Study of S=-2 baryonic states at FLAIR

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Contribution to: Nuclear and particle physics with antiprotons
within the FLAIR LoI

FLAIR – A Facility for Low-energy Antiproton and Ion Research @ FAIR

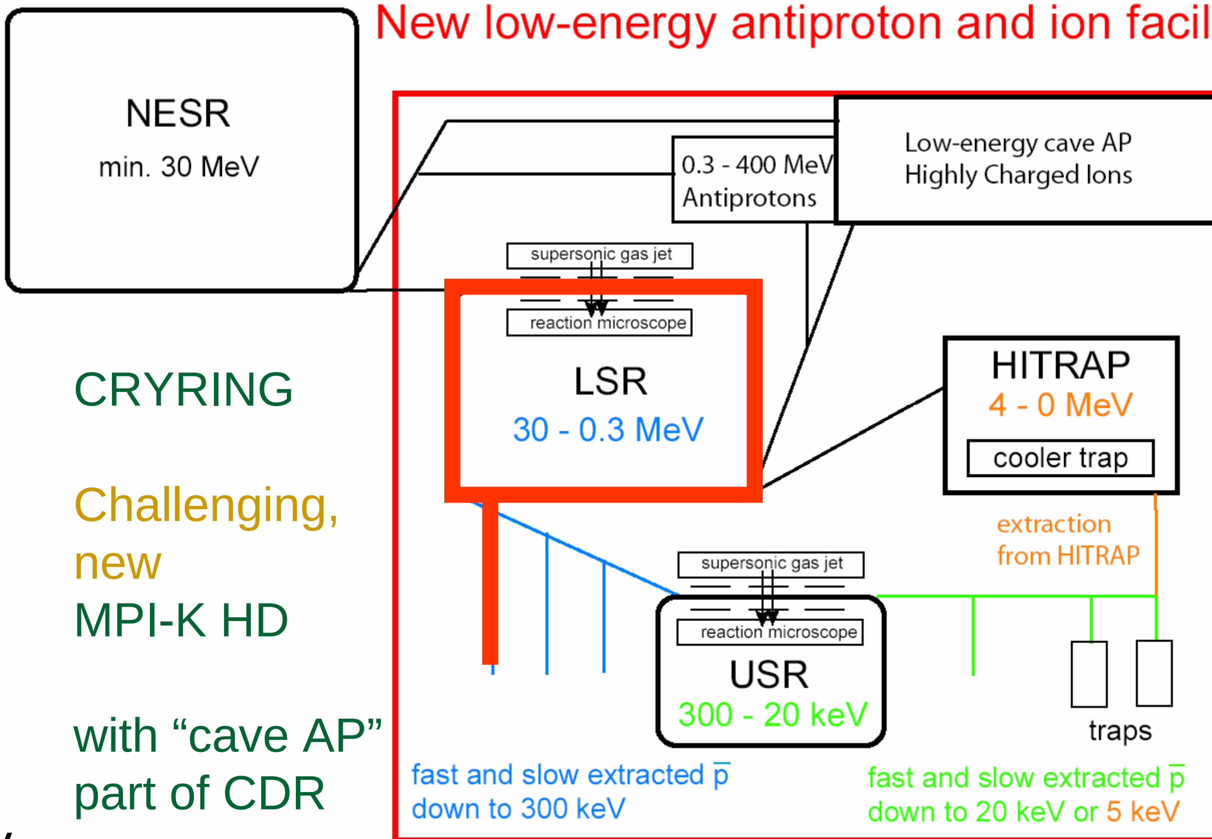
- *NESR*
  - Pbar & Ions 30 – 400 MeV
- *LSR*
  - Standard ring
  - Min. 300 keV
- *USR*
  - Electrostatic
  - Min. 20 keV
- *HITRAP*
  - pbar and ions
  - Stopped & ext-tracted @ 5 keV

CRYRING

Challenging, new MPI-K HD

with “cave AP” part of CDR

New low-energy antiproton and ion facility



Factor 100 more pbar trapped or stopped in gas targets than now

Production of S = -2 baryonic states

Study of baryon-baryon interaction
→ understanding of the strong interaction

NN	extensive data base detailed information
YN	poor data base caculations rely on flavour SU(3) symmetry
ΞN	studies limited to H-dibaryon search (H : [uu dd ss])

first proposed by Jaffe (PRL 38, 195, 1977)
m(H) ~ 80 MeV/c2 below ΛΛ threshold

Studies on H-particle search

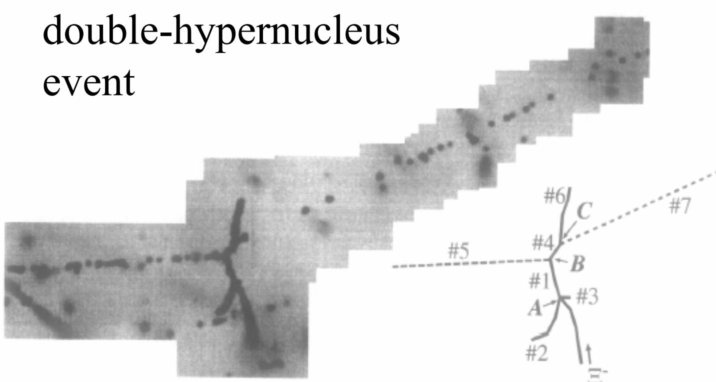
table taken from:
T. Sakai, K. Shimizu, K. Yazaki
Prog.Theo.Phys.Suppl. 137 (2000) 121

most effective Ξ production
via (K^- K^+) double strangeness exchange

$\Lambda\Lambda$-hypernuclei production

KEK E373: 1.66 GeV/c K^- → emulsion

double-hypernucleus
event



AGS E885: 2 GeV K^- : $K^- p \rightarrow \Xi^- K^+$
Ξ^- $^{12}C \rightarrow {}^{12}_{\Lambda\Lambda}B$ n
scintillating fibre array

Collaboration	reaction process (production/decay)	sensitive mass range
BNL E703 [77]	$p+p \to K^+ + K^+ + X$	$M_H = 2.0 \sim 2.5$ GeV
BNL E810 [86, 87, 104]	Si + Pb collision / $H \to \Sigma^- p, \Lambda p \pi^-$	
BNL E813 [88-92, 103, 104, 106]	$K^- + p \to K^+ + \Xi^-$, $(\Xi^- d)_{atom} \to H + n$	$-15 < B_H < 80$ MeV
BNL E830 [105]	$K^- + {}^3He \to K^+ + H + n$	
BNL E836 [90-93, 103, 104, 106]	$K^- + {}^3He \to K^+ + H + n$ $K^- + {}^6Li \to K^+ + H + X$	$B_H = 50 \sim 380$ MeV
BNL E864 [104, 105]	Au + Pb collision	
BNL E885 [92, 94, 95, 104]	$K^- + (p) \to K^+ + \Xi^-$, $(\Xi^- A)_{atom} \to H + X$ $K^- + A \to K^+ + X + H$	
BNL E886 [96, 104]	Au + Pt collision	
BNL E888 [97-99, 104, 106]	$p + A \to H + X$ / $H \to \Lambda n$ or $\Sigma^0 n$, $H + A \to \Lambda + \Lambda + A$	$M_H < 2150$ MeV
BNL E896 [100, 104, 105]	Au + Au collision / $H \to \Sigma^- p \to n \pi^- p$, $H \to \Lambda p \pi^- \to p \pi^- p \pi^-$, $H \to \Lambda n \to p \pi^- n$	
BNL E910 [101]	$p + A$ / $H \to \Lambda p \pi^-$, $H \to \Sigma^- p$	
BNL STAR [125, 102]	Au + Au collision	
KEK E176 [107-109, 115]	$K^- + (pp) \to K^+ + H$ $K^- + p \to K^+ + \Xi^-$, $\Xi^- + (p) \to H$	
KEK E224 [110-115]	$K^- + (pp) \to K^+ + H$ $K^- + (p) \to K^+ + \Xi^-$, $\Xi^- + (p) \to H$	
KEK E248 [116]	$p+p \to K^+ + K^+ + X$	
Fermilab E791 [119]	$H \to p + \pi^- + \Lambda$, $\Lambda \to p + \pi^-$, $H \to \Lambda + \Lambda \to p + \pi^- + p + \pi^-$	
Fermilab KTeV Collab. [120]	$p + A$ / $H \to p + \pi^- + \Lambda$	$M_H = 2194 \sim 2231$ MeV
Shahbazian et al. [79-83]	$p + {}^{12}C \to H(H^+) + X$ / $H \to \Sigma^- + p$, $\Sigma^- \to \pi^- n$ $H^+ \to p + \pi^0 + \Lambda$, $\Lambda \to p + \pi^-$ $H^+ \to p + \Lambda$, $\Lambda \to p + \pi^-$	
Alekseev et al. [84]	$n + A \to H + X$ / $H \to p \pi^- \Lambda$, $\Lambda \to p \pi^-$	
DIANA Collab. [117, 118]	$\bar{p} + Xe \to K^+ H X$, $K^+ K^+ H X$ / $H \to \Sigma^- + p$	
Condo et al. [78]	$\bar{p} + A \to H + X$ / $H \to \Sigma^- + p$	
Ejiri et al. [85]	$d \to H + \beta + \nu$, ${}^{10}Be \to {}^8Be + H$, ${}^{72}Ge \to {}^{70}Ge + H + \gamma$, ${}^{127}I \to {}^{125}I + H + \gamma$, ${}^{127}I \to {}^{125}Te + H + \beta^+ + \nu$	$M_H < 1875.1$ MeV
CERN NA49 [121]	Pb + Pb collision / $H \to \Sigma^- p, \Lambda p \pi$	
CERN WA89 [122]	$\Sigma^- + A \to X + H$ / $H \to \Lambda\Lambda, N\Xi$, $H \to \Lambda p \pi^-, \Sigma^- p, \Sigma^0 n, \Lambda n$	
CERN WA97 [123]	Pb + Pb collision	
CERN ALICE [125]	Pb + Pb collision	
CERN OPAL [124]	Z^0 decay	

Ξ – Production data:

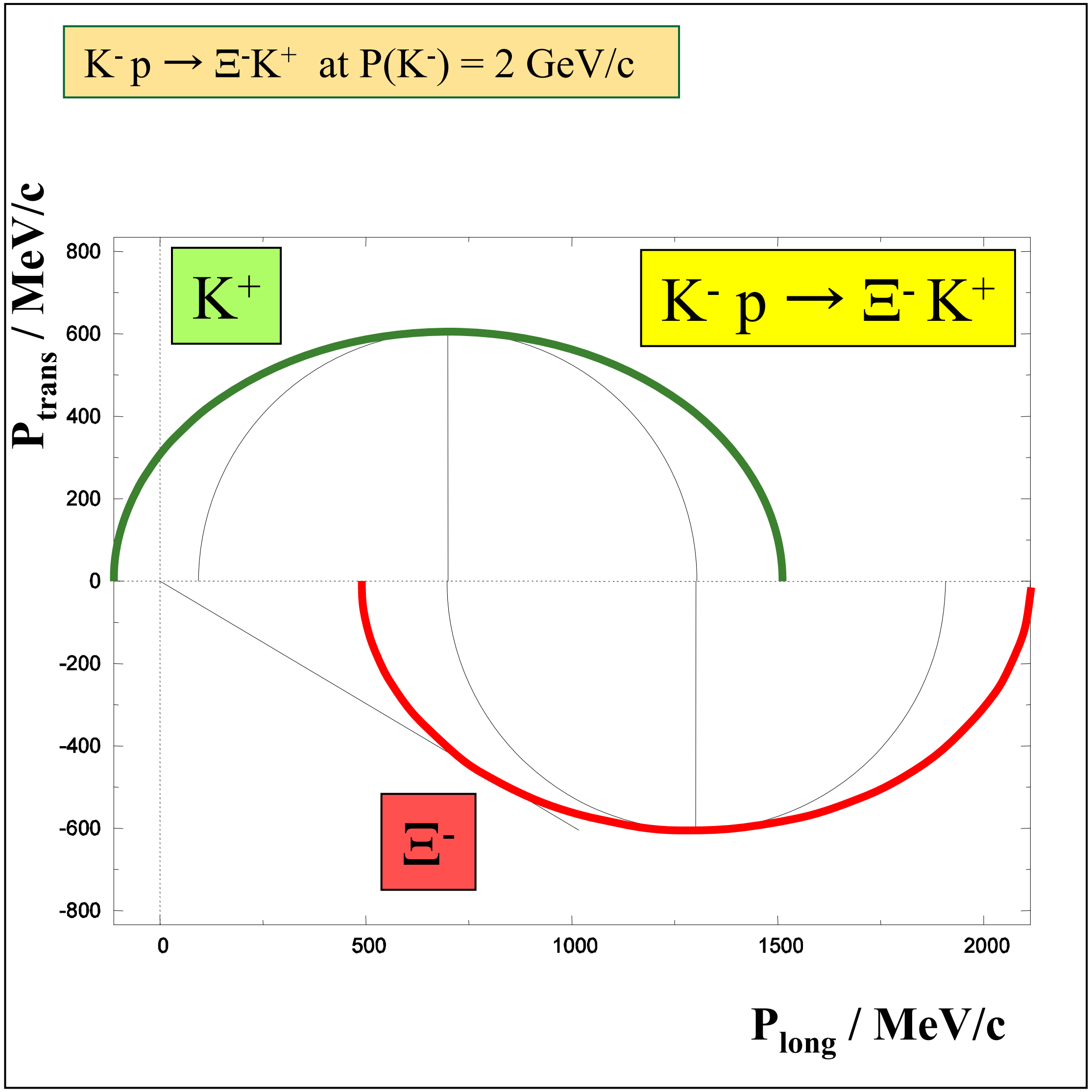
$K^- p \rightarrow \Xi K (\pi)$ properties of Ξ^0 and Ξ^-

Heavy ion collisions $\rightarrow$ multistrange yields
(AGS, SPS, RHIC) (QGP)

$\Sigma\ A \rightarrow \Xi(*)\ X$ spectrum of Ξ
WA89, CERN excited states

$\gamma p \rightarrow K^+K^+\ \Xi^{-(0)}\ (\pi^-)$
CLAS , JLAB

K^-K^+ double strangeness exchange using a K^- beam



→ Ξ^- 'beam' $\tau(\Xi^-) = 1.6\ 10^{-10}$ s
$P_{lab}(\Xi^-) > 500$ MeV/c

stopped Ξ^- ($P_{lab}(\Xi^-) = 0$)
interact with targetnuclei

⇓

produce stopped Ξ^-
with $P_{lab}(\Xi^-) = 0$

→ not possible !

double strangeness exchange using $\bar{p}\,p$ annihilation

$(\, s, \bar{s}\,)$

$\uparrow$

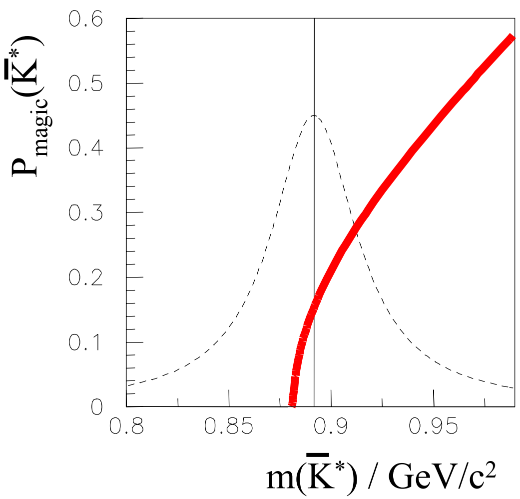
	annihilation channel	branching ratio	kaon momentum
$K^- = \bar{u}\, s$	$\bar{p}\, p \rightarrow K^+ K^-$	$1 \cdot 10^{-3}$	$P(K^-) = 780$ MeV/c
$\bar{K}^0 = \bar{d}\, s$	$\bar{p}\, p \rightarrow K^0 \bar{K}^0$	$3 \cdot 10^{-3}$	$P(\bar{K}^0) = 780$ MeV/c
$K^{*-} = \bar{u}\, s$	$\bar{p}\, p \rightarrow K^{*+} K^{*-}$	$1.5 \cdot 10^{-3}$	$P(K^{*-}) = 290$ MeV/c
$\bar{K}^{*0} = \bar{d}\, s$	$\bar{p}\, p \rightarrow K^{*0} \bar{K}^{*0}$	$3 \cdot 10^{-3}$	$P(\bar{K}^{*0}) = 290$ MeV/c
	$\bar{p}\, p \rightarrow K\, \bar{K}^*$	$1 \cdot 10^{-3}$	$P(\bar{K}^*) = 620$ MeV/c

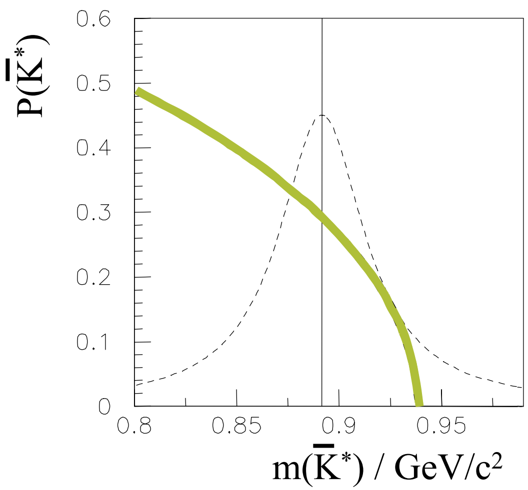
$\bar{K}^*\, N \rightarrow \Xi\, K$

$P(\bar{K}^*) = P_{magic}$

$\downarrow$

$P(\Xi)_{lab} = 0$





Reaction channels for Ξ production via ($\bar{K}^*$, K)

K^{*-}	p	$\rightarrow$ Ξ^0	K^0	K^{*-}	p	$\rightarrow$ Ξ^-	K^+
($s\bar{u}$)	(uud)	(uss)	($\bar{s}d$)	($s\bar{u}$)	(uud)	(dss)	($\bar{s}u$)
$\bar{K}^{*0}$	p	$\rightarrow$ Ξ^0	K^+	K^{*-}	n	$\rightarrow$ Ξ^-	K^0
($s\bar{d}$)	(uud)	(uss)	($\bar{s}u$)	($s\bar{u}$)	(udd)	(dss)	($\bar{s}d$)
$\bar{K}^{*0}$	n	$\rightarrow$ Ξ^0	K^0	$\bar{K}^{*0}$	n	$\rightarrow$ Ξ^-	K^+
($s\bar{d}$)	(udd)	(uss)	($\bar{s}d$)	($s\bar{d}$)	(udd)	(dss)	($\bar{s}u$)

$\Xi^0 \rightarrow \Lambda\, \pi^0$ (99.5 %)

$c\tau = 8.71$ cm

$\Xi^- \rightarrow \Lambda\, \pi^-$ (99.9 %)

$c\tau = 4.91$ cm

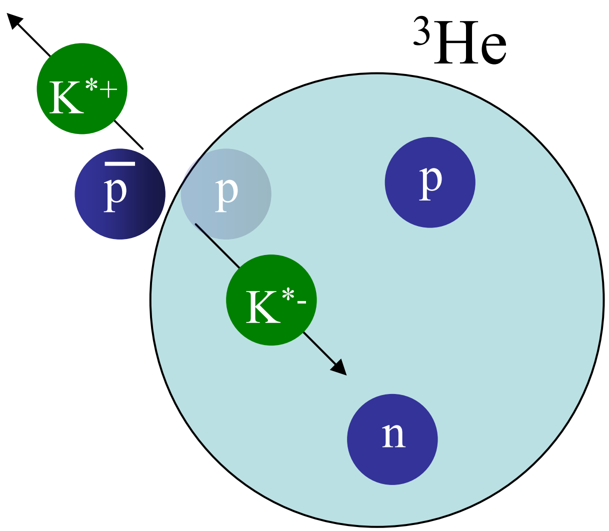
Production of S = -2 baryonic states

via $(\bar{K}^{*}, K)$ using stopped $\bar{p}$ e.g. :

<u>step 1 :</u>

$\bar{p}$ (p n p) $\rightarrow K^{*-} K^{*+}$

large $\bar{p}$ stop rate on a ^{3}He target

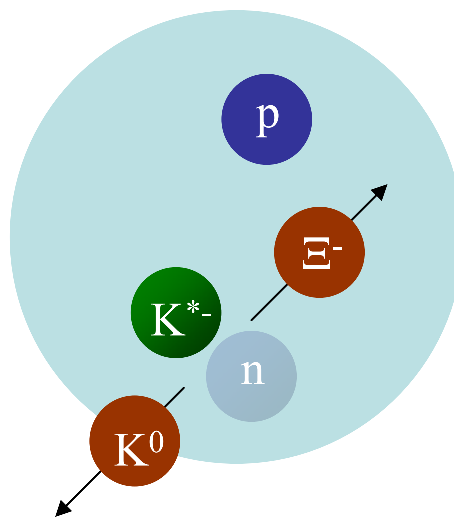


<u>step 2 :</u>

K^{*-} (n p) $\rightarrow \Xi^{-} K^{0}$

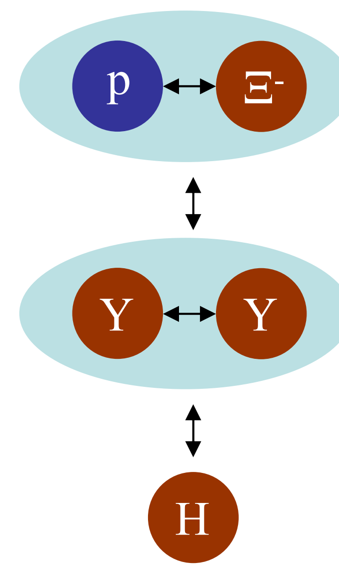
very low recoil on Ξ^{-}

(recoil free kinematics)



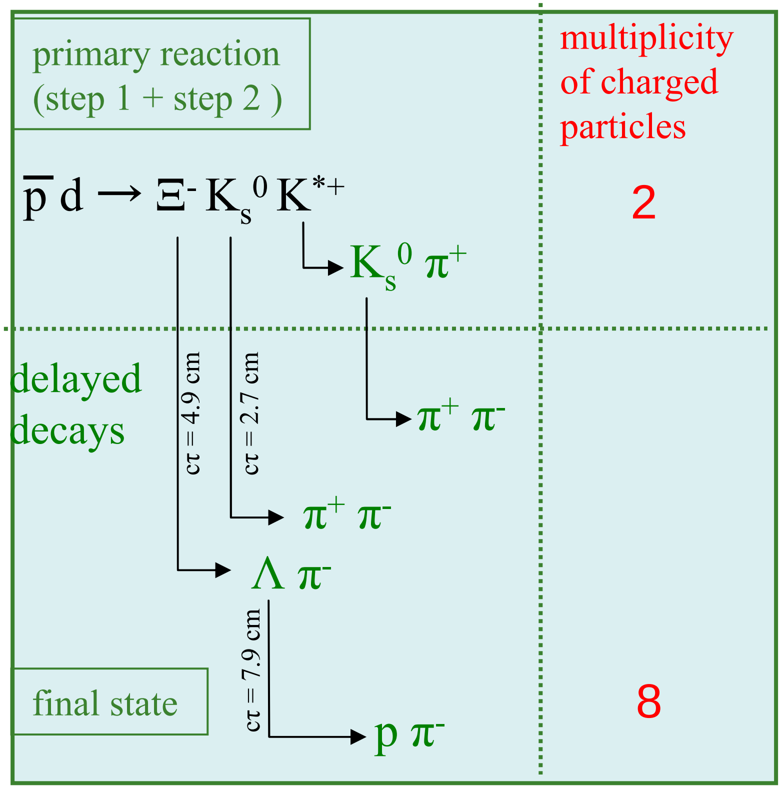
S= - 2 states

low relative energy



Production of S = -2 baryonic states

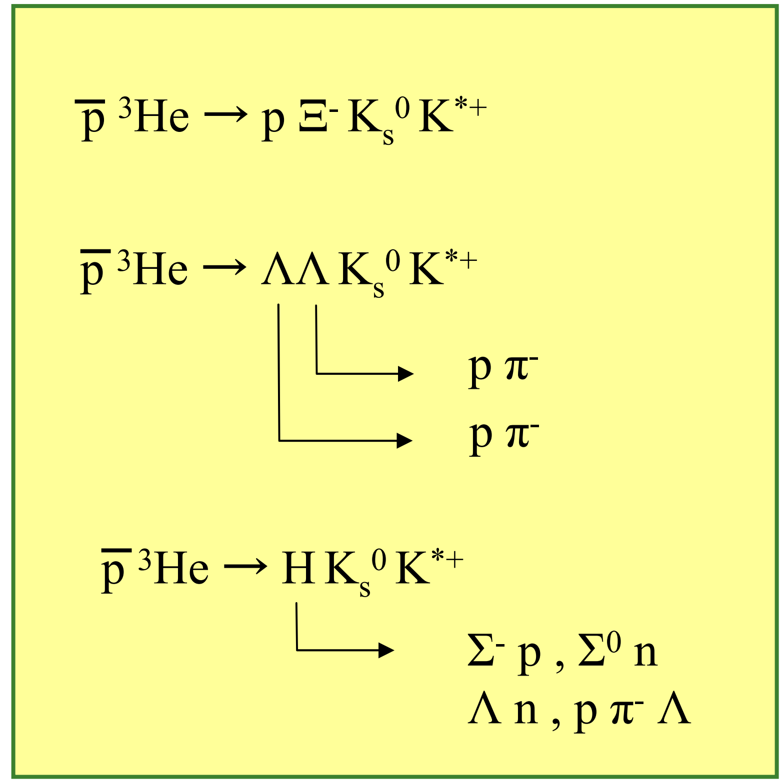
Ξ^- production



→ reaction trigger = multiplicity increase

geometry → event reconstruction

Ξ^- p interaction



Production of S = -2 baryonic states

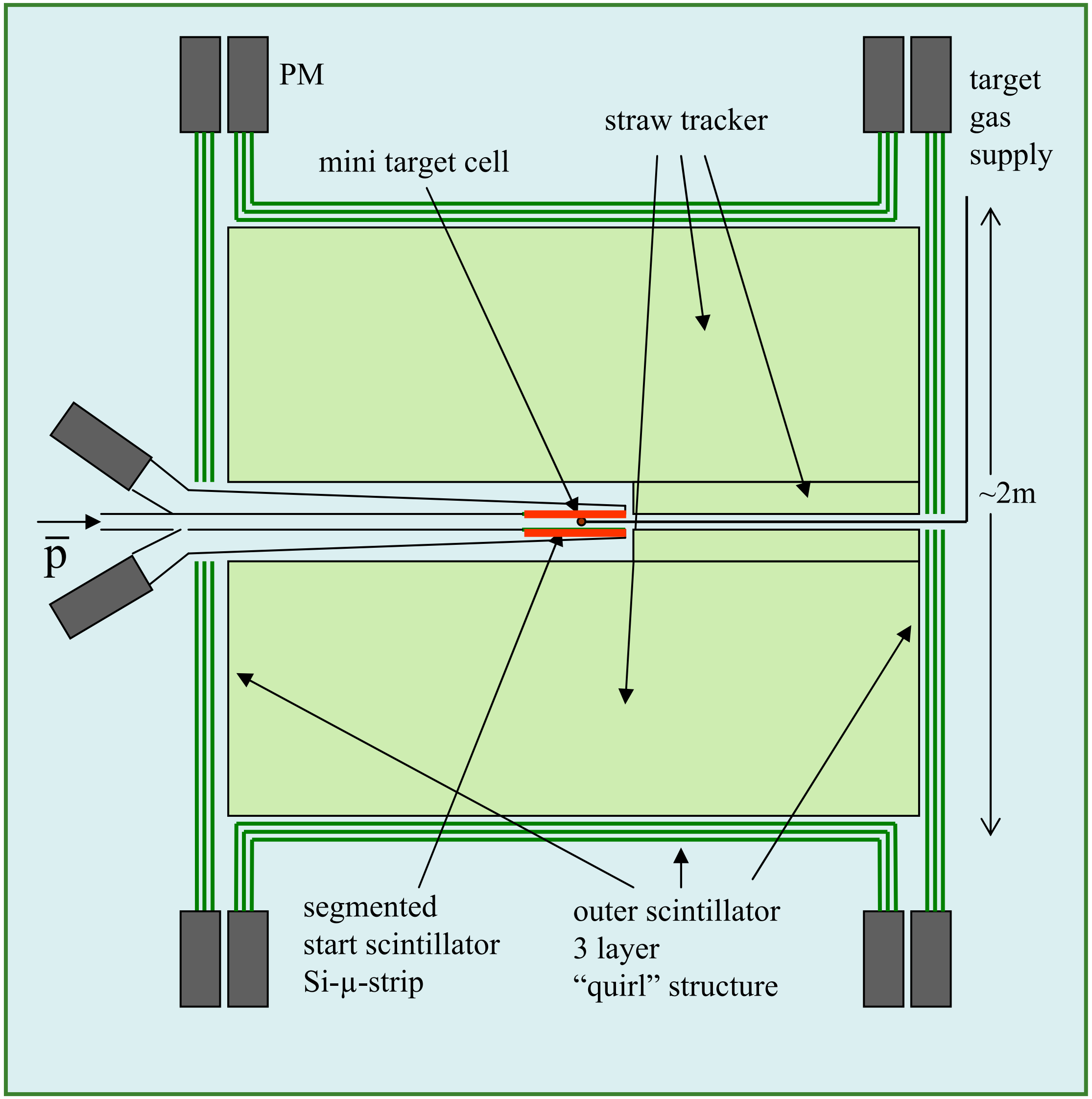
detector

plastic scintillator layer
1. close to the target
2. ~1m distance

→ multiplicity trigger
timing

3-d tracking detector
straw tubes
in different directions

→ tracks of
charged particles
decay vertices

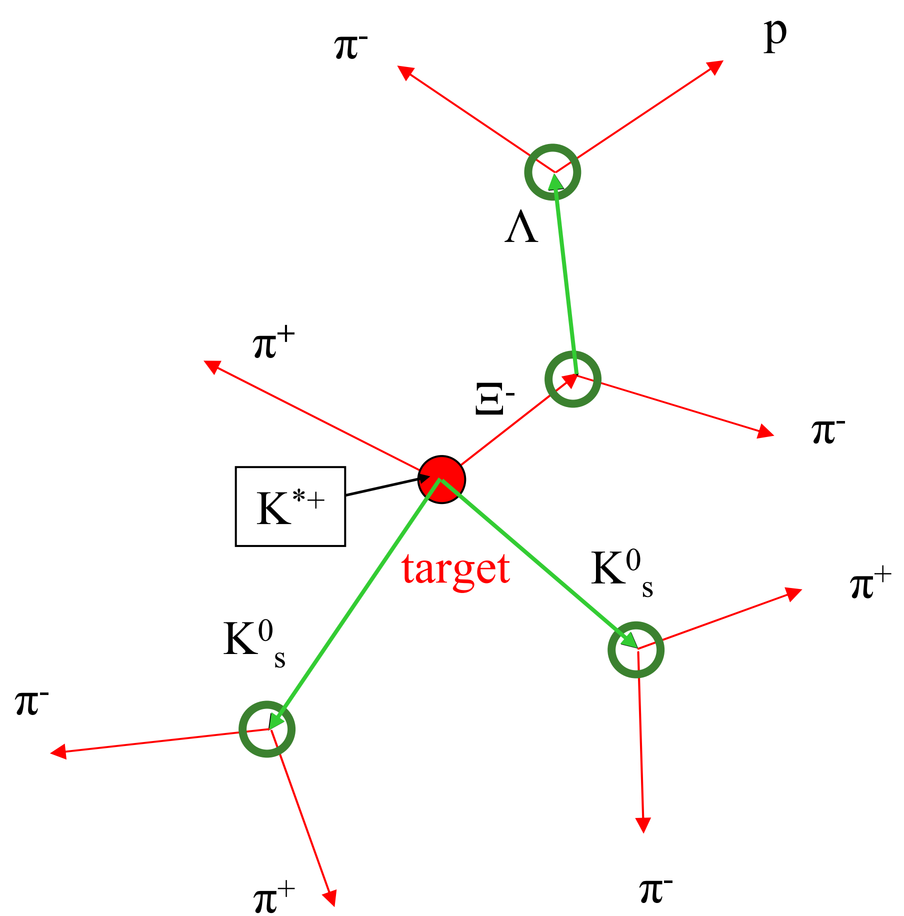


Production of S = -2 baryonic states

Event reconstruction

$\bar{p}\, d \to \Xi^- K_s^0 K^{*+}$

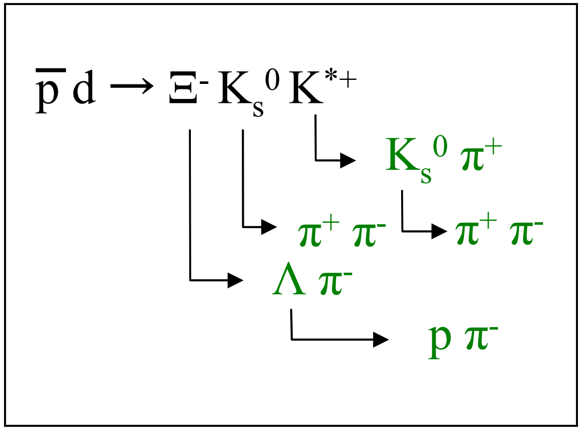
- $K^{*+} \to K_s^0\, \pi^+$
  - $K_s^0 \to \pi^+ \pi^-$
- $K_s^0 \to \pi^+ \pi^-$
- $\Xi^- \to \Lambda\, \pi^-$
  - $\Lambda \to p\, \pi^-$



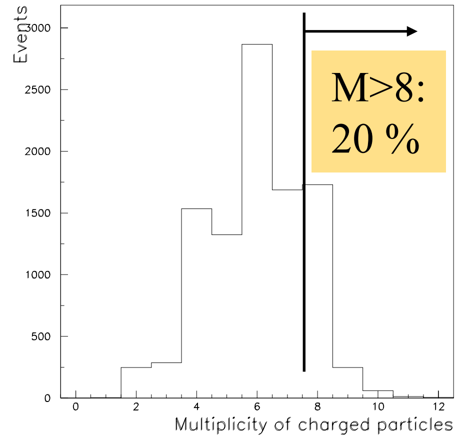
geometry

→ kinematical complete event reconstruction

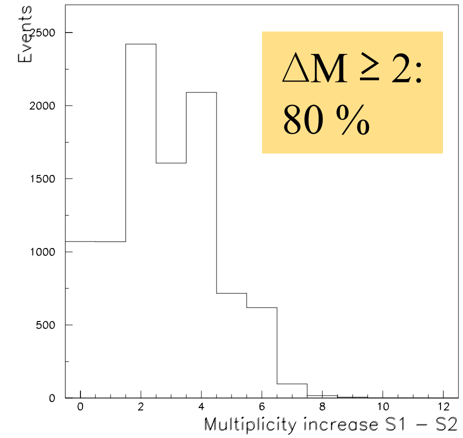
Production of S = -2 baryonic states

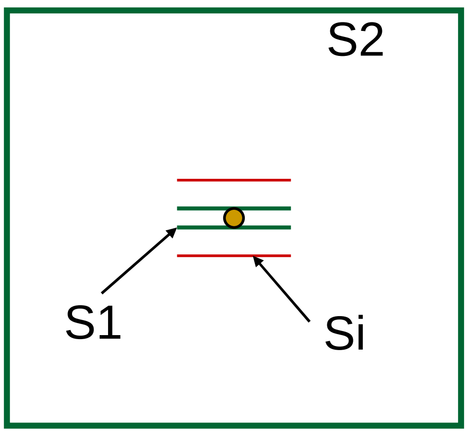


multiplicity of charged particles in S2

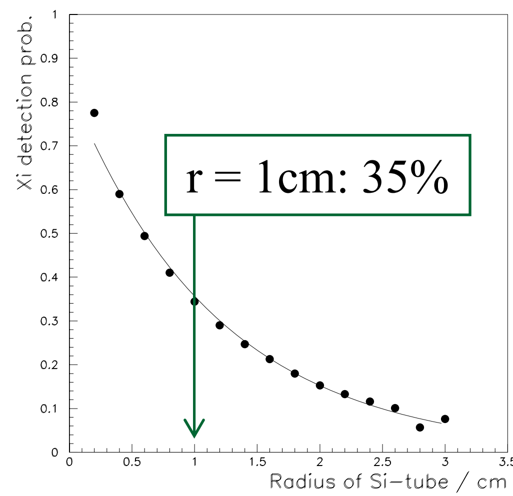


multiplicity increase S1 → S2

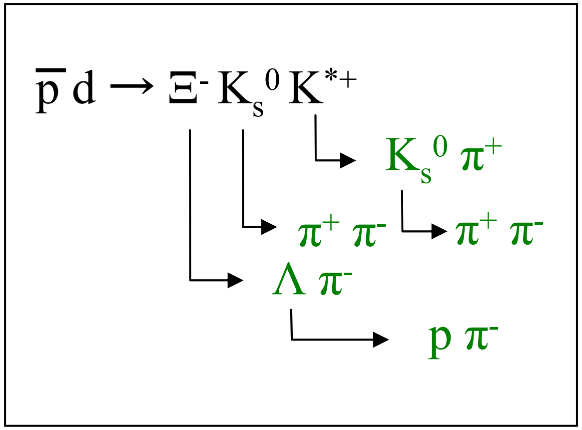


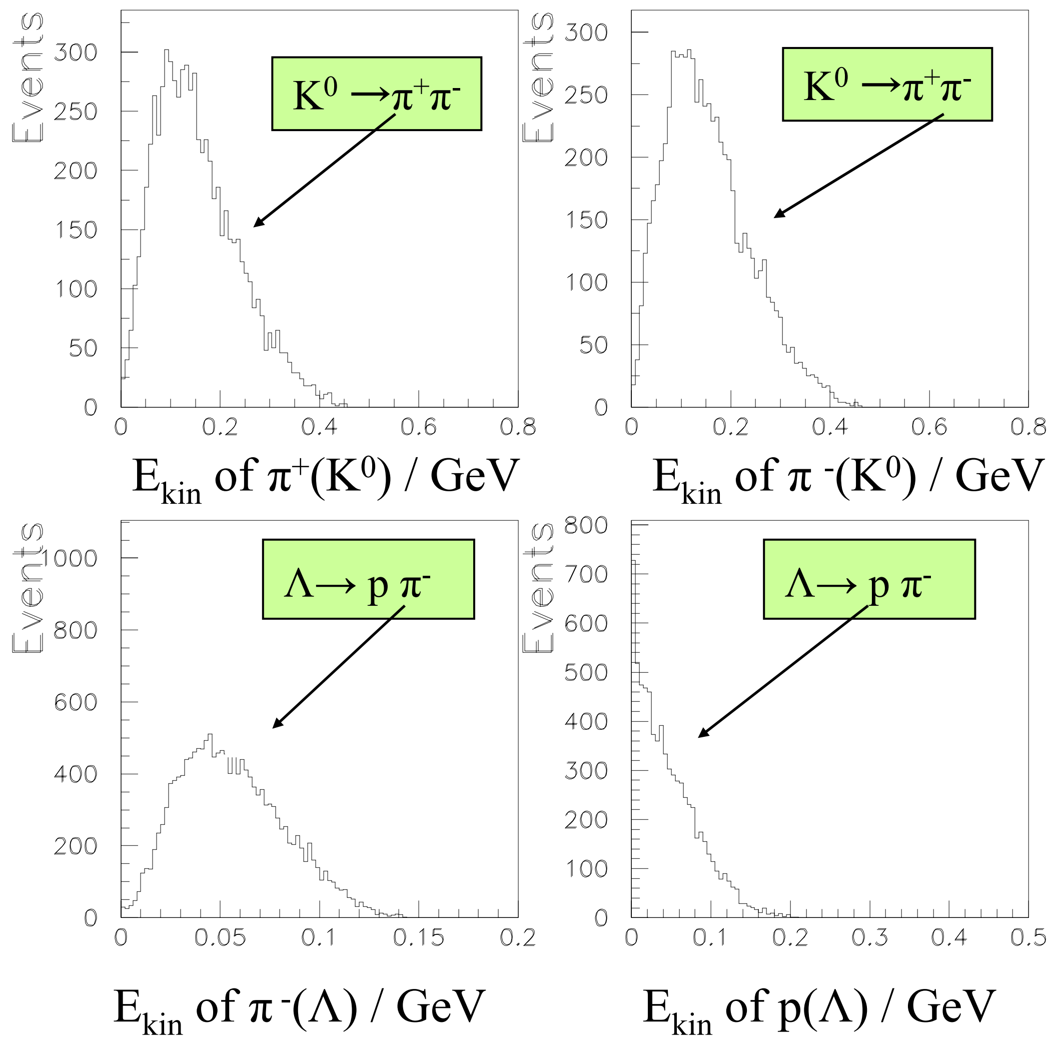


efficiency of Ξ^- to pass Si



Production of S = -2 baryonic states





Production of S = -2 baryonic states

Rate estimates

Beam : $3 \cdot 10^5$ $\bar{p}$/s stopped in ^{3}He target

annihilation BR into $\bar{K}^* K^* \sim 3 \cdot 10^{-3}$

0.3 of $\bar{K}^*$ hit remaining 2N system

0.5 of $\bar{K}^*$ survive until interaction

$\sigma(\bar{K}^* N \to K\,\Xi) / \sigma(\bar{K}^* N \to X) > 10^{-3}$

trigger efficiency ~ 20 %

Ξ detection efficiency ~ 35 %

→ 800 Ξ / day

Summary

Production of S = -2 baryonic states

- *stopped $\bar{p}$ annihilation efficient source for low momentum $\bar{K}^*$*
  - K^* momenta well matched for Ξ production in recoil-free kinematics
  - recoil-free kinematics results in strongly interacting ΞN systems
- *event reconstruction by geometry*
  - “simple“ detector configuration
- *high production rates*
  - detailed studies possible