

Σ^- -Hyperon Radius

Charge Radius and Total Cross Section Measurement at E781/Selex

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- Electromagnetic Probe (e.g. e^-):

$$\langle r^2 \rangle = 4\pi \int r^2 \cdot \rho(r) r^2 dr$$

Electromagnetic Charge Radius

- Hadronic Probe (e.g. p) in absorption region:

$$\langle r_{\text{st}}^2 \rangle_h = \langle r_{\text{st}}^2 \rangle_p \frac{\sigma_{\text{hp}}^{\text{tot}}(s)}{\sigma_{\text{pp}}^{\text{tot}}(s)}$$

Total Cross Section

⇒ Classical Methods – Modern Techniques

Are Charge Radii Flavor dependent ?

	mean square radius [fm ²]	
	electromagn. inter.	strong interaction
p ^a	0.74 ± 0.02	0.72 ± 0.02
p ^b	0.79 ± 0.03	
p ^c	0.72 ± 0.01	
n	−0.11 ± 0.03	
Σ [−]	0.9 ± 0.5	0.62 ± 0.02
Ξ [−]		0.54 ± 0.02
π [−]	0.44 ± 0.01	0.43 ± 0.02
K [−]	0.34 ± 0.05	0.37 ± 0.02
K ⁰	−0.054 ± 0.026	

^aMainz 1974

^bGarching 1997 (Lamb shift)

^cDispersion analysis 1996

π [−] ($\bar{u}d$)	−	K [−] ($\bar{u}s$):	Δ⟨r ² ⟩ ≈	0.1 fm ²
p (uud)	−	Σ [−] (dds):	Δ⟨r ² ⟩ ≈	0.1 fm ² ?
p (uud)	−	Ξ [−] (dss):	Δ⟨r ² ⟩ ≈	0.2 fm ² ?

Measuring the Strangeness Distribution inside Hadrons

Distribution of strange quarks $\phi(s)$

Distribution of up/down quarks $\phi_{\Sigma^-}(d) = \phi_p(u) = \phi(q)$

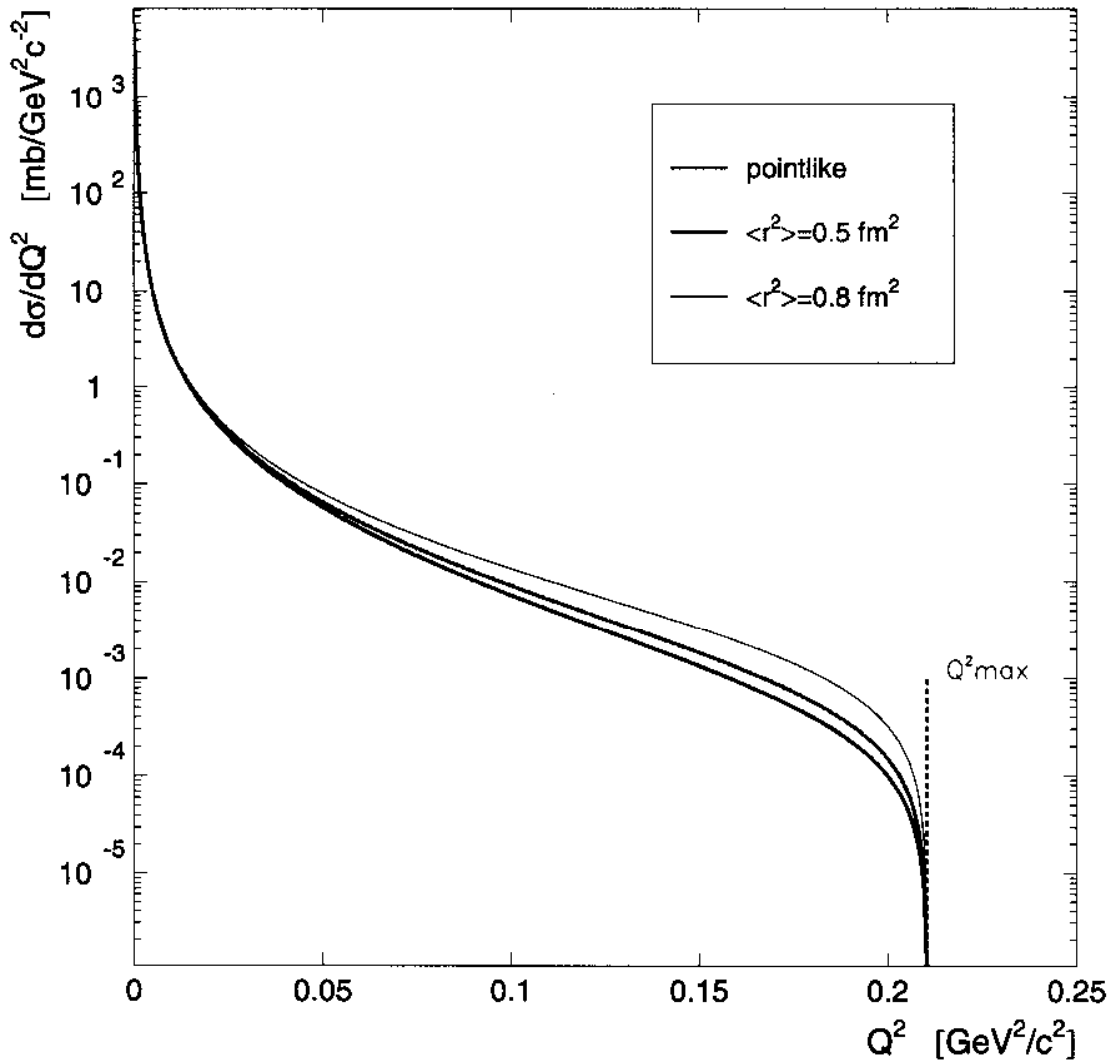
$$p \ (uud): \quad \langle r_{ch}^2 \rangle_p = \int \rho \, r^2 \, d^3r = \left| \int [\phi(q) \right. \left. \right] r^2 \, d^3r |$$

$$\Sigma^- (dds): \quad \langle r_{ch}^2 \rangle_{\Sigma^-} = \int \rho \, r^2 \, d^3r = \left| \int \left[-\frac{2}{3}\phi(q) - \frac{1}{3}\phi(s) \right] r^2 \, d^3r \right|$$

$$\Delta \langle r_{ch}^2 \rangle = \boxed{\langle r_{ch}^2 \rangle_p - \langle r_{ch}^2 \rangle_{\Sigma^-}} = \boxed{\frac{1}{3} \int [\phi(q) - \phi(s)] \, r^2 \, d^3r}$$

$$= \langle r_{ch}^2 \rangle_{\pi^-} - \langle r_{ch}^2 \rangle_{K^-} = \frac{1}{3} \int [\phi(q) - \phi(s)] \, r^2 \, d^3r$$

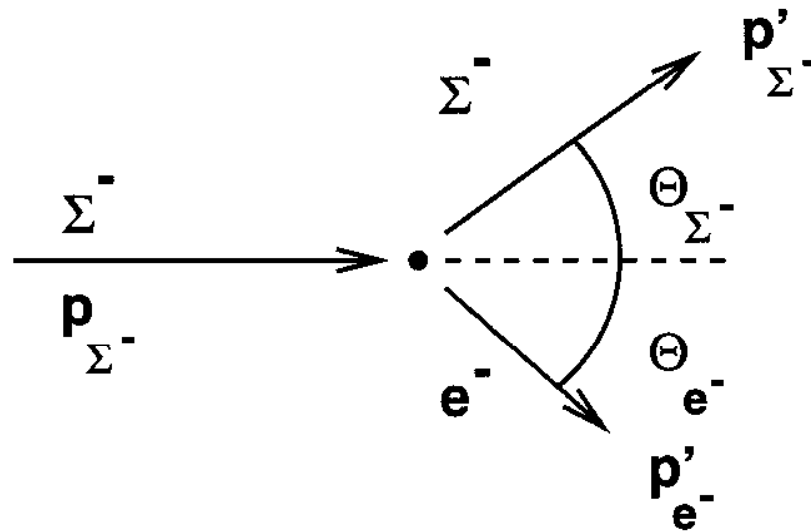
Differential cross section for elastic Σ^- - e^- scattering



$$\frac{d\sigma}{dQ^2} = \frac{4\pi\alpha^2\hbar^2}{Q^4} \left(1 - \frac{Q^2}{Q_{max}^2}\right) \cdot F^2(G_E, G_M, Q^2)$$

$$G_E(Q^2) = \frac{1}{\kappa - 1} G_M(Q^2) = \left(1 + \frac{1}{12}Q^2\langle r_{ch}^2\rangle\right)^{-2}$$

Kinematics of elastic hadron electron scattering

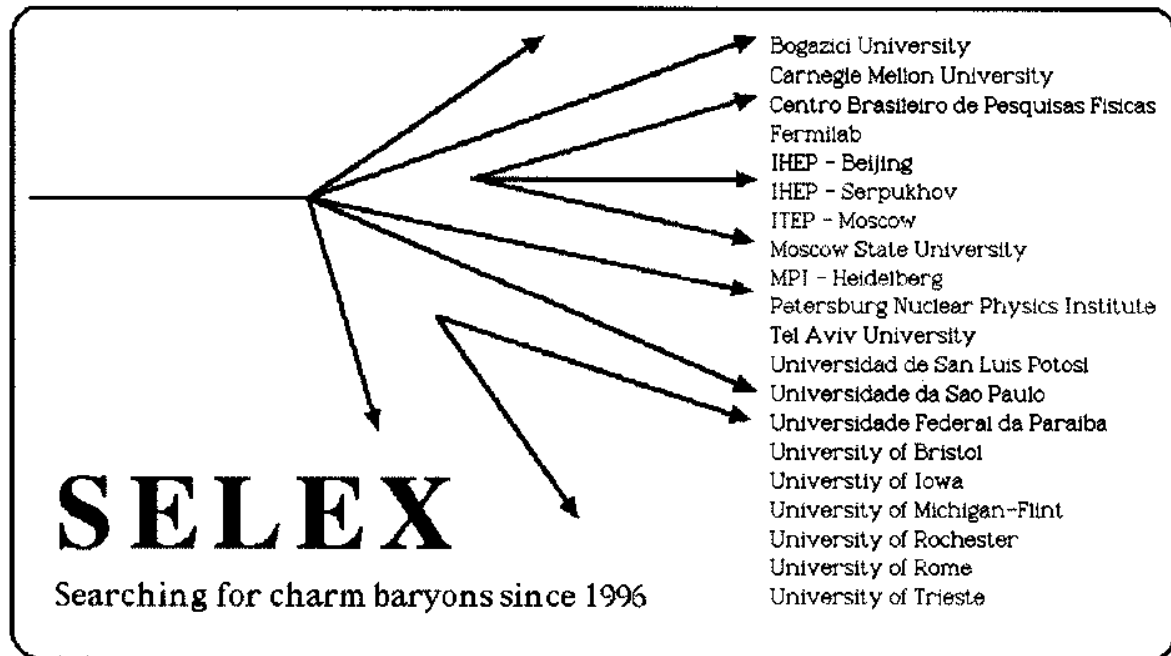


Event variables: Q^2, s

Observables: $p_{\Sigma^-}, p'_{\Sigma^-}, \theta_{\Sigma^-}, \theta_{e^-}, (p'_{e^-})$

Requirements to the experiment:

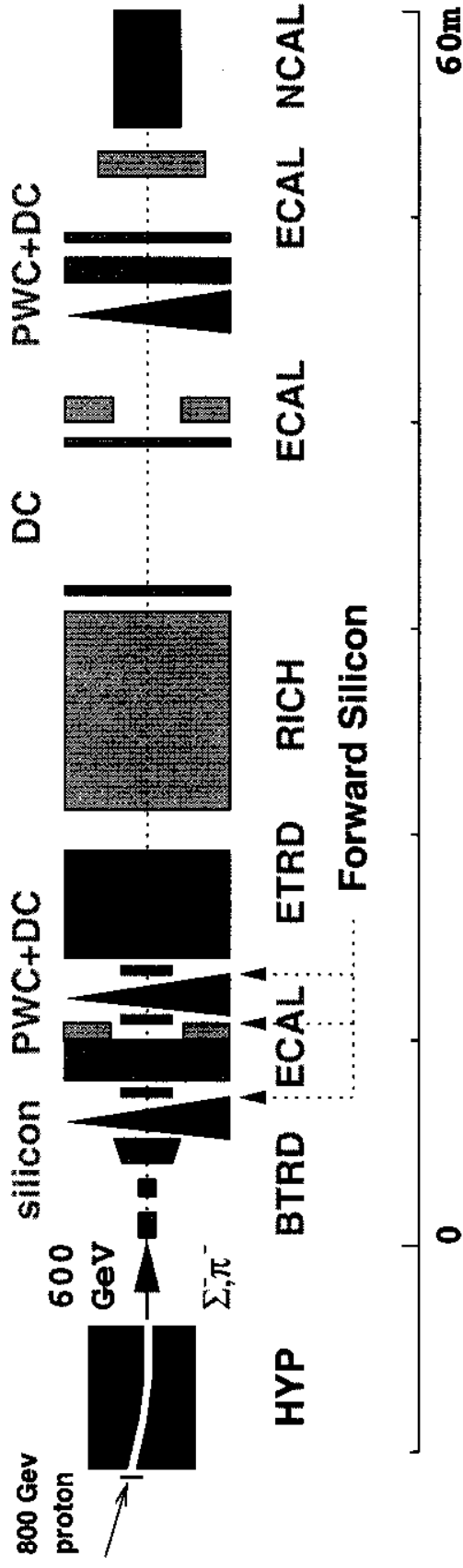
- Σ^- beam
- scattering angle $\rightarrow$ silicon microstrip detectors
- good momentum resolution $\rightarrow$ spectrometer



Segmented Large x_F Baryon Spectrometer

- Fixed target experiment at Fermilab using a 600 GeV/c Σ^- -hyperon beam
- Collaboration with 120 members from 20 countries
- Main topic: Charm baryon production and spectroscopy
- Rich hyperon physics program

Schematic setup of E781/Selex



Hyperon beam: (600 ± 40) GeV/ c secondary beam, Σ^- : $\pi^- = 1:1$, ca. 2 % Ξ^- ;

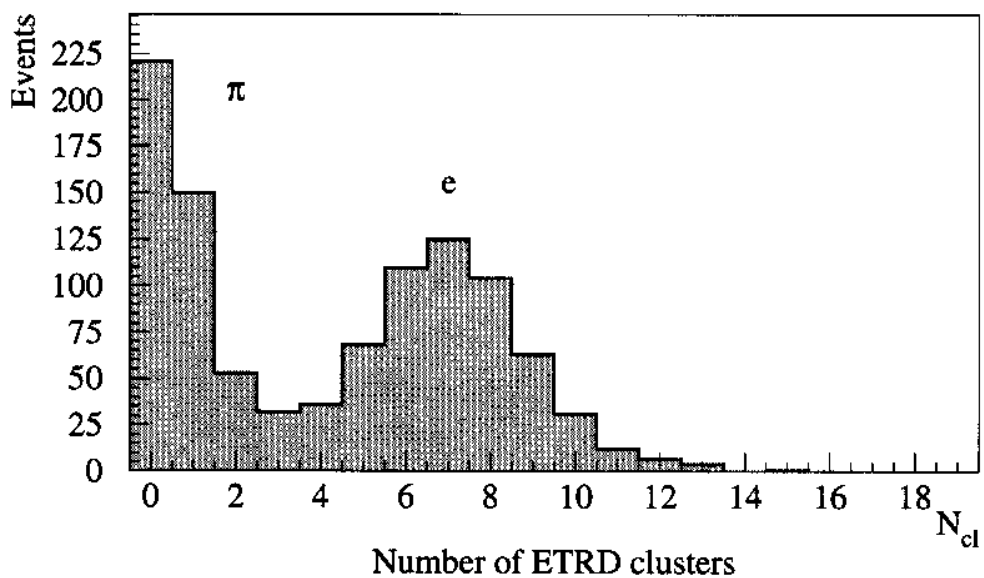
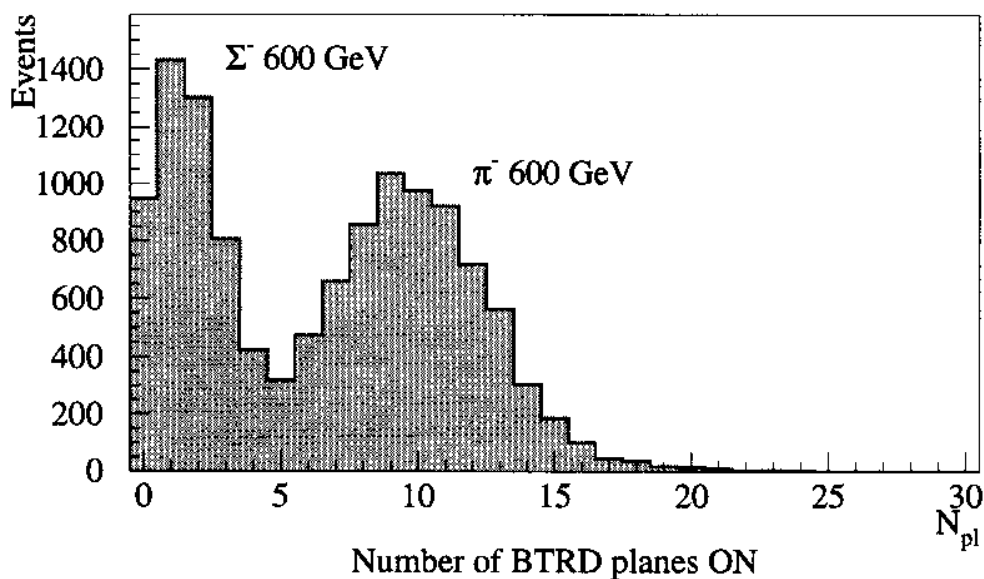
Spectrometer: 2 copper, 3 diamond targets, three spectrometer magnets;

Track reconstruction: 28 silicon microstrip detectors, 4 μm transverse resolution, 26 PWC layers ($\sigma \sim 1mm$), 3×24 vector drift chambers ($\sigma \sim 100\mu m$);

Particle identification: 2 transition radiation detectors for Σ^-/π^- and e^- identification, RICH (K/π separation up to 165 GeV), 3 lead glas calorimeter, neutron calorimeter

Forward silicon: 3 stations of 6 silicon microstrip detectors

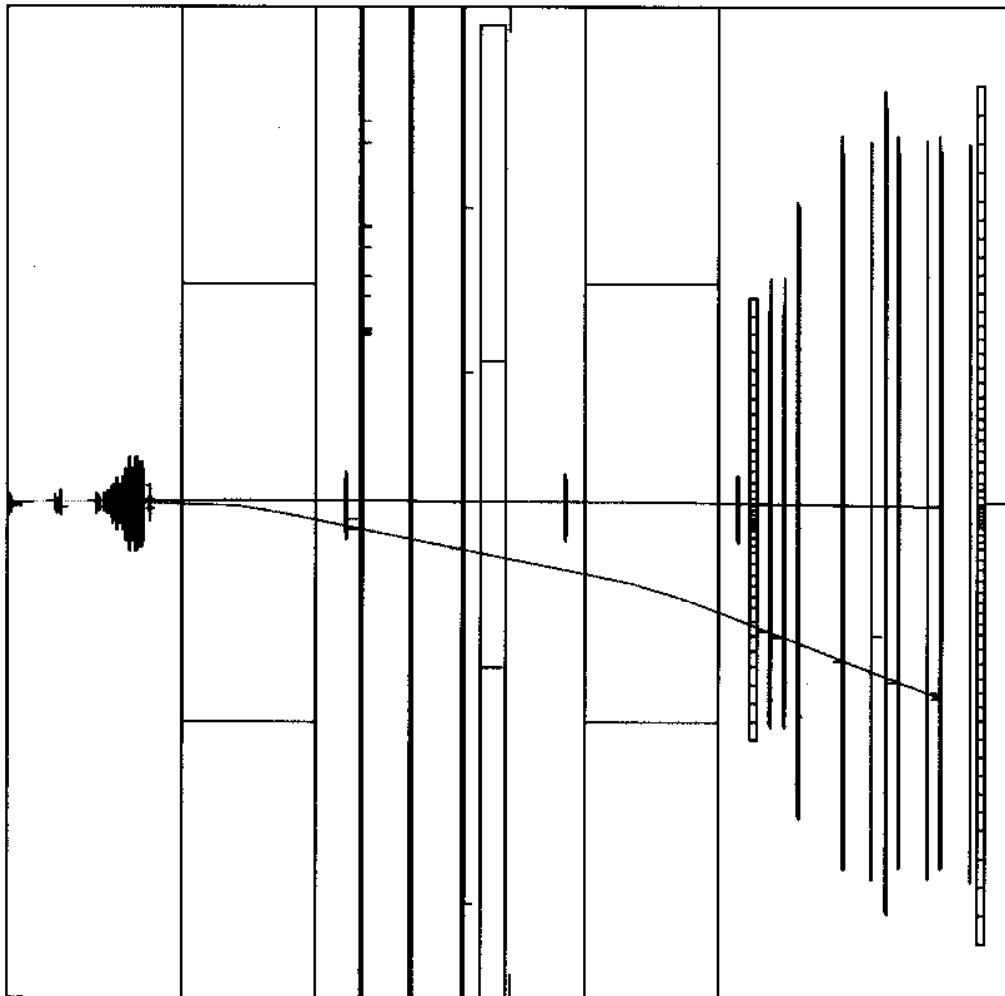
Particle identification



- 91.5 % efficiency of Σ^- identification (BTRD)
- 95 % efficiency of e^- identification (ETRD) at 20 GeV/ c

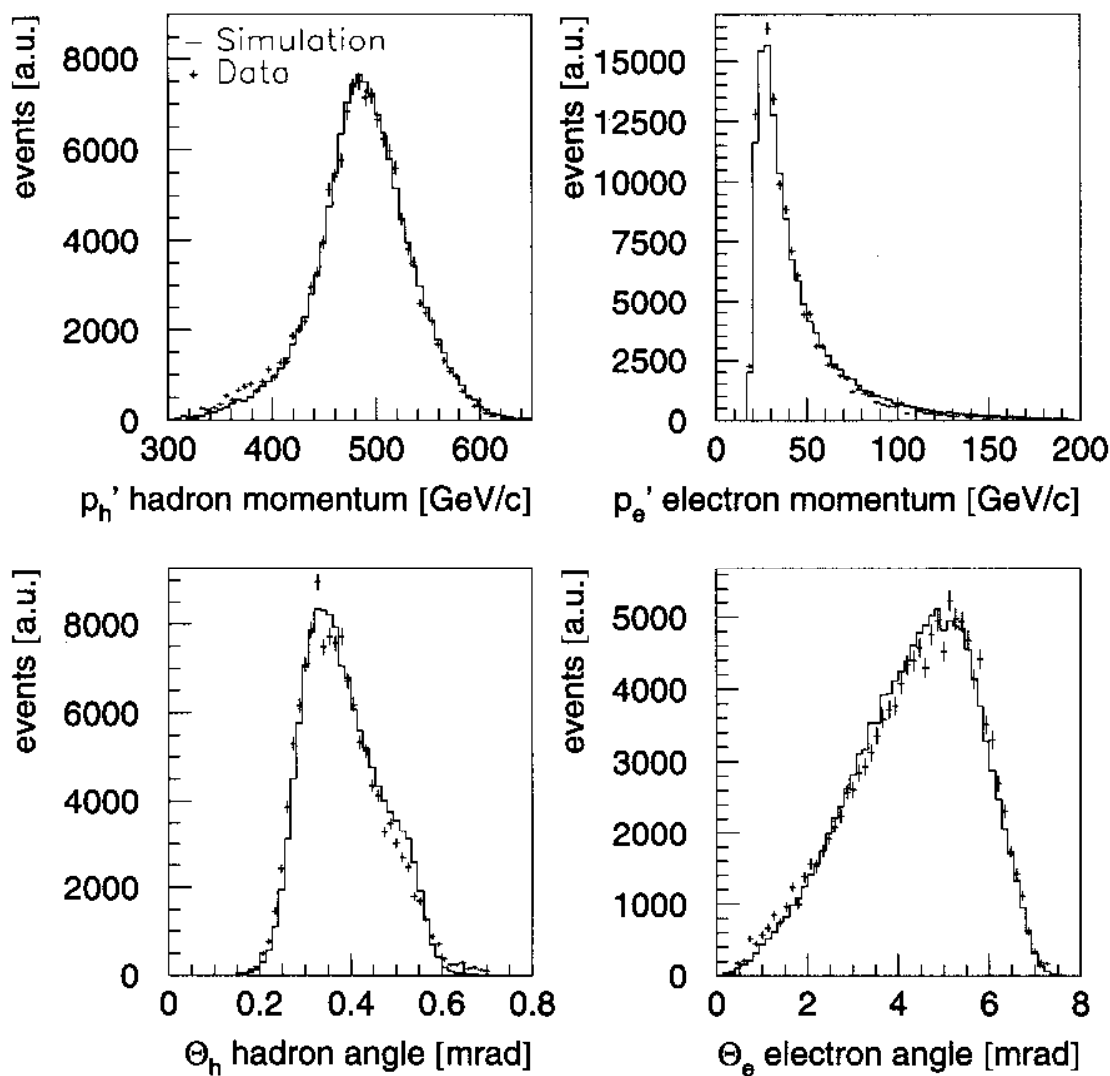
A typical elastic Σ^- - e^- scattering event

Event: 20026833 Run: 9150



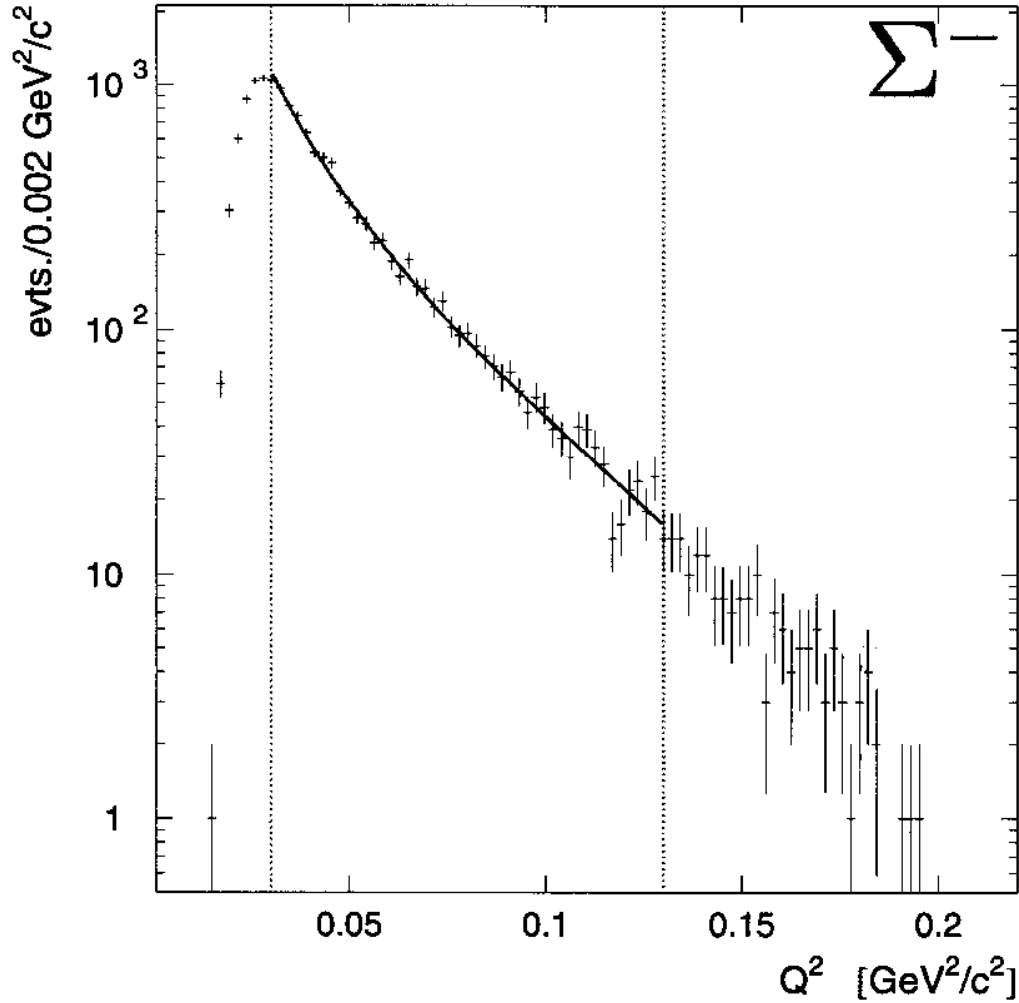
Comparison Data–Simulation

Simulation using GEANT package:



Q^2 -resolution: 2.7 % (C-tgt) to 4.2 % (Cu-tgt)

Preliminary Results

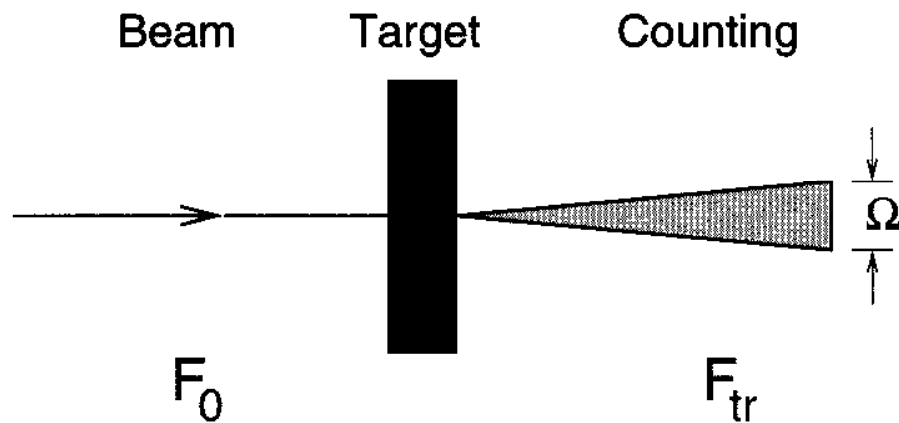


	SELEX $\langle r^2 \rangle [fm^2]$	$\langle r^2 \rangle [fm^2]$
Σ^-	$0.60 \pm 0.08 \pm 0.08$	
p	$0.70 \pm 0.06 \pm 0.06$	0.72 ± 0.01^a
π^-	$0.50 \pm 0.06 \pm 0.06$	0.44 ± 0.01^b

^aMergell *et al*, Nucl.Phys.A **596**, (1996) 596

^bAmendolia *et al* [NA7 Collaboration], Nucl.Phys.B **277**, (1986) 168

Σ^- -p Total Cross Section at 600 GeV



Transmission ratio yields partial cross section; extrapolate to $\Omega = 0$ for total cross section:

$$\sigma_{tot}(\Omega) := \frac{1}{\rho L} \lim_{\Omega \rightarrow 0} \log \left[\frac{F_0}{F_{tr}(\Omega)} \cdot \frac{E_{tr}(\Omega)}{E_0} \right]$$

(F : target *in* – E : target *out*)

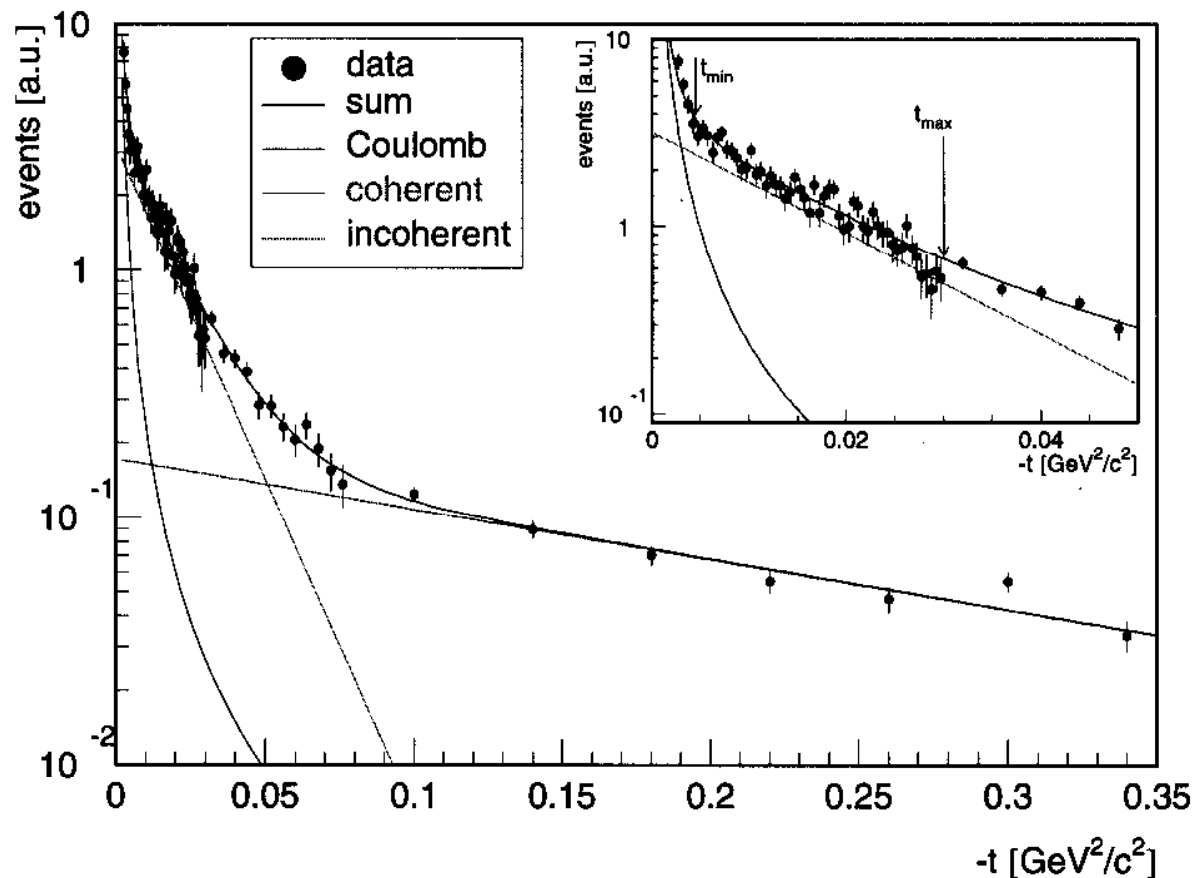
SELEX : no liquid hydrogen target. Two alternatives:

- (1) Use C and CH_2 targets and take difference
- (2) calculate from ratio of proton-nucleus and Σ^- -nucleus cross sections

$\Rightarrow$ En route we also obtain A-dependence of Σ^- cross section

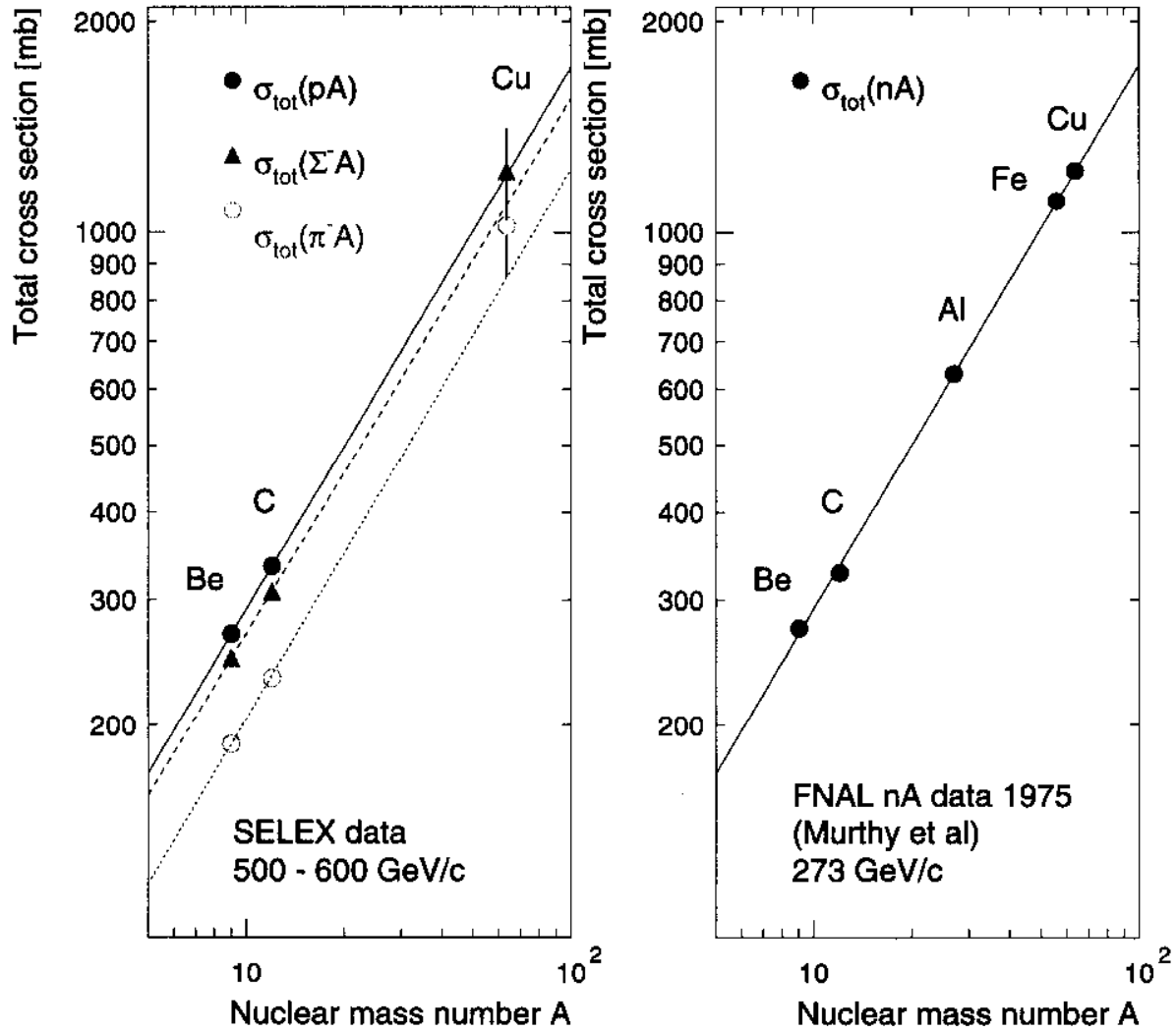
Extrapolation to Total Cross Section

Differential scattering spectrum for Σ^- carbon:



- Clear visibility of Coulomb, coherent and incoherent region,
- restrict to coherent region, extrapolate to $t = 0$

A-Dependence of Total Cross Section

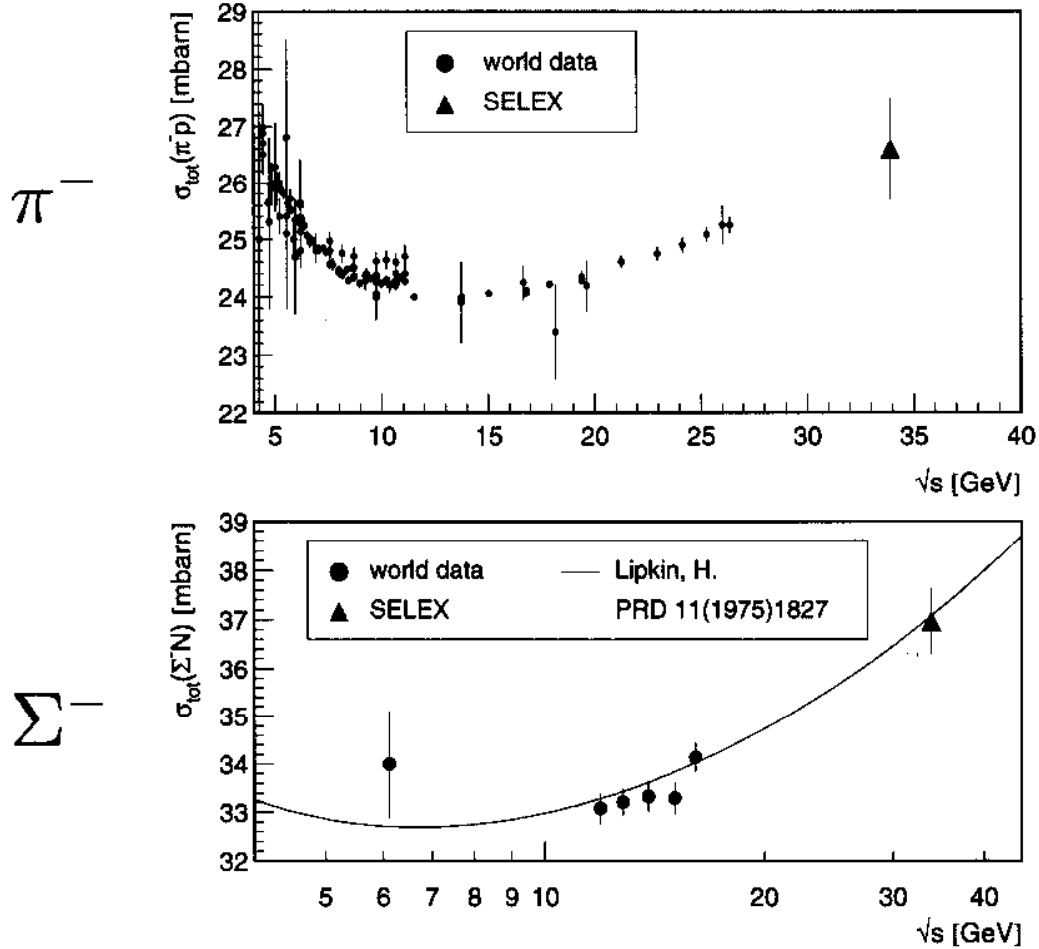


$$\sigma_{tot}(XA) = \sigma_0 A^\alpha ; \alpha \simeq 0.77 \pm 0.05$$

Use Glauber model to extract $\sigma_{tot}(\Sigma^- p)$ from x-section ratios:

$$\frac{\sigma_{tot}(\Sigma^- A)}{\sigma_{tot}(pA)} = \frac{\xi(A, \sigma_{tot}(\Sigma^- p))}{\xi(A, \sigma_{tot}(pp))}$$

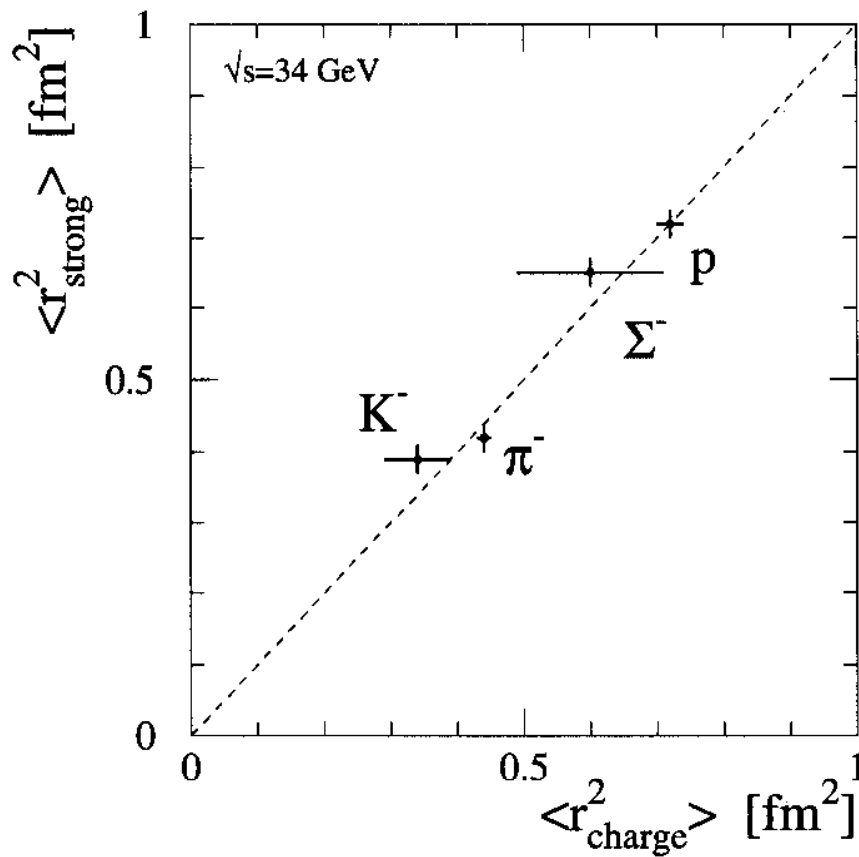
π^- -N and Σ^- -N Total Cross Sections



$$p_{lab} = 610 \text{ GeV}/c \quad (\sqrt{s} = 33.9 \text{ GeV}/c)$$

method	$\sigma_{tot}(\Sigma^- N) [\text{mb}]$	$\sigma_{tot}(\pi^- N) [\text{mb}]$
CH2-C difference	33.7 ± 3.1	26.0 ± 2.1
$\sigma_{tot}(\text{Be target})$	37.4 ± 1.3	27.1 ± 1.5
$\sigma_{tot}(\text{C target})$	37.0 ± 0.8	26.4 ± 1.3
total result	37.0 ± 0.7	26.6 ± 0.9

Conclusion: Strong and Electromagnetic Radii



Preliminary results from E781/SELEX:

- $\sigma_{\text{tot}}(\Sigma^- N) = 37.0 \pm 0.7 \text{ mb}$ ($\sqrt{s} = 33.9 \text{ GeV}$)
- Charge radius $\langle r^2 \rangle_{\Sigma^-} = 0.60 \pm 0.08 \text{ fm}^2$