Hyperon–Proton Scattering Experiments at the J-PARC

- **Background**
- **Available data**
  - **bubble chamber**
  - **SCIFI&IIT @ KEK**
- **Experimental Objectives at J-PARC**
- **Experiments**
- **Requests & Works**

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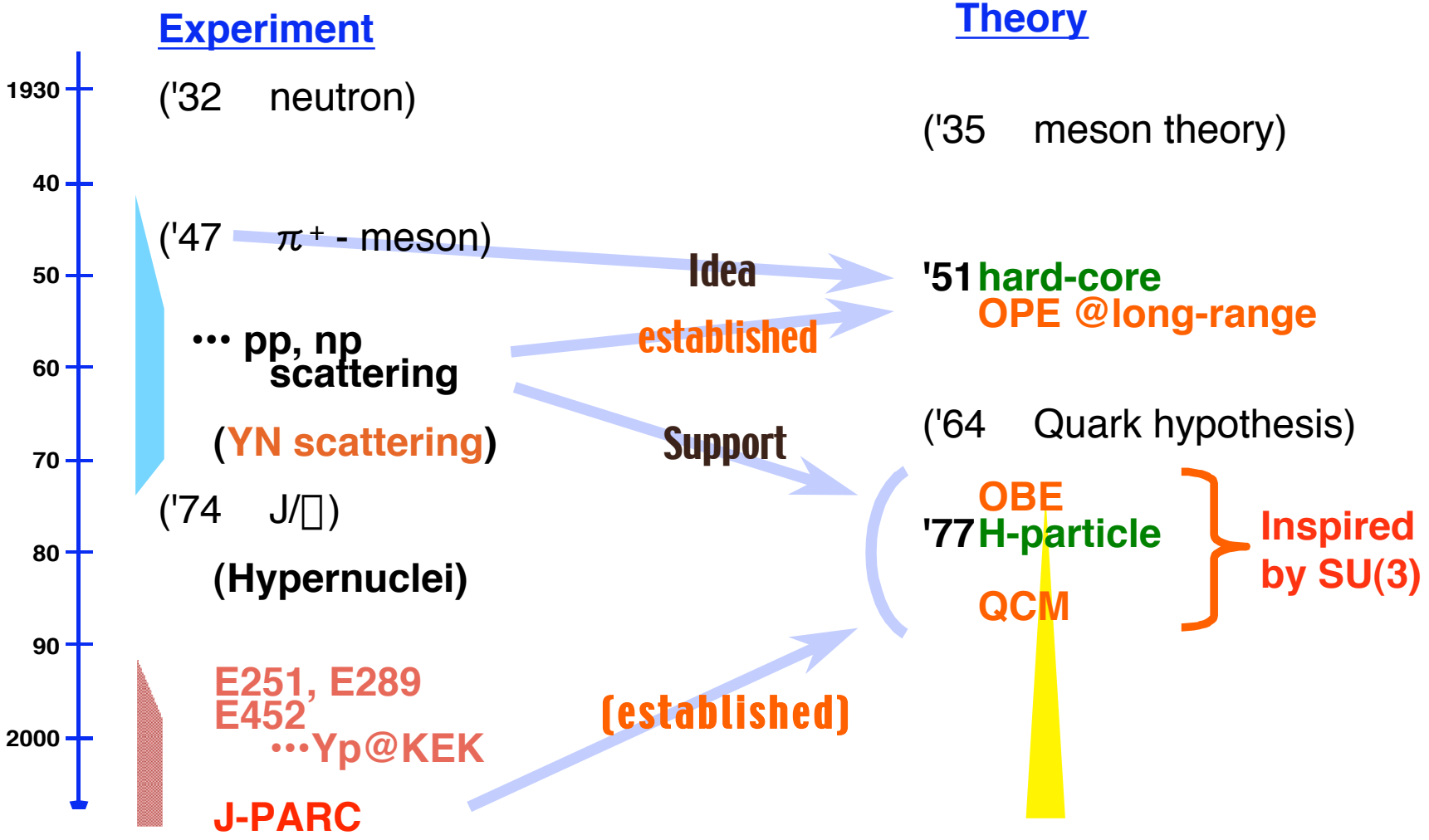
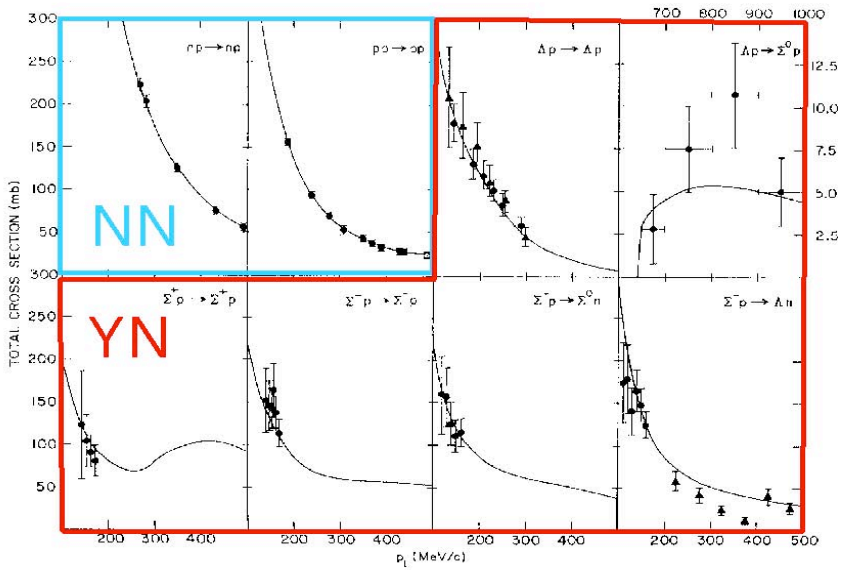
JSPS meeting, September 10, 2003

Milestone


Experiment
Theory
1930
40
50
60
70
80
90
2000
('32 neutron)
('47 π+ - meson)
••• pp, np scattering
(YN scattering)
('74 J/ψ)
(Hypernuclei)
E251, E289
E452
•••Yp@KEK
J-PARC
('35 meson theory)
Idea
established
'51 hard-core
OPE @long-range
Support
('64 Quark hypothesis)
OBE
'77 H-particle
QCM
Inspired by SU(3)
(established)

Available YN scatt. Data [1]

— Yp scatt. at bubble chamber era '60-'70s —



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

Numbers of data points in angular distributions

	pp	pn	YN
• dσ/dΩ	2080	3777	23(+39)
• P	1275	814	a few
• Other obs.	1444	304	0

from Arndt et al. PRD28(83)97

No Data for $\Sigma^{\pm}$p @ p_{Σ} ≤ 1 GeV/c

@ 12 GeV KEK-PS since 1990

E251 Σ^{+}p elastic [11 events]

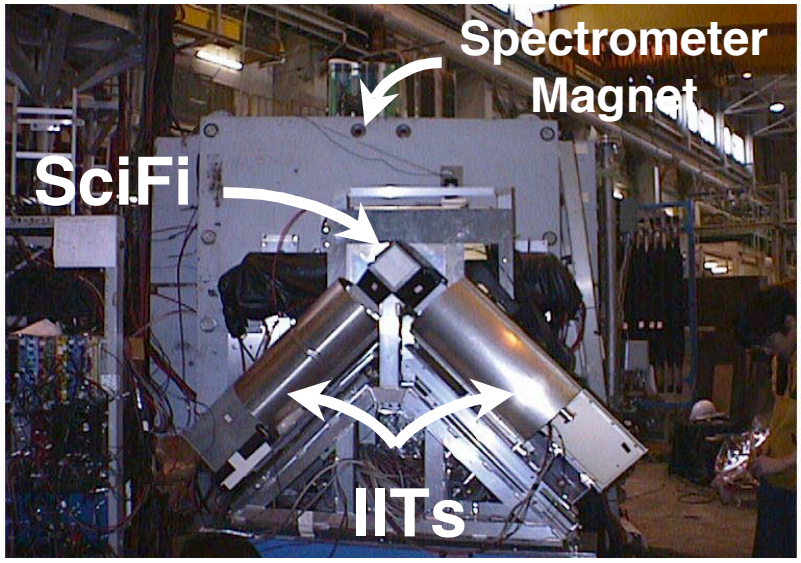
E289 Σ^{-}p elastic [30 events]
Σ^{+}p elastic [in analysis]
Σp elastic [in analysis]

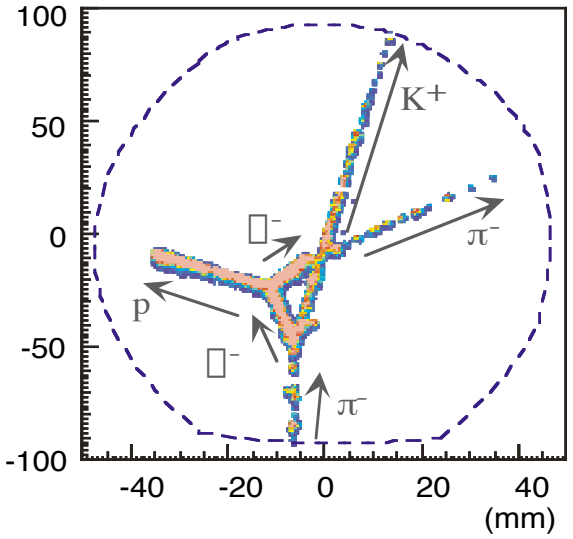
E452 Σ^{+}p & Σp elastic [in analysis]

Available YN scatt. Data [2]

— Yp scatt. at the present 12 GeV KEK-PS : Method —

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



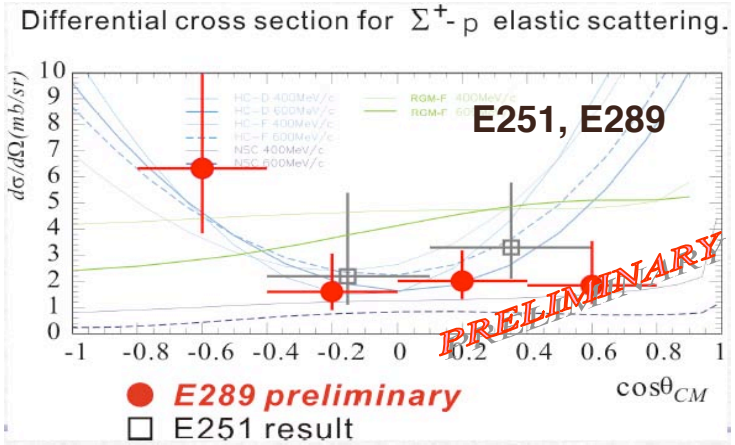


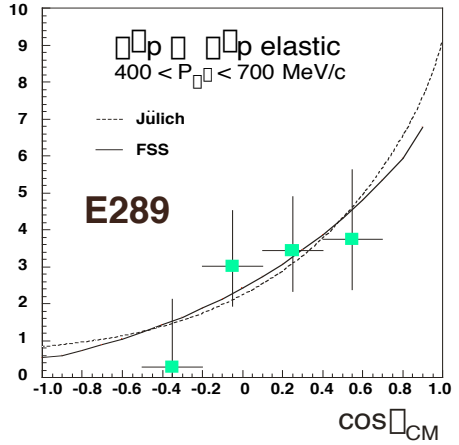
Incident beam rate limit < 10^5 Hz

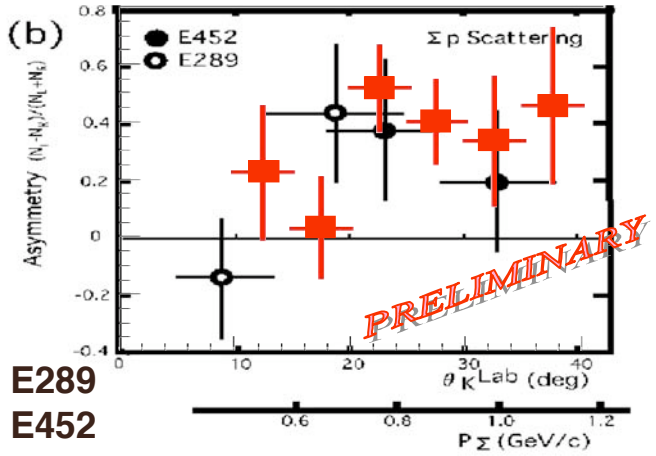
Available YN scatt. Data [3]

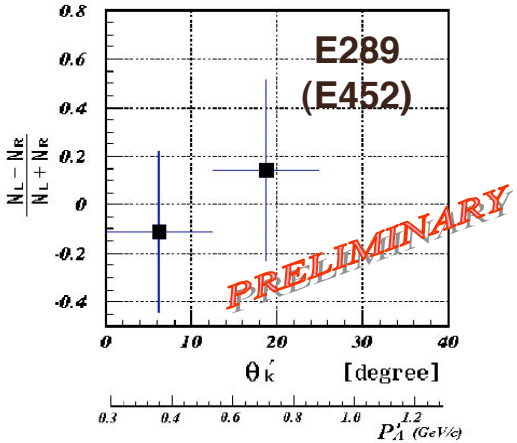
— Yp scatt. at the present 12 GeV KEK-PS : Results —

- E251, E289 for d□/d□ (□⁺p & □⁻p)
- E452 for polarization (□⁺p & □p)







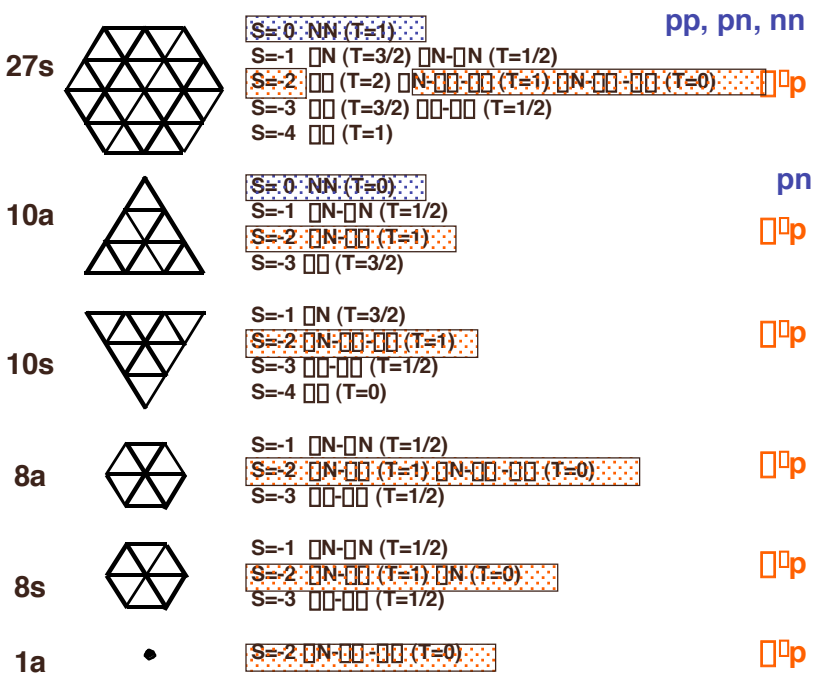


List of Hyperon-proton scatterings

	cτ [cm]	production reaction	(σ[μb] @P[GeV/c])	outgoing particle	Y-p scattering	scattered particle		decay mode	α	decay particles	
Λ	7.89	$\pi^- p \to K^0 \Lambda$	(700 @1.0)	$\pi^+\pi^-$	$\Lambda p \to \Lambda p$	p	Λ	$\to p\pi^-$	0.642	p, π^-	★
		$K^- p \to \pi^0 \Lambda$	(3500@0.9)	2γ				$\to n\pi^0$	0.65	n, 2γ	
					$\to \Sigma^0 p$	p	Σ^0	$\to \Lambda\gamma$		p, π^-, γ	★
										n, 2γ, γ	
Σ^+	2.396	$\pi^+ p \to K^+\Sigma^+$	(500 @1.6)	K^+	$\Sigma^+ p \to \Sigma^+ p$	p	Σ^+	$\to p\pi^0$	–0.980	p, 2γ	★
		$K^- p \to \pi^-\Sigma^+$	(1500@1.2)	π^-				$\to n\pi^+$	0.068	n, π^+	★
Σ^-	4.434	$\pi^- p \to K^+\Sigma^-$	(250 @1.5)	K^+	$\Sigma^- p \to \Sigma^- p$	p	Σ^-	$\to n\pi^-$	–0.068	n, π^-	★
		$K^- p \to \pi^+\Sigma^-$	(1500@1.0)	π^+	$\to \Lambda n$	n	Λ	$\to p\pi^-$	0.642	p, π^-	★
								$\to n\pi^0$	0.65	n, 2γ	
					$\to \Sigma^0 n$	n	Σ^0	$\to \Lambda\gamma$		p, π^-, γ	
										n, 2γ, γ	
Σ^0	2.22×10^{-9}										
Ξ^0	8.71	$K^- p \to K^0\Xi^0$	(90 @1.6)	$\pi^+\pi^-$	$\Xi^0 p \to \Xi^0 p$	p	Ξ^0	$\to \Lambda\pi^0$	–0.411	p, π^-, 2γ	
										n, 2γ, 2γ	
Ξ^-	4.91	$K^- p \to K^+\Xi^-$	(160 @1.6)	K^+	$\Xi^- p \to \Xi^- p$	p	Ξ^-	$\to \Lambda\pi^-$	–0.456	p, π^-, π^-	★
										n, 2γ, π^-	
					$\to \Lambda\Lambda$	Λ	Λ	$\to p\pi^-$	0.642	p, π^-, p, π^-	★
								$\to n\pi^0$	0.65	p, π^-, n, 2γ	
					$\to \Xi^0 n$	n	Ξ^0	$\to \Lambda\pi^0$	–0.411	p, π^-, 2γ	
										n, 2γ, 2γ	

Experimental Objectives at J-PARC

- *S= - 2*



- *Anti-symmetric spin-orbit* … better to wait for E452 results

$$M = a + c\,(\vec{\sigma}_n^{\,1} + \vec{\sigma}_n^{\,2}) + b\,(\vec{\sigma}_n^{\,1} - \vec{\sigma}_n^{\,2}) + m\,\vec{\sigma}_n^{\,1}\vec{\sigma}_n^{\,2} + g(\vec{\sigma}_P^{\,1}\vec{\sigma}_P^{\,2} + \vec{\sigma}_K^{\,1}\vec{\sigma}_K^{\,2}) + h(\vec{\sigma}_P^{\,1}\,\vec{\sigma}_P^{\,2} - \vec{\sigma}_K^{\,1}\,\vec{\sigma}_K^{\,2})$$

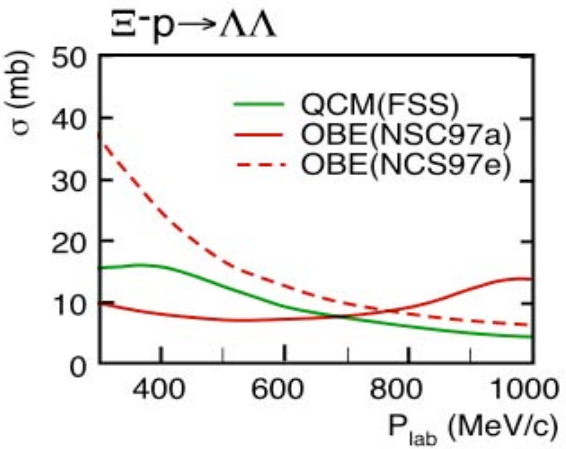
$$I_0 P_y = 1/4\ \mathrm{Tr}(M M^{\dagger} \vec{\sigma}_n^{\,1}) = 2\ \mathrm{Re}[(a+m)c^* + (a-m)b^*]$$

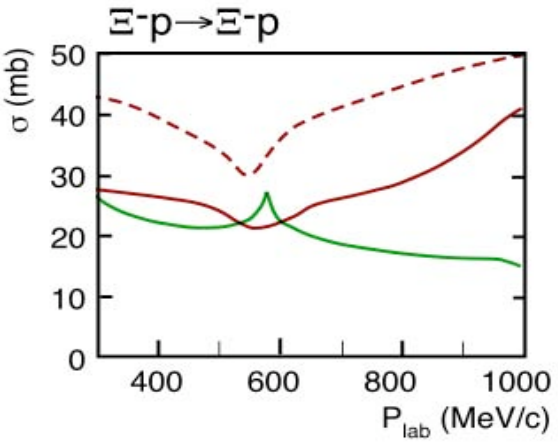
$$(\ I_0 A_y^{\,T} = 1/4\ \mathrm{Tr}(M \vec{\sigma}_n^{\,2} M^{\dagger}) = 2\ \mathrm{Re}[(a+m)c^* - (a-m)b^*]\ )$$

Calculation by Models

S=-2

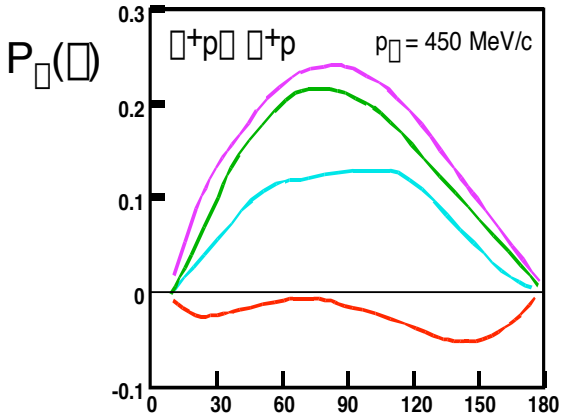
□⁻p □ □□, □⁻p□ □⁻p



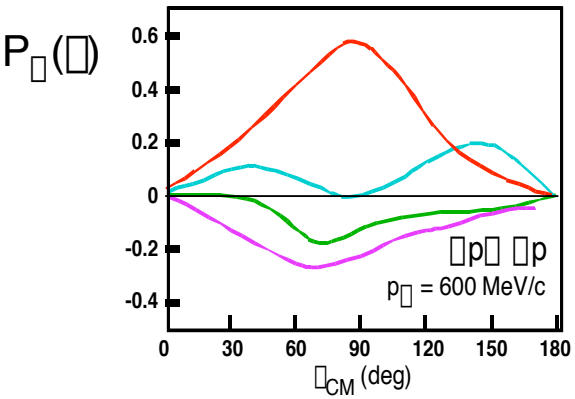


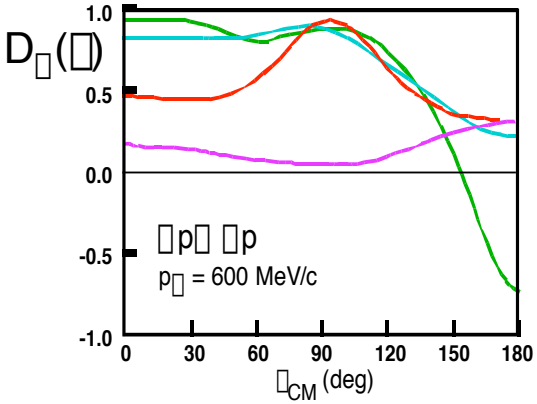
Polarization observables

(≈ Anti-symmetric spin-orbit)



QCM(RGM-H)
QCM(FSS)
OBE(NSC)
OBE(Julich B)



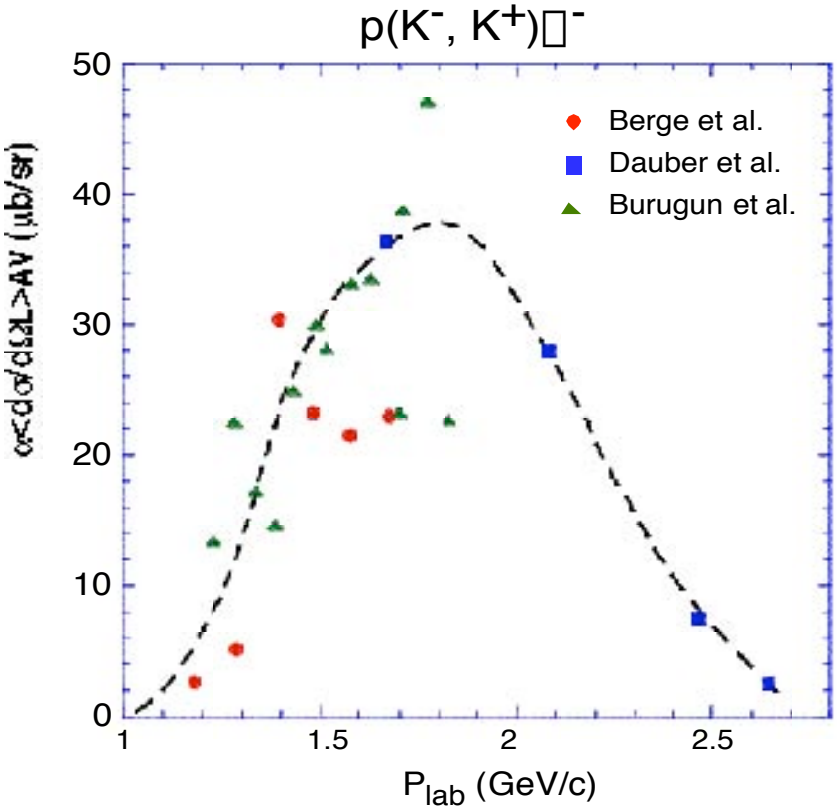


Request for Secondary Beam Line Momentum

⇨ $p(K^-, K^+)\Xi^-$

P_{K^-} : 1.6 ~1.8 GeV/c

(K^- / π^- > 1)



⇨ $p(\pi^+, K^+)\Sigma^+$ P_{π^+} : 1.5 ~1.7 GeV/c

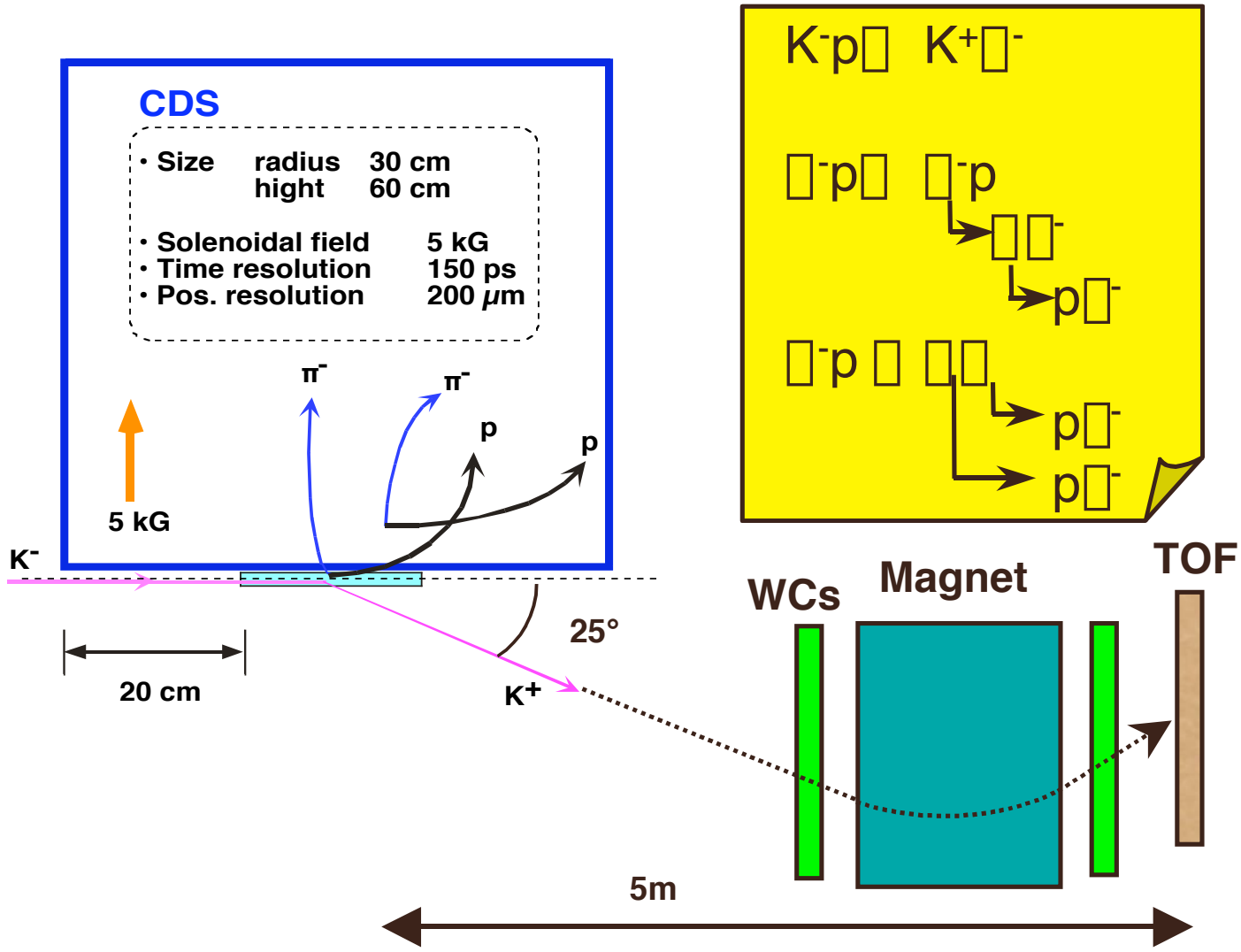
Experimental Method

...basically, "double scattering" technique
hyperon production reaction
hyperon scattering
, and hyperon decay

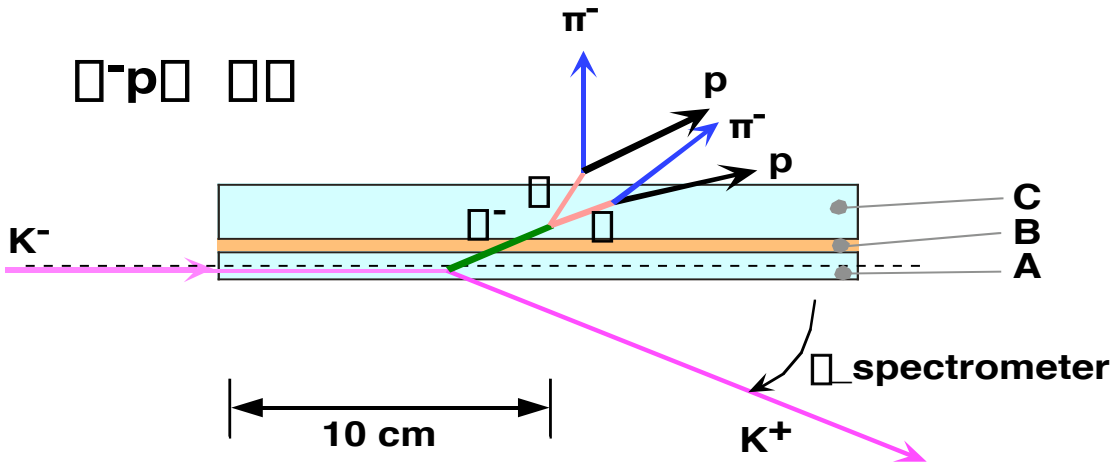
- Vertex image detector
  Scintillating Fiber at KEK since 1990
  KEK-PS E251 for □+P
  E289 for □+p, □-p, □p
  Liquid Scintillator
  KEK-PS E452 for □+p, □p asymmetry

- Liq. H2 + Cylindrical Drift Chamber ⟸ □□p
  (developed by BNL E906 group)

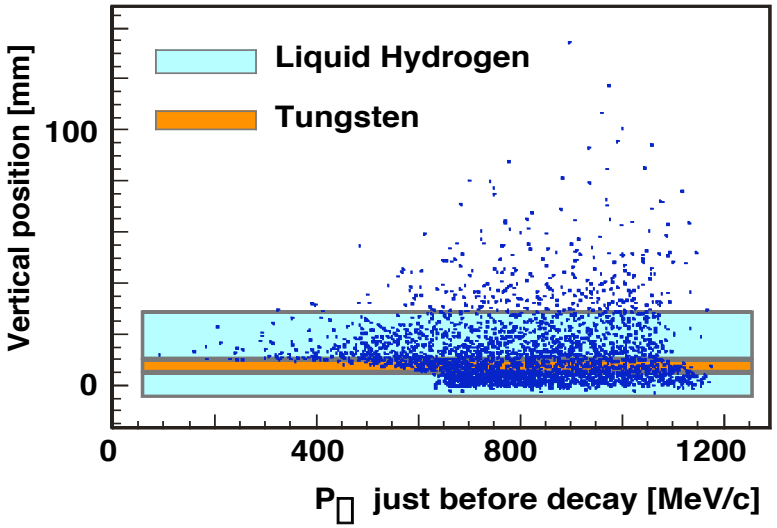
□□p scattering



Target region

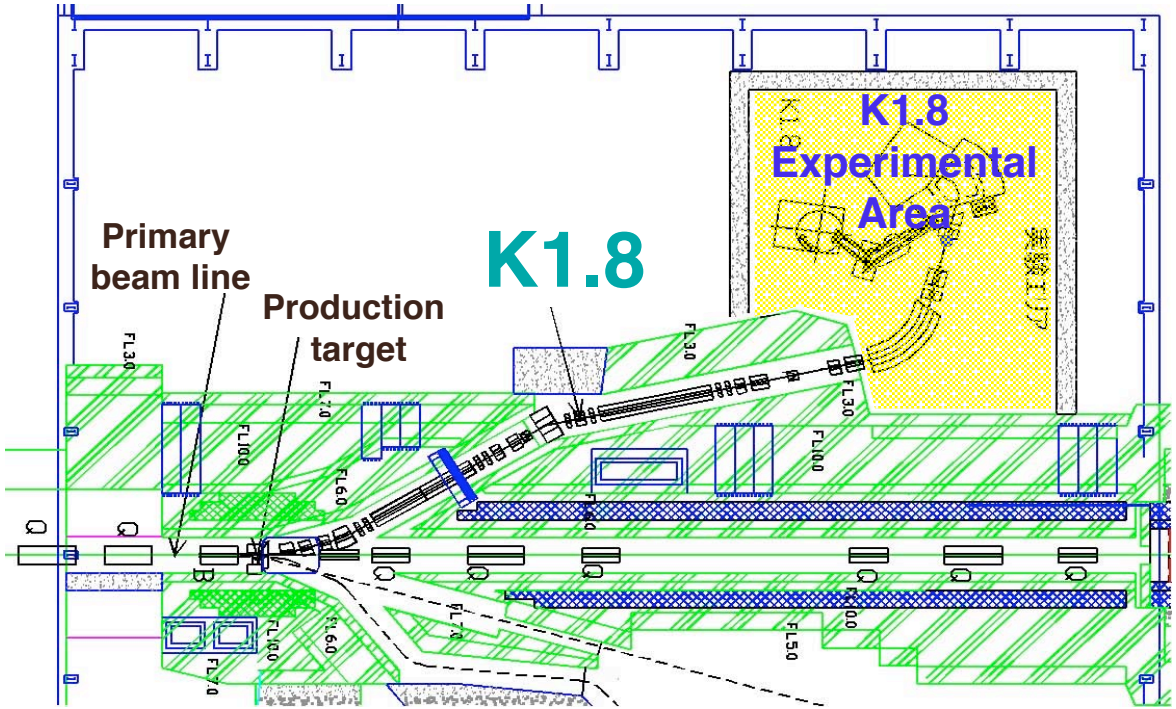


- Target 5 cm wide × 20 cm long
  - A: production 1 cm Liq. Hydrogen
  - B: degrader 0.5 cm Tungsten
  - C: scattering 2 cm Liq. Hydrogen
- K^+ spectrometer
  - θ_spectrometer ~ 25° at center
- K^- beam (assumption @ LOI)
  - Intensity 10^7 K^-/sec
  - Momentum 1.7 GeV/c
  - Size θ_horizontal 15 mm
    θ_vertical 1 mm



K1.8 beam line

- Length 42.35 m
- Intensity
  - 0.7×10^7 K^-/s@50GeV
  - (1.0×10^7 K^-/s@37.5m&50GeV)
  - (0.9×10^7 K^-/s@37.5m&40GeV)

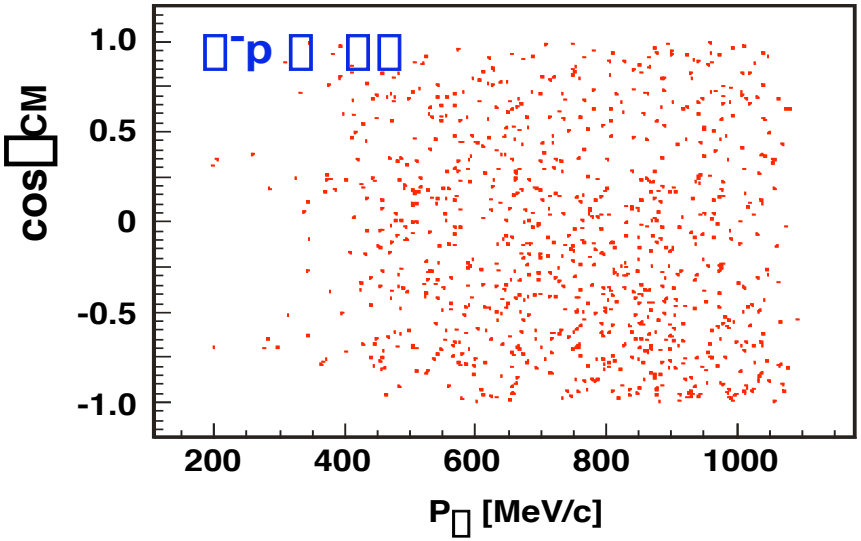


- Size@Liq.H_2
  - trial tuning just downstream of MS2
  - σ_x = 8.8 mm
  - σ_θ = 16.8 mr
  - σ_y = 2.4 mm
  - σ_θ = 3.6 mr

94 % of K^- beam pass through Liq. H_2
of 20cm long with 1cm thickness & 5cm width

Yields estimation

• 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

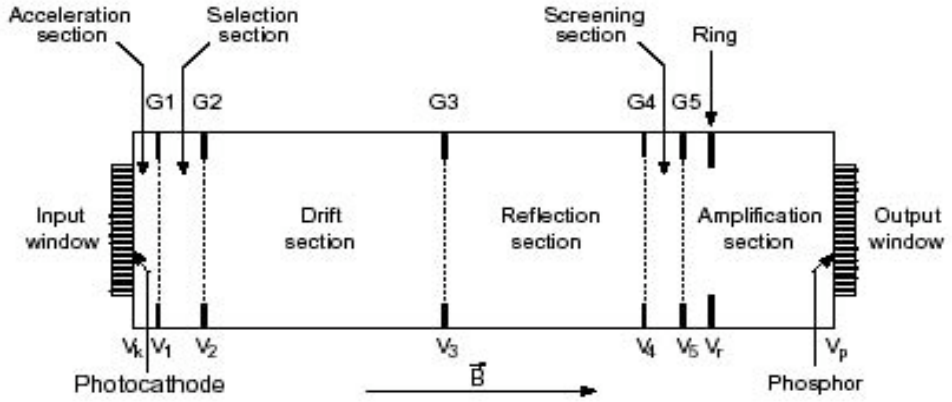


	$\Xi^-p \to \Xi^-p$	$\Xi^-p \to \Xi\Xi$
• reaction rate [s^{-1}]	0.009	0.0043
• 100 days	78000	37000
• Detectable number	2300	550

□⁺p & □p : Method

R&D needed for …

- Imaging device
  - Improve rate limit
    - 10^5 Hz
    - ⇩
    - 10^7 Hz ⟺



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

- Online trigger rate
  - — (□, K) cut
  - — Image brightness cut

Assuming success of these R&D, …

an estimation from KEK-E452

10000 □⁺p & □p elastic @10^7 □⁺/sec , in 10 days

Requests & Works

for Ξ^-p (S= -2), K^+p & $\bar{p}p$ (Polarization obs.)

——— reasonably doable at J-PARC

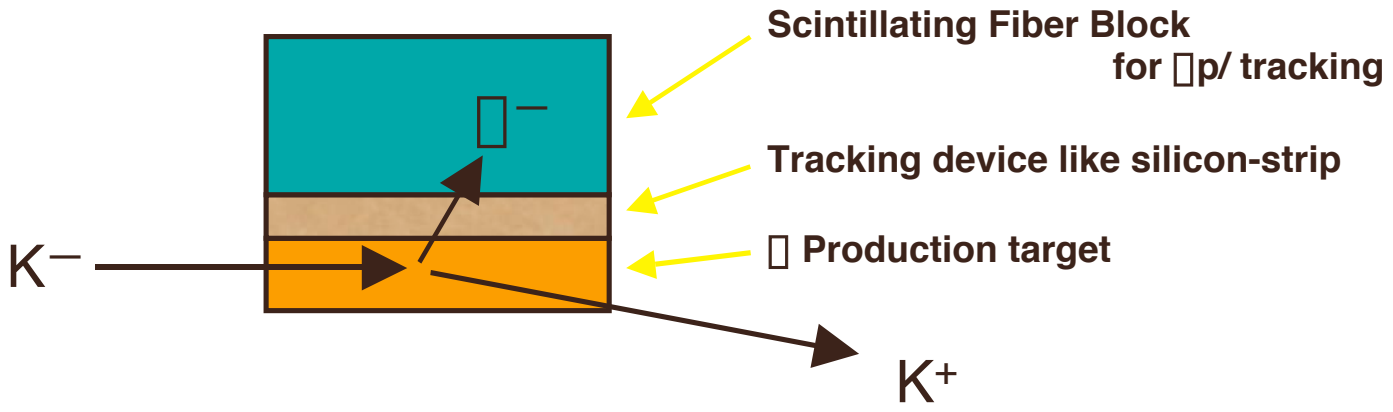
- Separated beam line around 1.5 - 1.8 GeV/c
- K^- intensity 10^7/sec with $K/\pi > 1$
- Liquid hydrogen facility

- Review of E251, E289 & E452 @ KEK
- Realistic Optimization of Setup
- Background estimation (physical & instrumental)
- Fast imaging device, Trigger consideration

If… (in the beginning)

- K^- intensity is low at around 10^6/sec
- No Liquid hydrogen facility

□□p / ^{12}C(K^-,K^+□□) experiments with imaging device



When…

- Polarized H_2 target available

Measure A_y^T, D^T

E289 □-p simulation & Proposal

• Incident π-/spill	1.5×10^{5}	2×10^{5}
• Shifts	80	100
• Total π-	8.6×10^{10}	14.4×10^{10}
• (π-, K+) □-	5.8×10^{5}	9.6×10^{5}
with vertex cut	2.8×10^{5}	
• □-p [from H]	70	240
• Eye-scan ,kinematical	45	
obtained @E289	30 from H	
	68 from C&H	