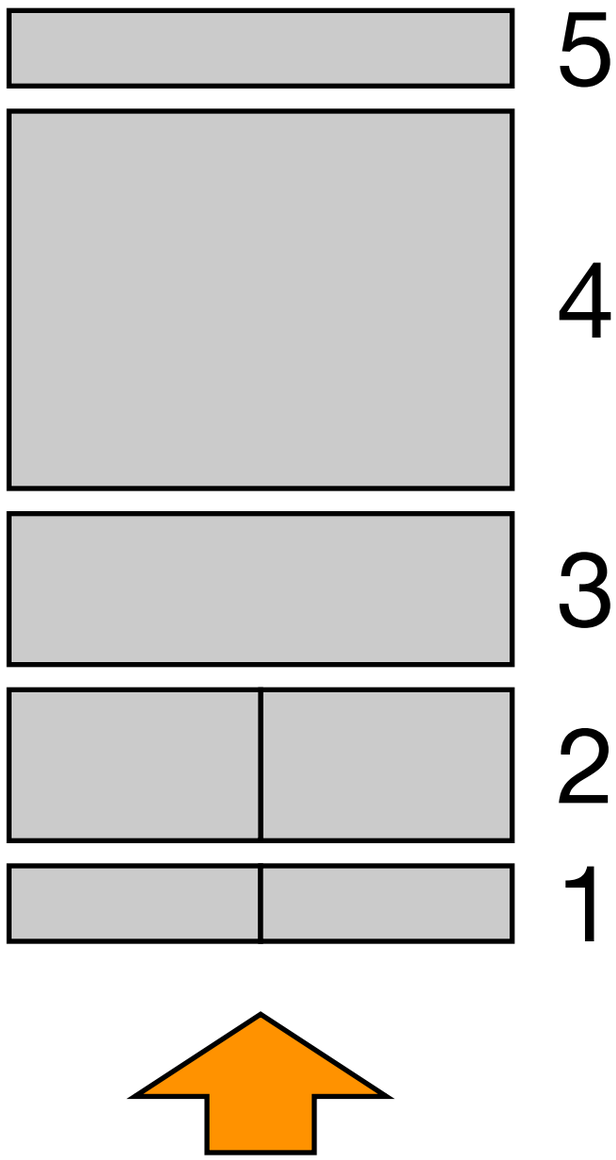
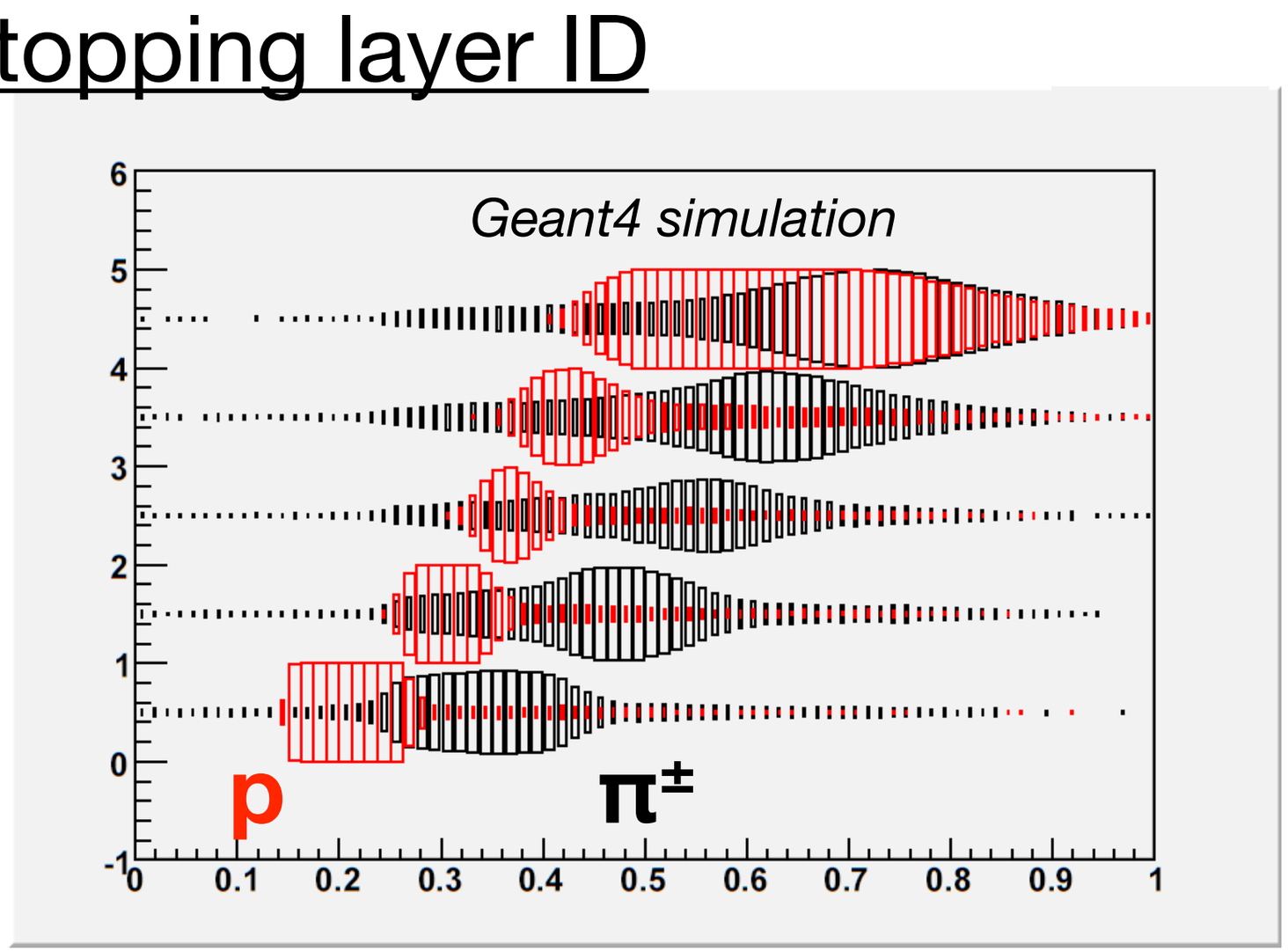




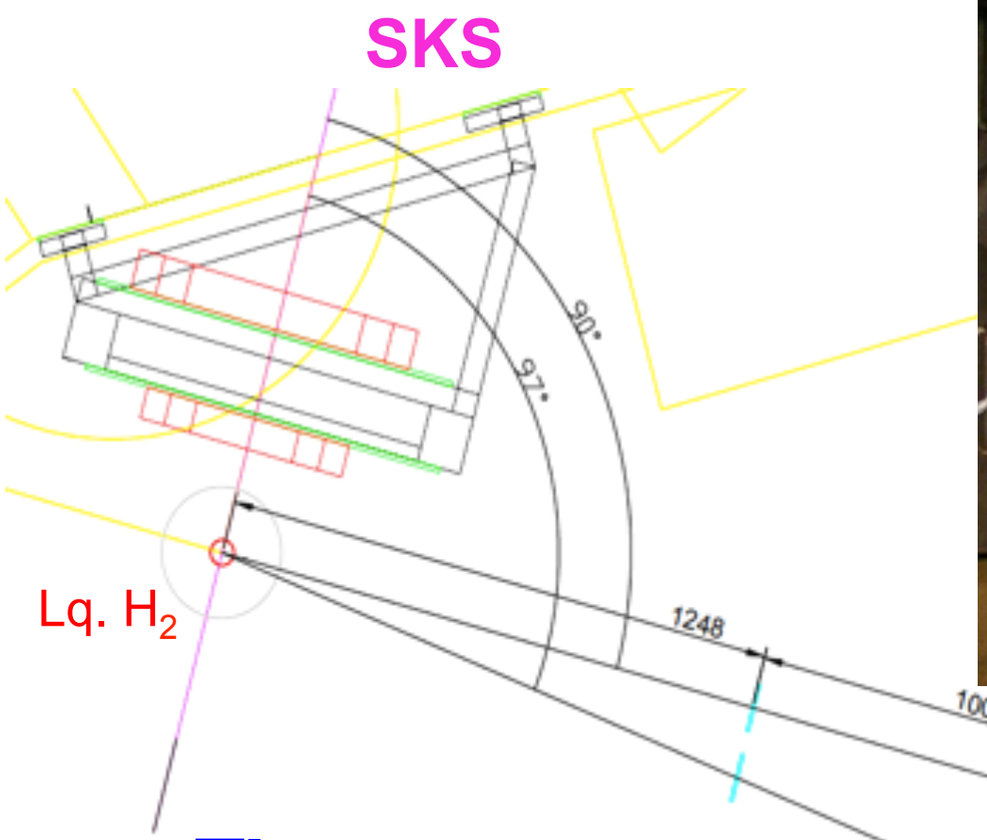
Thickness of range counter

- Good p/π separation by using information on “stopping layer”, velocity, dE/dx





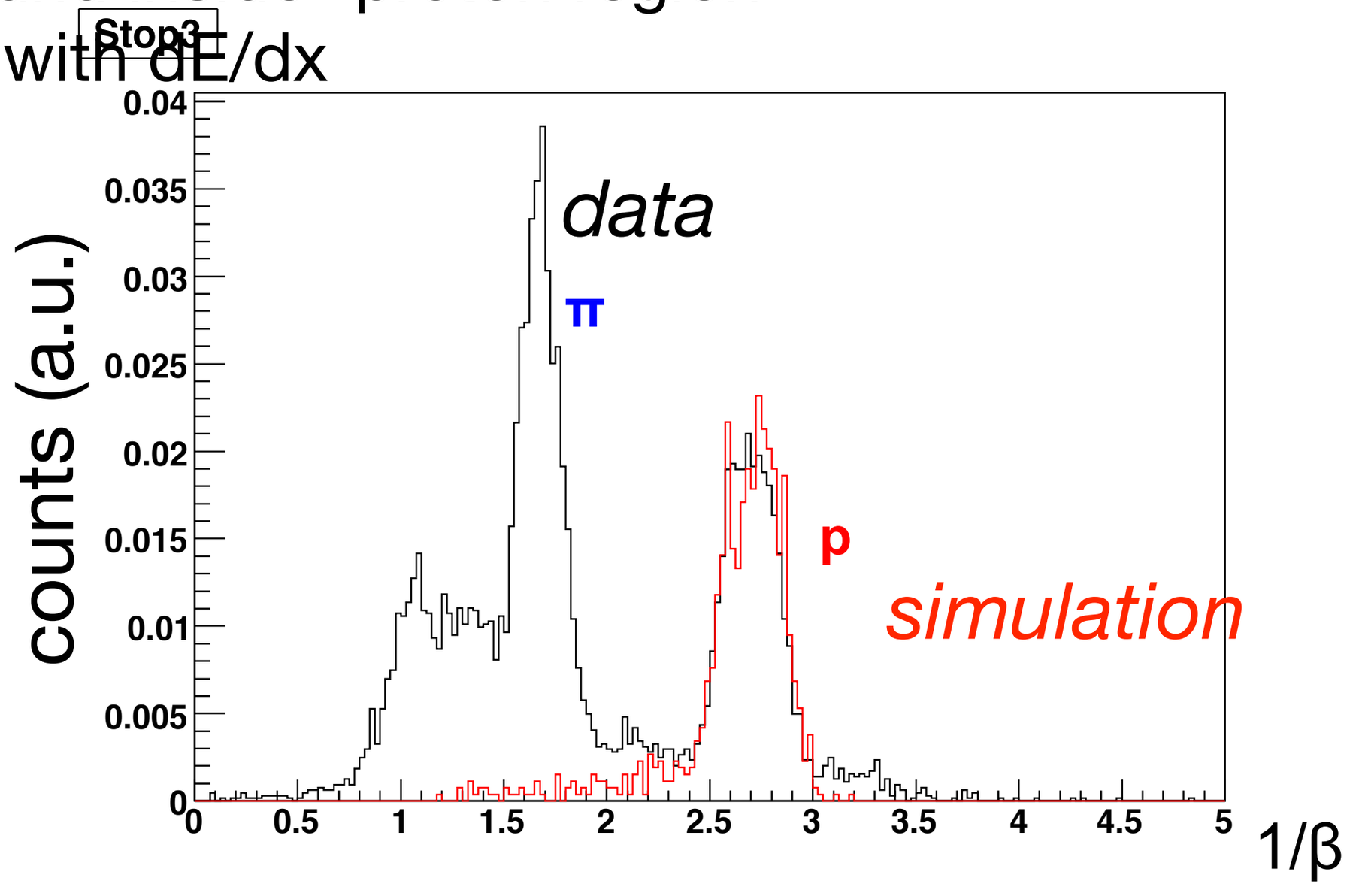
Test experiment @ J-PARC K1.8 (Nov. 2010)



Range Counter
(2 Units)

Results (“stopping layer ID=3” vs velocity)

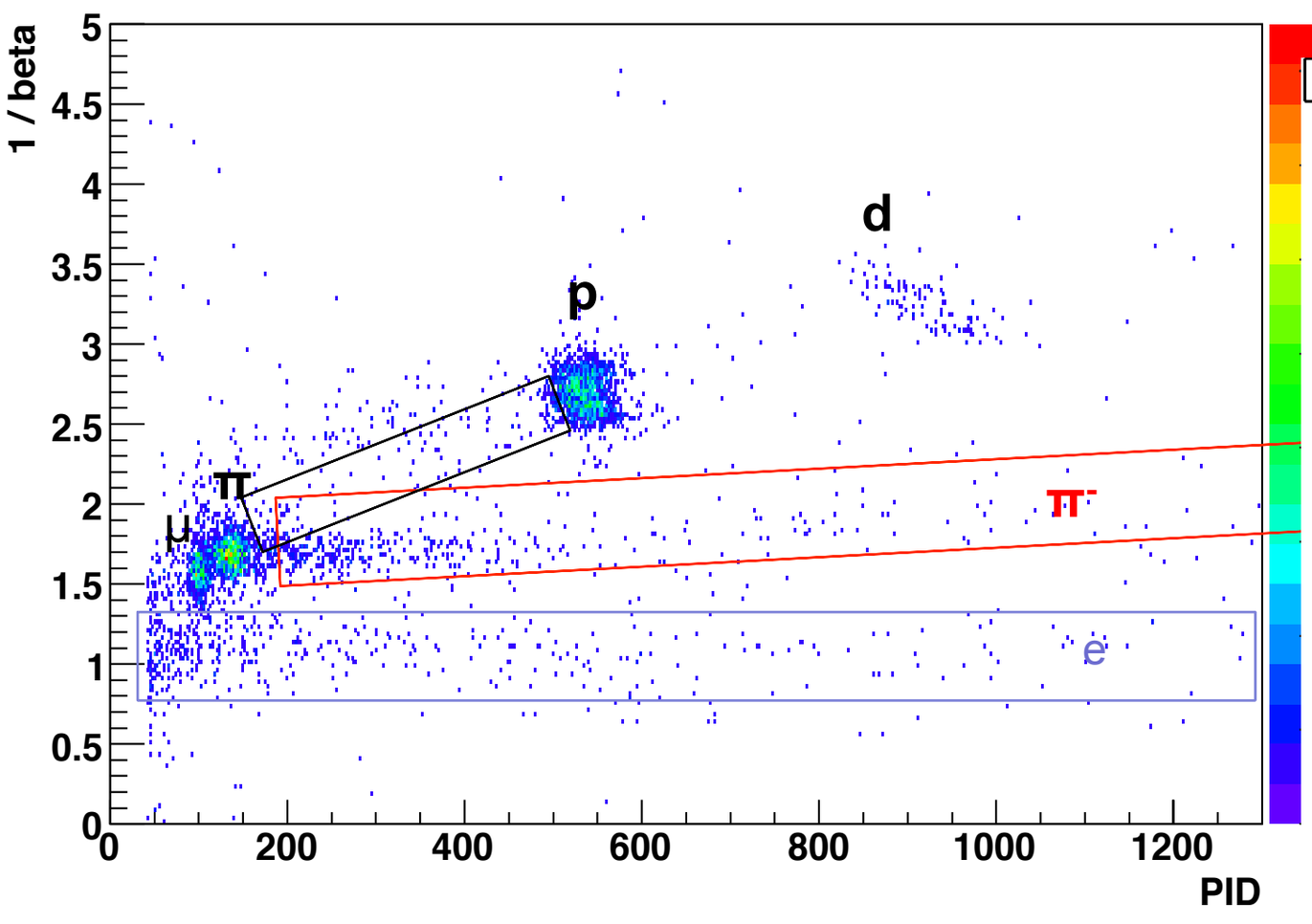
- consistent with Monte Carlo simulation
- some background inside “proton region”
  --> further cut with dE/dx

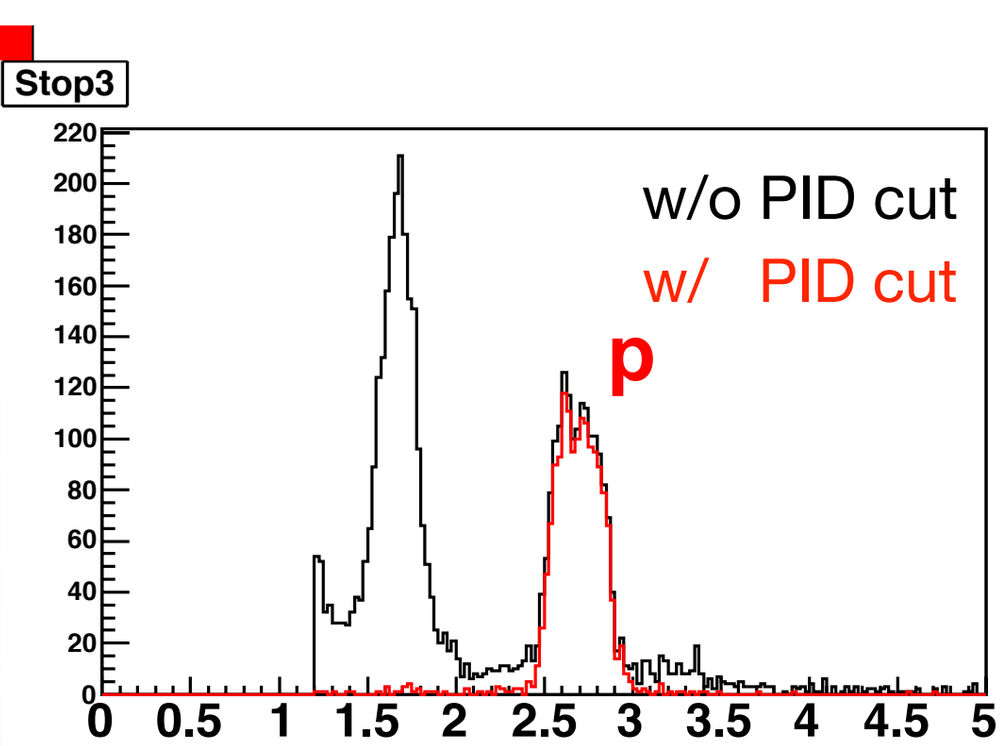


Further cut with PID Function

- PID = $(dE_{i-1} + dE_i)^{\alpha} - dE_i^{\alpha}$ ($\alpha \sim 1.75$)
  -- independent of incident energy

- Much better separation with 2D cut





Run plan in Apr. 2011

- First data taking (~2.5% of requested beam time)
  - 1M/spill * 7 days [cf. 5M/spill * 40 days (proposal)]
- Inclusive measurement (for the first time!)
  - $d(\pi^+, K^+)$ & $p(\pi^+, K^+)$ for comparison @ 1.6GeV/c
- Exclusive measurement with ***one***-proton tagging
  - Background reduction : protons from hyperon decay are almost out of acceptance of the range counter!

Expected background (@1.69GeV/c)

- based on the cross sections by Thomas et al. (NPB 56, 15 (1973)) and Pan et al. (PRD 2, 449 (1970)).
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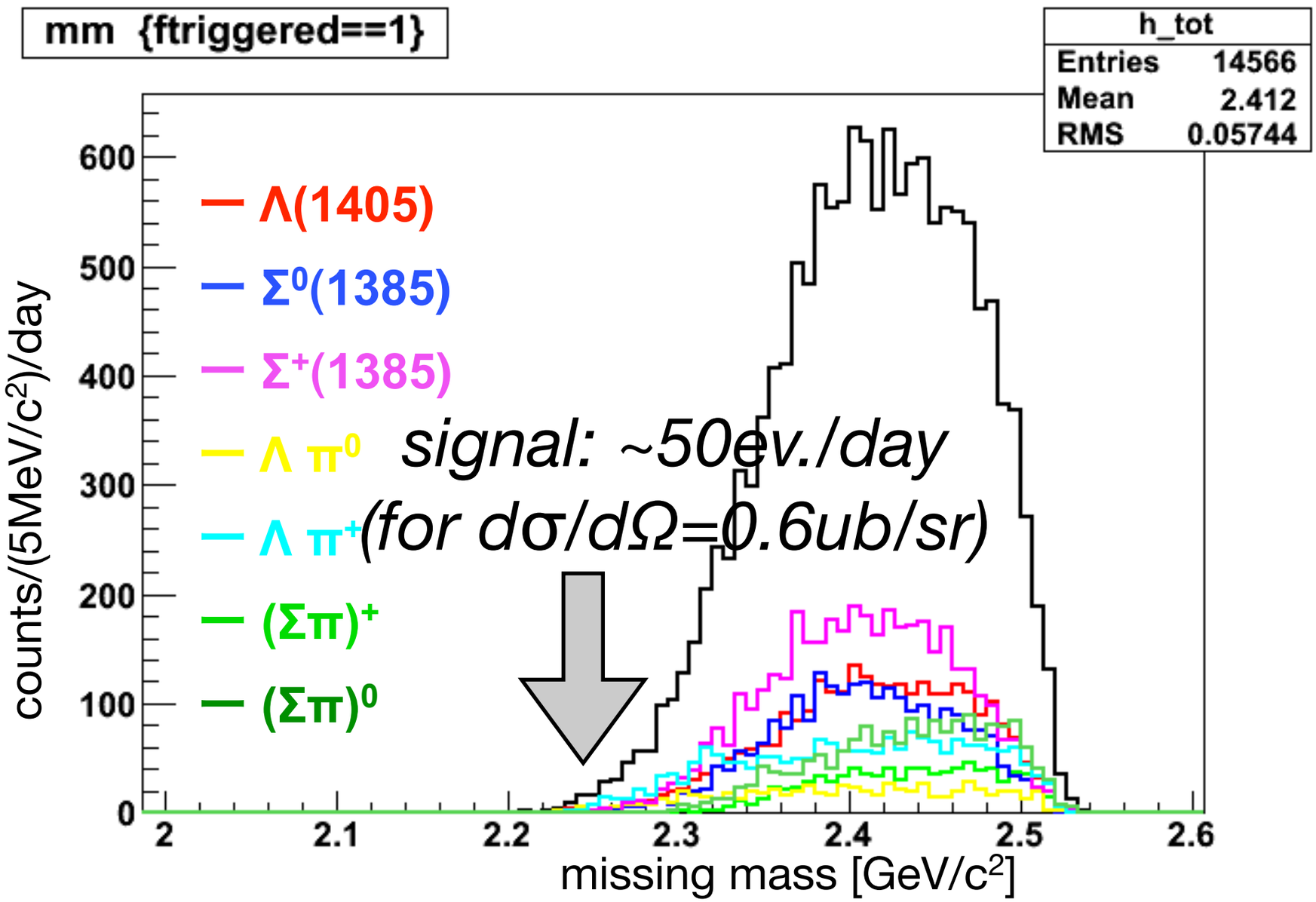

Summary

- Search for K^-pp bound state via (π^+, K^+) reaction

- Two-proton tagging for distinguishing non-mesonic decay of K^-pp from other quasi-free processes.

- Range counter for good p/π separation is almost ready, and will be installed within a month.

- First experiment will start in April 2011. One-proton tagging method will be applied to reduce backgrounds.