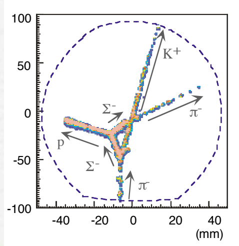
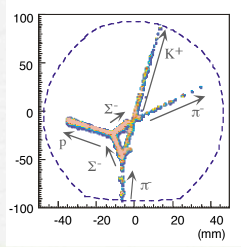
Hyperon-Proton Scattering at the J-PARC



- ☑ Motivation
  - historic background
  - YN scattering experiment at KEK-PS
  - … and at J-PARC
- ☑ Objective
- ☑ Method
- ☑ High-Speed Image Delay Tube
  - What is it ?
  - Characteristics & Performances expected
- ☑ a simulation

IEIRI Masaharu
これから研究会
09.02.21 @ Miyazaki

Historic Background



1930
40
50
60
70
80
90
2000
10

Experiment

('32 neutron)

('47 π+ - meson)

··· pp, np scattering

(YN scattering)

('74 J/ψ)

(Hypernuclei)

E251, E289
E452
···Yp@KEK

E##
···Yp@J-PARC

Idea

established

Support

(get the picture)

Theory

('35 meson theory)

'51 hard-core
OPE @long-range

('64 Quark hypothesis)

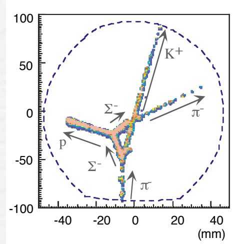
OBE
'77 H-particle
QCM

Inspired by SU(3)f

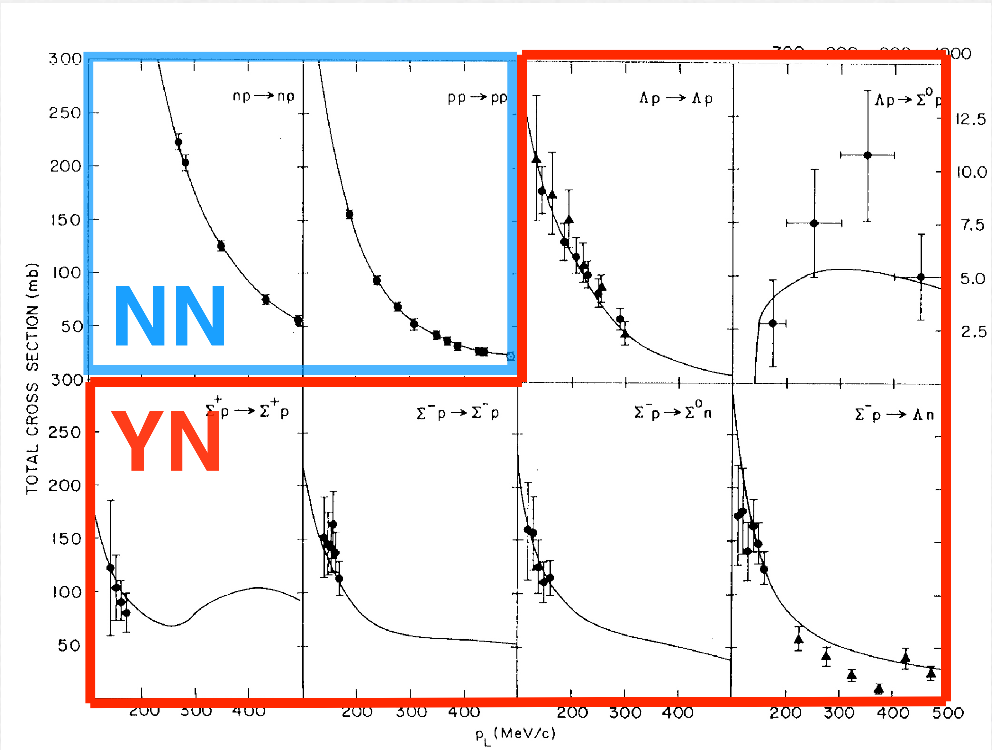
NN&YN by Lattice
... based on SU(2)/SU(3)f

Available Yp scatt. Data [1]

- bubble chamber era '60-'70s -



☑ bubble chamber era '60-'70s

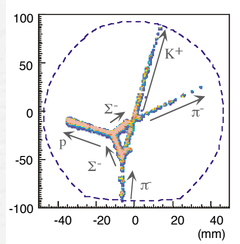


from Dover & Feshbach Ann.Phys.198(90)321

Numbers of data points in angular distributions

	pp	pn	YN
• $d\sigma/d\Omega$	2080	3777	23(+39)
• P	1275	814	a few
• Other obs.	1444	304	0

from Arndt et al. PRD28(83)97

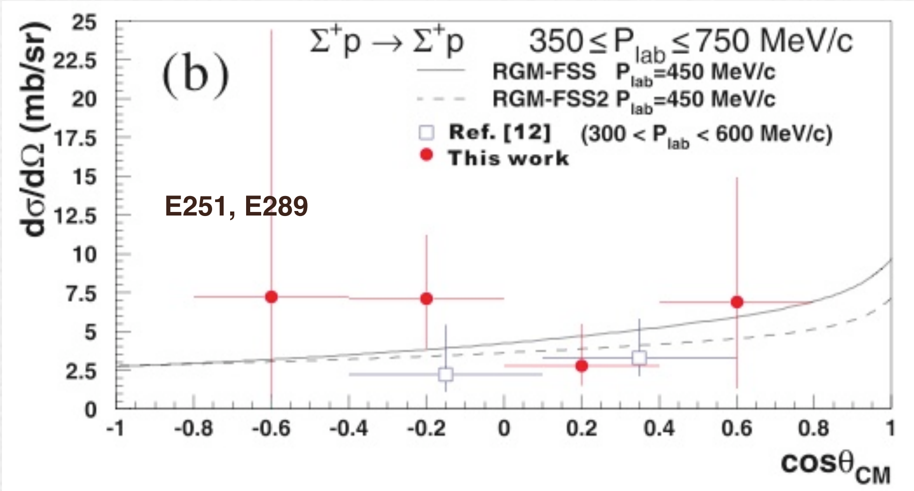


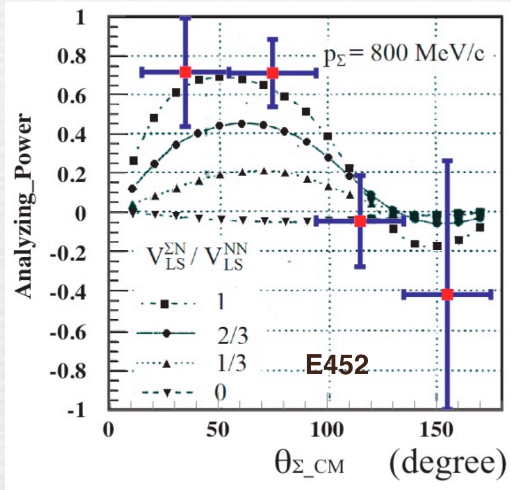
Available Yp scatt. Data [2]

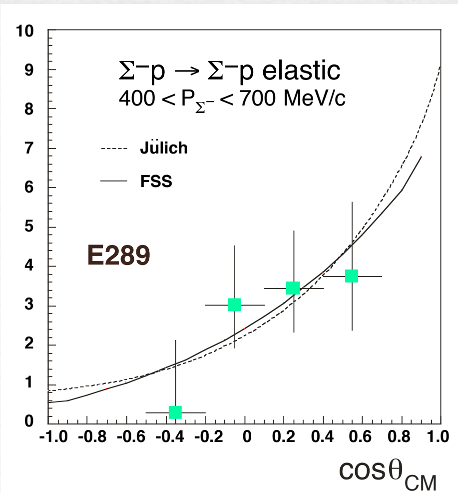
- at 12 GeV KEK-PS -

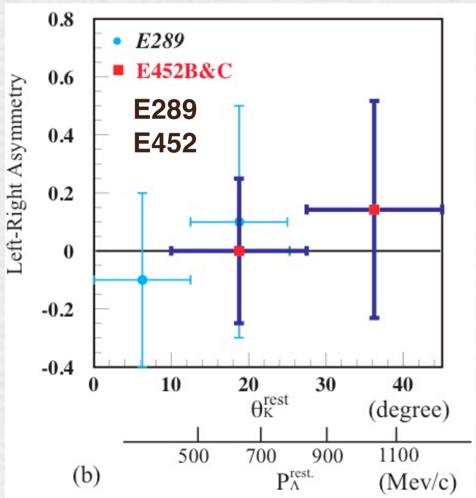
☑ at 12 GeV KEK-PS

- E251, E289 for dσ/dΩ (Σ^+p & Σ^-p)
- E452 for polarization (Σ^+p & Λp)

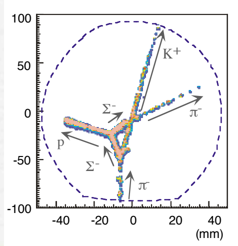


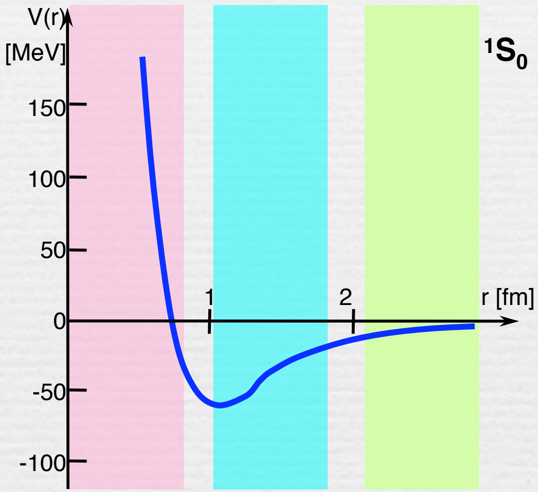


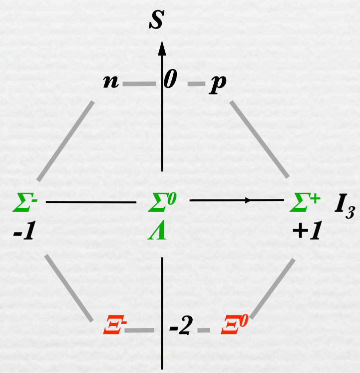




Baryon-Baryon potential







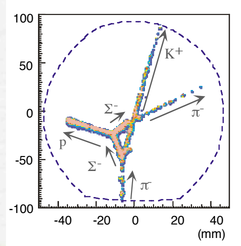
OBE HC, ω ρ,σ, ••• π

- Paris
- Nijmegen
- Bonn-Julich

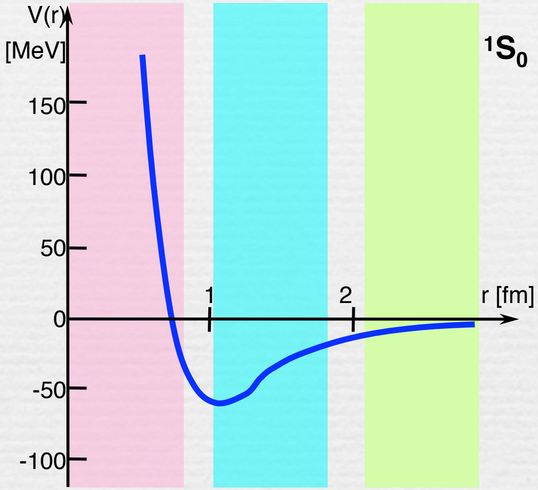
QCM (λ•λ)(σ•σ) Pauli Eff.Meson Exch. pot.

- Tokyo
- Kyoto
- Tubingen

••• Flavor SU(3)



Baryon-Baryon potential



OBE HC, ω ρ,σ, ••• π

• Paris
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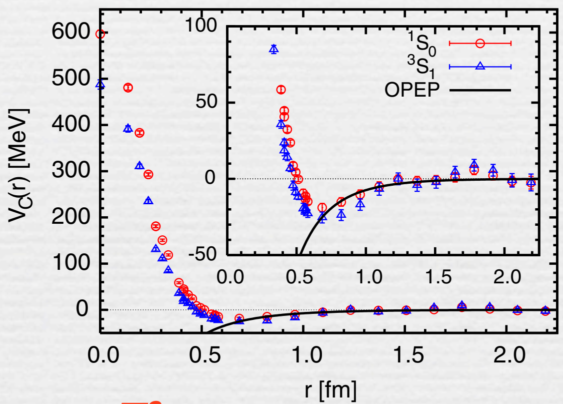
• Tokyo
• Kyoto
• Tubingen

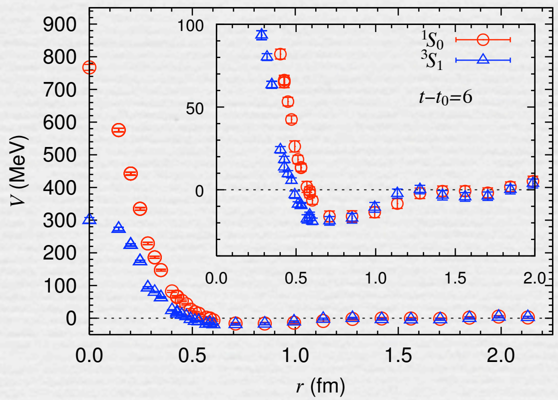
••• Flavor SU(3)

Lattce QCD simulation

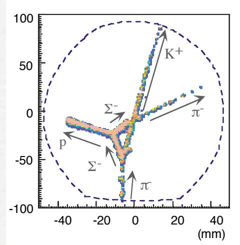
NN



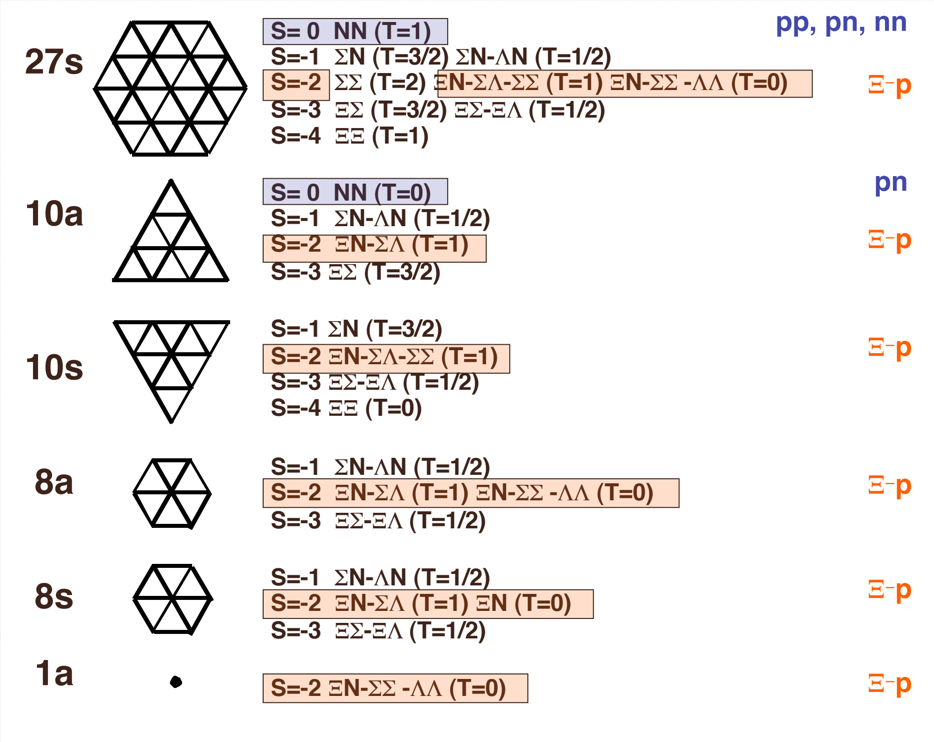
Ξ^0p

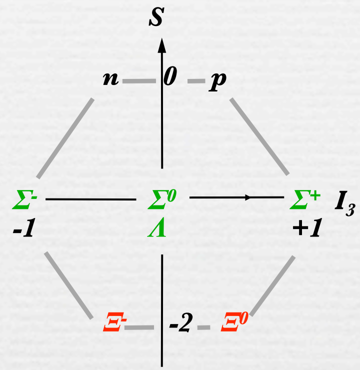


Experimental Objectives at J-PARC



- S= - 2



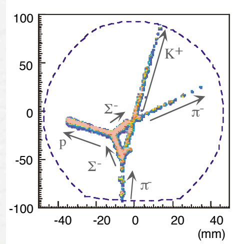


- Anti-symmetric spin-orbit

$$M = a + c\,(\sigma_n^1 + \sigma_n^2) + b\,(\sigma_n^1 - \sigma_n^2) + m\sigma_n^1\sigma_n^2 + g(\sigma_P^1\sigma_P^2 + \sigma_K^1\sigma_K^2) + h(\sigma_P^1\,\sigma_P^2 - \sigma_K^1\,\sigma_K^2)$$

$$I_0P_y = 1/4\,\mathrm{Tr}(MM^\dagger\sigma_n^1) = 2\,\mathrm{Re}[(a+m)c^* + (a-m)b^*]$$

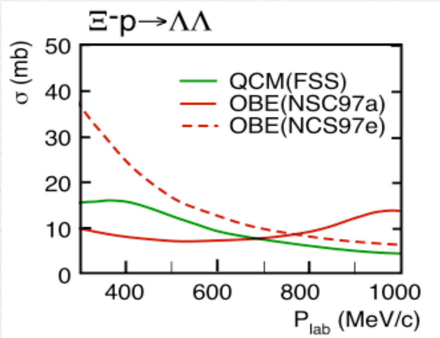
$$(\ I_0A_y^T = 1/4\,\mathrm{Tr}(M\sigma_n^2M^\dagger) = 2\,\mathrm{Re}[(a+m)c^* - (a-m)b^*]\ )$$

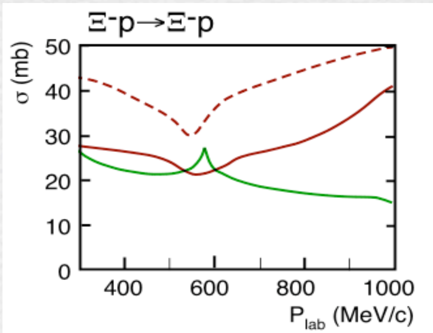


Calculation by Models

S=-2

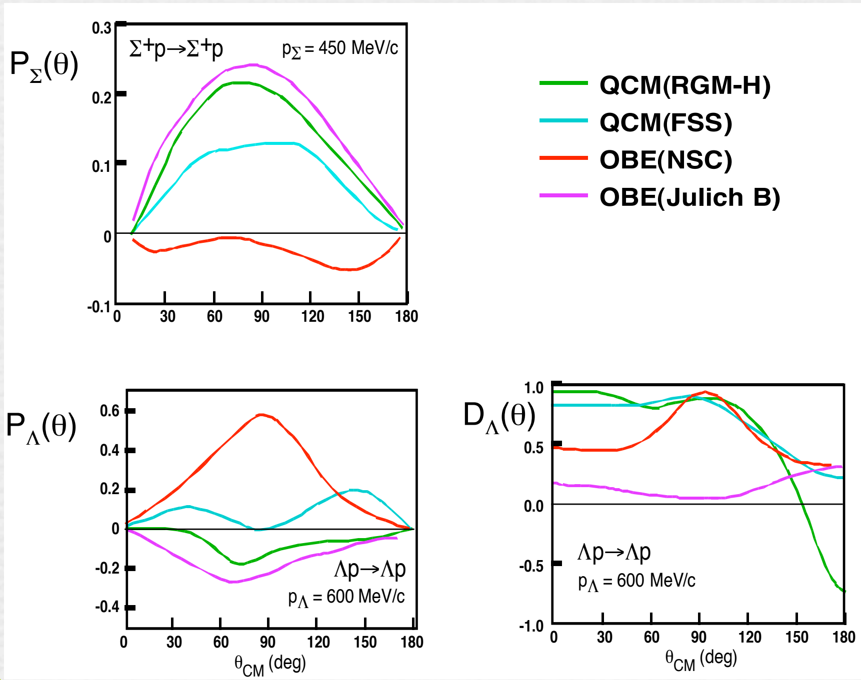
$\Xi^- p \rightarrow \Lambda\Lambda$, $\Xi^- p \rightarrow \Xi^- p$





Polarization observables

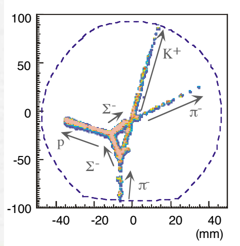
(≈ Anti-symmetric spin-orbit)



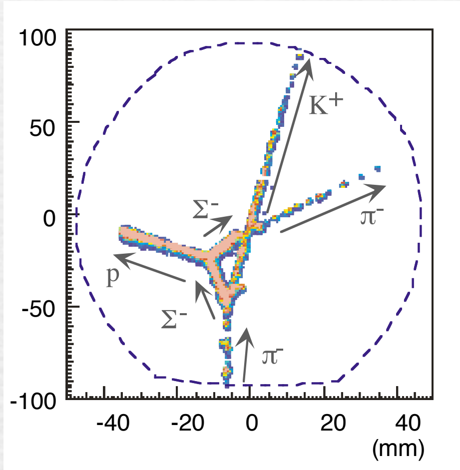
$\Delta(\sigma) \approx 10\%$

Δ(pol)≈a few - 10%

Method



☑ "double" scattering & decay (self-polarimeter)

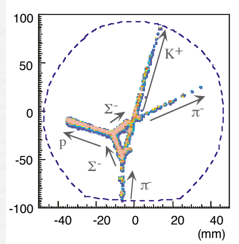


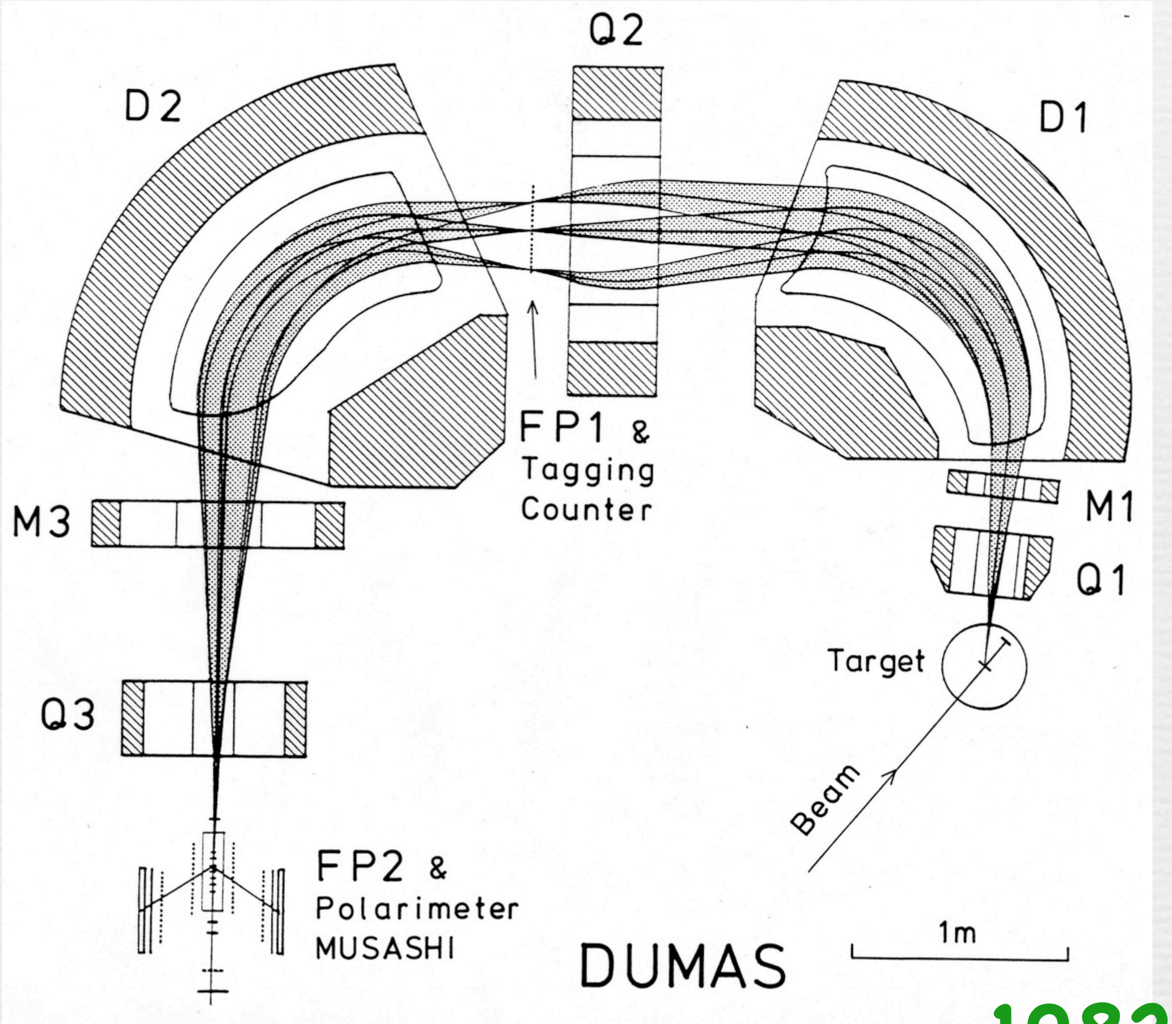
- Production $\pi^+ + p \rightarrow K^+ + \Sigma^+$ (CH)n
- Scattering $\Sigma^+ + p \rightarrow \Sigma^+ + p$ (CH)n
- Decay $\Sigma^+ \rightarrow p + \pi^0$ (51.57 %, α = -0.980)
  $\Sigma^+ \rightarrow n + \pi^+$ (48.30 %, α = 0.068)

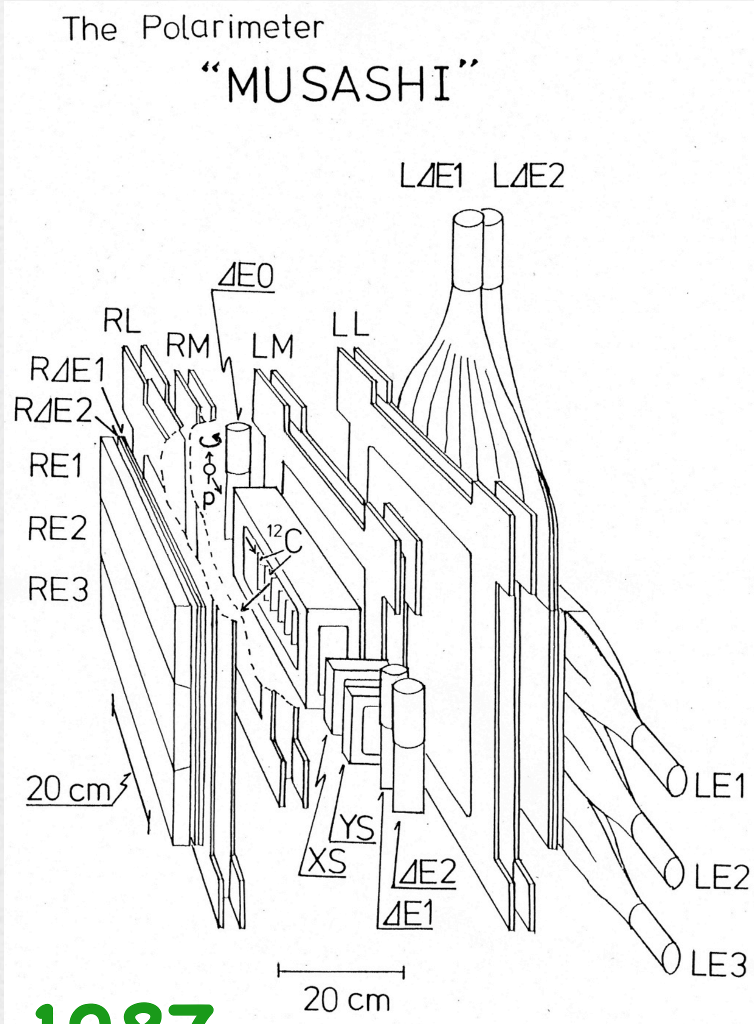
Mean range of related charged particles...

Σ^+(incident)	8 mm
Σ^+(scattered)	5 mm
p (recoil)	18 mm
p (decay)	19 mm
π^+(decay)	44 mm

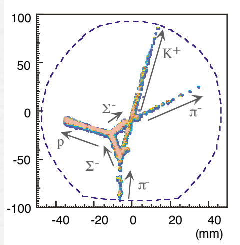
"double" scattering & polarimeter





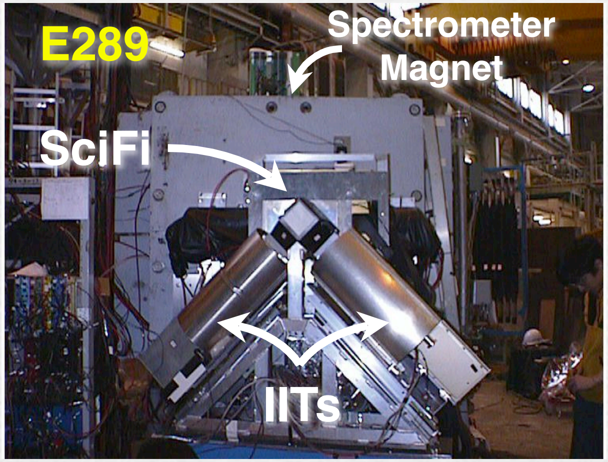


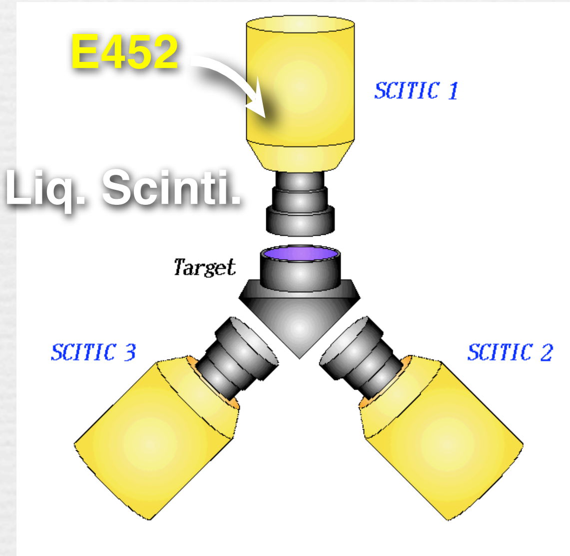
1982-1987

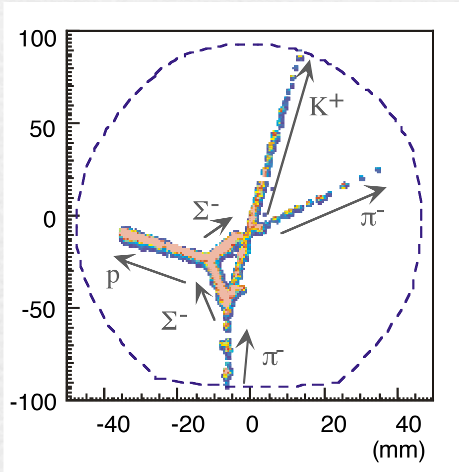


Experiments at KEK-PS

- Heart of experiments (DUMAS & MUSASHI ≈ SciFi & IIT)

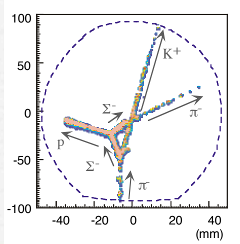






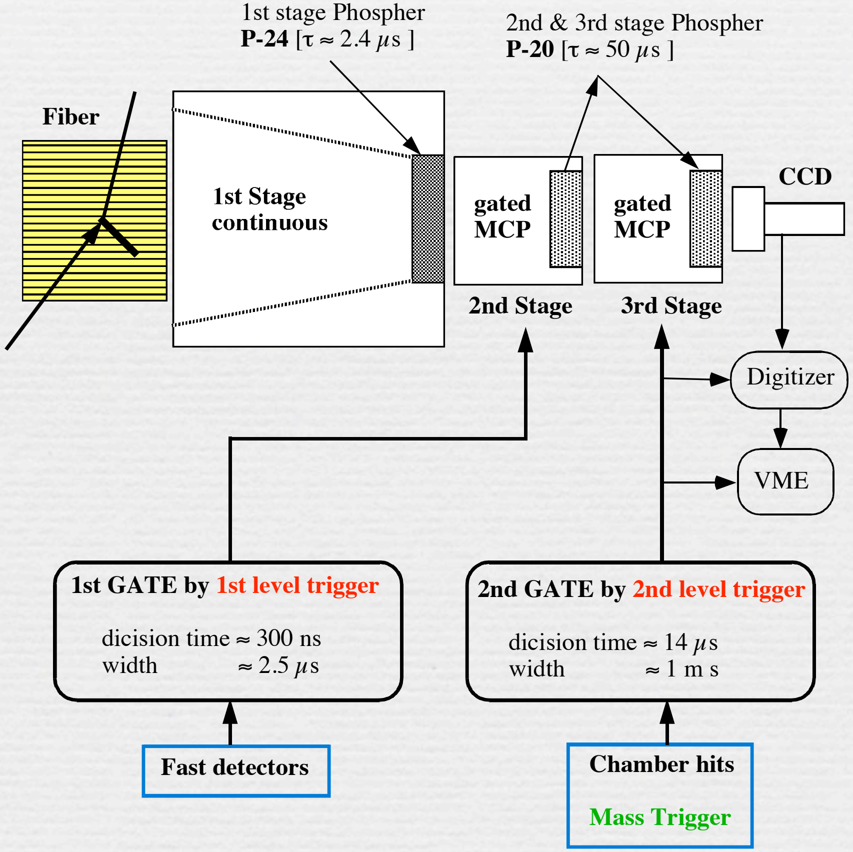
Scintillating Fiber (or Liquid Scintillator) with IIT-CCD Camera triggered by Spectrometer system

Experiments at KEK-PS



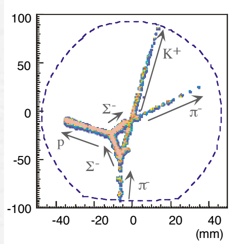
- IIT & Triggers
  - Phosphor Decay Time
    - a few μs
  - Decision Time
    - several hundreds ns
  - CCD image handling
    - several tens ms

Double trigger system for IIT



Beam rate ≤ 10^5Hz

Image rate ≤ 10Hz



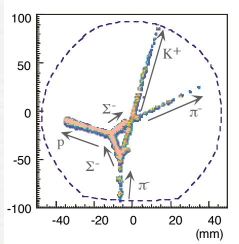
Requests & Works at J-PARC

for $\Xi^{-}p$(S=-2), $\Sigma^{+}p$ and Λp(polarization obs.)
— reasonably doable at J-PARC

- Requests
  - Separated beam line around 1.5 - 1.8 GeV/c
  - K^{-} intensity 10^{7}/sec with K/p > 1
  - Liquid hydrogen facility
- Work
  - Realistic Optimization of Setup
  - Background estimation (physical & instrumental)
  - Fast imaging device
  - Trigger consideration

Improve "rate limit"
10^{5}Hz → $10^{7(8)}$Hz

High-Speed Image Delay Tube
- What is it ? -



Prototypes

- ON THE OPTOELECTRONIC SCHEME OF A SCINTILLATING FIBRE TRACKING DETECTOR FOR FUTURE LARGE HADRON COLLIDER
  J.P.Fabre, T.Gys and M.Primout: CERN/EF/4147H/TG/mnb 8 November 1988

- THE BASIC PRINCIPLE OF A VACUUM IMAGE PIPELINE
  T. Gys : CERN/EF/4304H/TG/mnb 12 January 1989

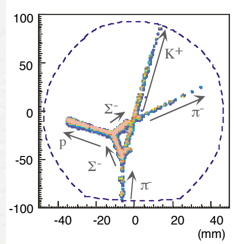
- Conceptual design for an optelectric delay line
  J.P.Fabre, T.Gys, M.Primout and L.Van hamme: Revue Phys. Appl. 24(1989)1019

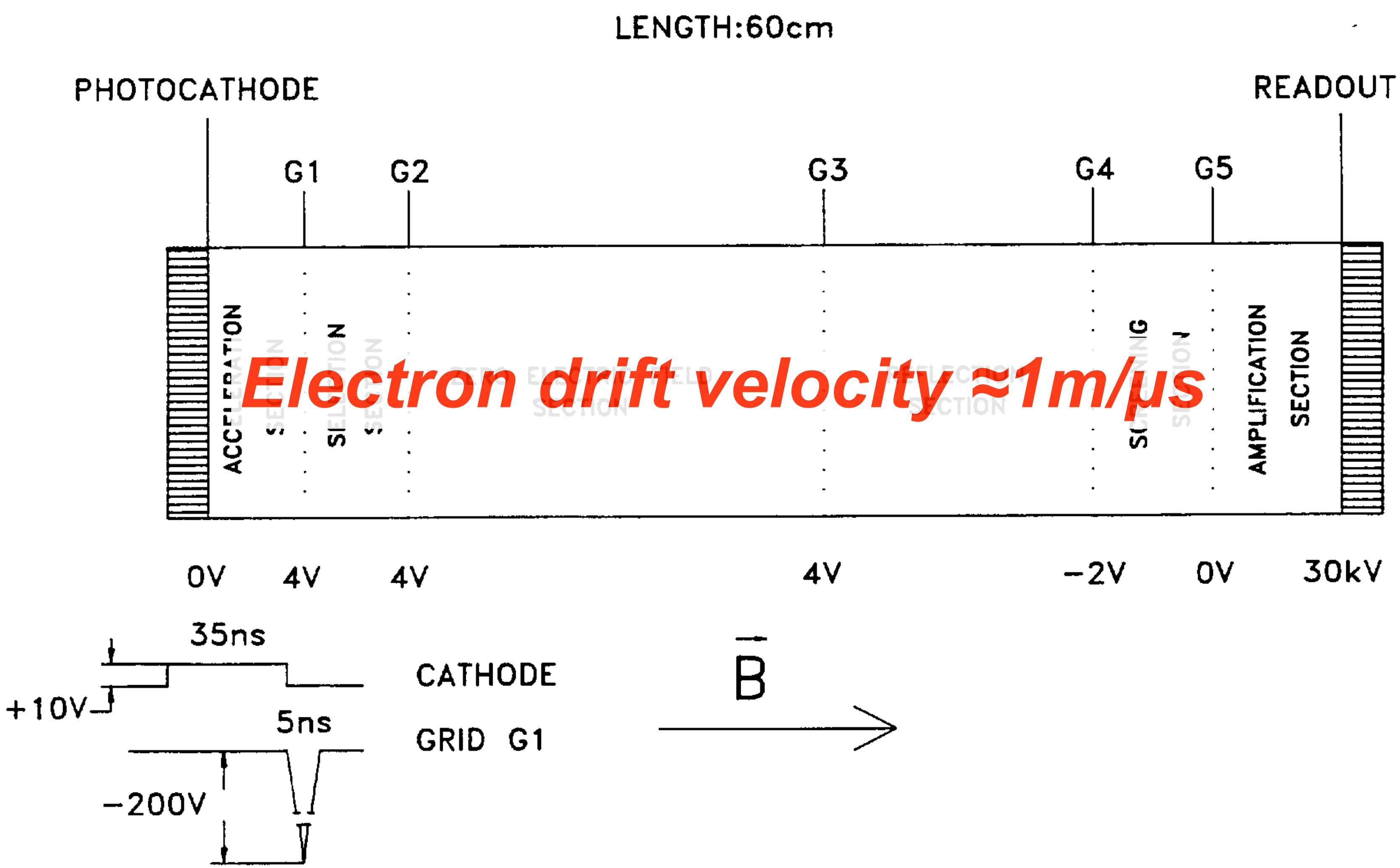
- OPTOELECTRONIC DELAY FOR THE READ-OUT OF PARTICLE TRACKS FROM SCINTILLATING FIBRES
  T. Gys et al. : CERN/EF 89-25, DERN/LAA-SF91-3, CERN/DRDC 92-42

- OPTO-ELECTRIC DELAY TUBES
  T. Gys et al. : DERN/LAA/SF 90-20

- A high-speed gateable image pipeline
  Berkovski et. al. NIM A380(1996)537

High-Speed Image Delay Tube
- What is it ? -

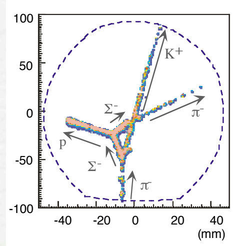




Electron drift velocity ≈1m/μs

KEK - HSIDT

(High-Speed Image Delay Tube)



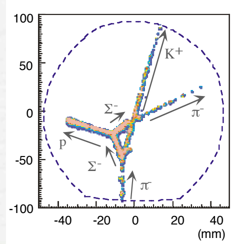
1. Visit Dr. T.Gys at CERN in June … learn things and hints …

2. examine the structure of a tube,
   and decide to assemble as a sectional detector
   … drawing & drawing & …

   - Input photocathode and output phosphor, grids, field-shaping electrodes, ceramic insulation, solenoid magnet, pulse generator, …

3. now assembling and test will be started soon …

KEK - HSIDT
(High-Speed Image Delay Tube)



1. Visit Dr. T.Gys at CERN in June ... learn things and hints ...

2. ex
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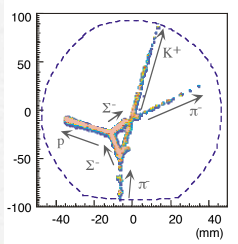
...
ing

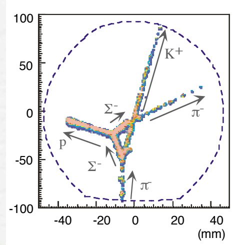
3. no

Yp scattering exp. at J-PARC



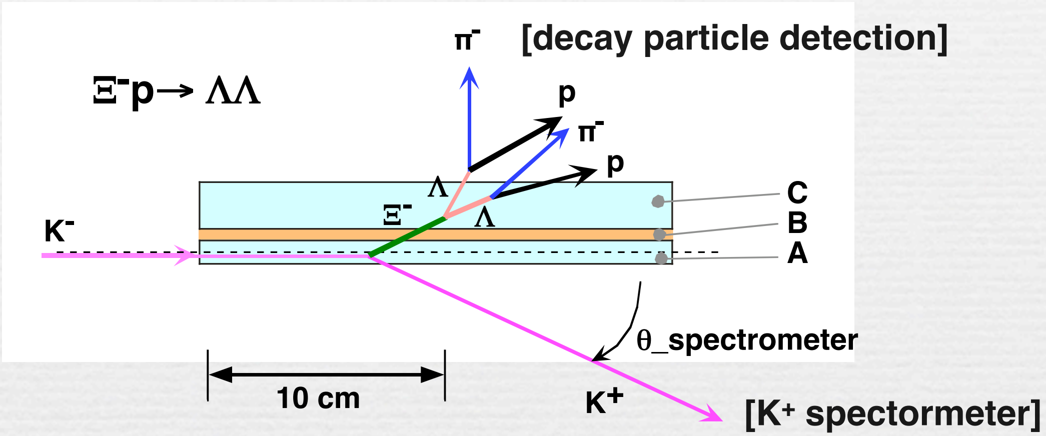
	Channels	T	Observables
p,n	pp → pp	1	dσ/dΩ, Py, D, ..
	pn → pn	1, 0	dσ/dΩ, Py, D, ..
Λ	Λp → Λp	1/2	dσ/dΩ, Py, AyT, D
Σ^+	Σ^+ p → Σ^+ p	3/2	dσ/dΩ, Py, AyT, D
Σ^-	Σ^- p → Σ^- p	3/2, 1/2	dσ/dΩ, Ay
	Σ^- p → Λn	1/2	dσ/dΩ, Py
Ξ^-	Ξ^- p → Ξ^- p	1, 0	dσ/dΩ, Py, AyT (, D)
	Ξ^- p → Λ Λ	0	dσ/dΩ, Py, AyT (, D)

Yp scattering exp. at J-PARC



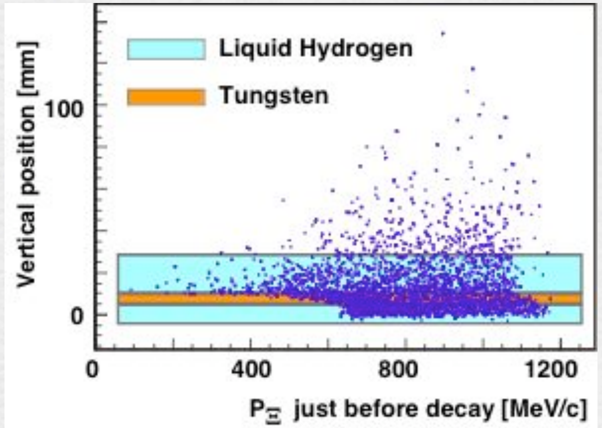
☑ with a CDC tracking detector

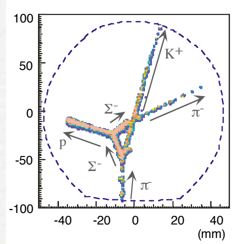
SciFi & HSIDT



- **Target** 5 cm wide × 20 cm long
  - A: production 1 cm Liq. Hydrogen
  - B: degrader 0.5 cm Tungsten
  - C: scattering 2 cm Liq. Hydrogen
- **K^+ spectrometer**
  - θ_spectrometer ~ 25° at center
- **K^- beam (assumption @ LOI)**

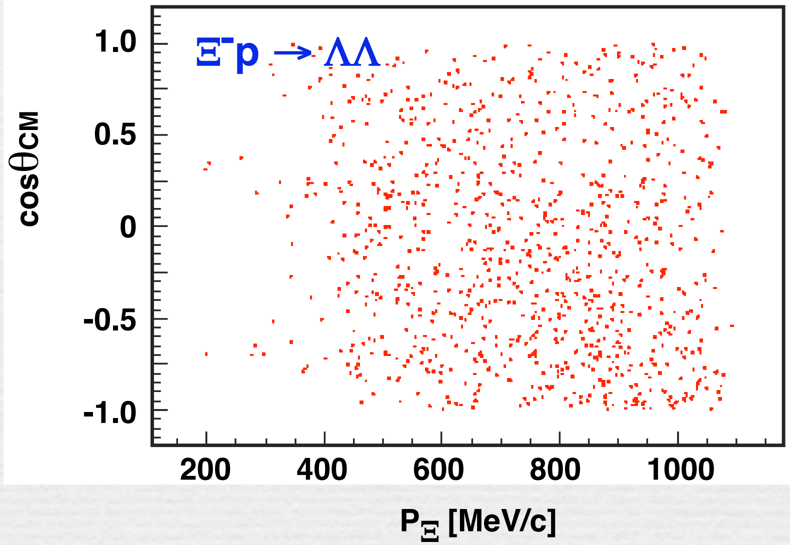
Intensity		10^7 K^-/sec
Momentum		1.7 GeV/c
Size	σ_horizontal	15 mm
	σ_vertical	1 mm





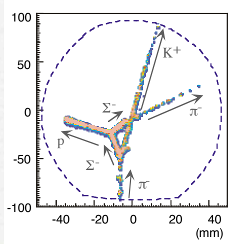
a simulation

• K^- intensity	[s^{-1}]	10^7
• Number of Hydrogen	[/cm2]	8.5×10^{23}
• Spectrometer	[deg]	25
• Spectrometer TOF	[m]	5
• Trigger rate (K^+)	[s^{-1}]	11
• Momentum of Ξ^-	[MeV/c]	300 - 1100



	$\Xi^- p \rightarrow \Xi^- p$	$\Xi^- p \rightarrow \Lambda\Lambda$
• reaction rate [s^{-1}]	0.009	0.0043
• 100 days	78000	37000
• Detectable number	2300	550

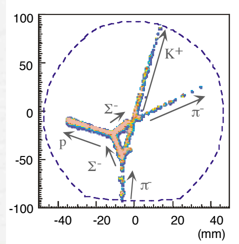
Summary



- ☑ Designing a Yp experiment
  - Realistic Optimization of Setup for selected Yp channel
  - Background estimation (physical & instrumental)
  - Fast imaging device
  - Trigger consideration

- ☑ High-Speed Image Delay Tube (made in Japan) will soon be available
  - Delay capability, Intrinsic time resolution of ≈10ns,
    Data reduction ≈10^{-3}, Space resolution of ≲30μm,
    Good efficiency …
  - Next step : Fast readout device keeping good space resolution with large area

極限状態の物理



弾性散乱
≈極低温反応

Yp弾性散乱
≈これからの極低温反応@strangeness

“二回散乱”と“偏極”