Recent Results from SELEX

Heavy Quark 2000
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On behalf of the SELEX Collaboration

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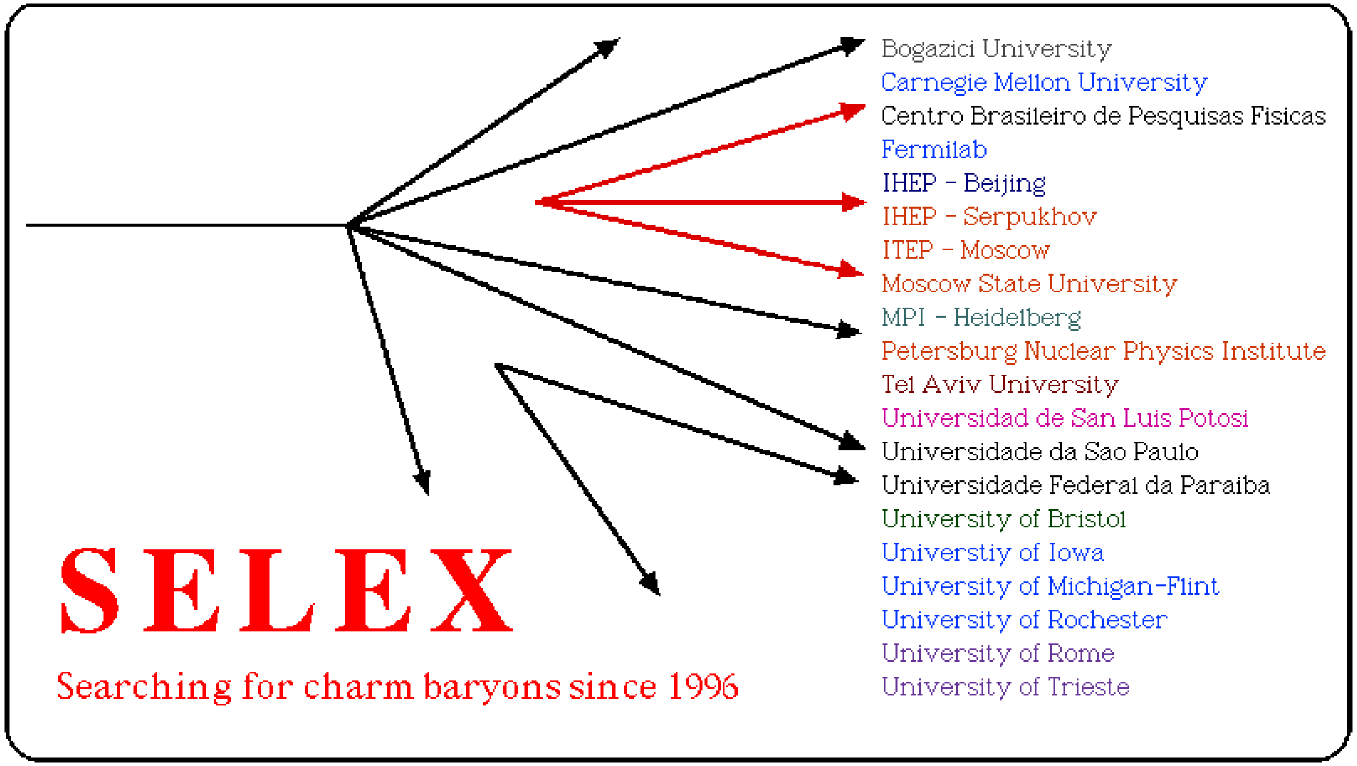


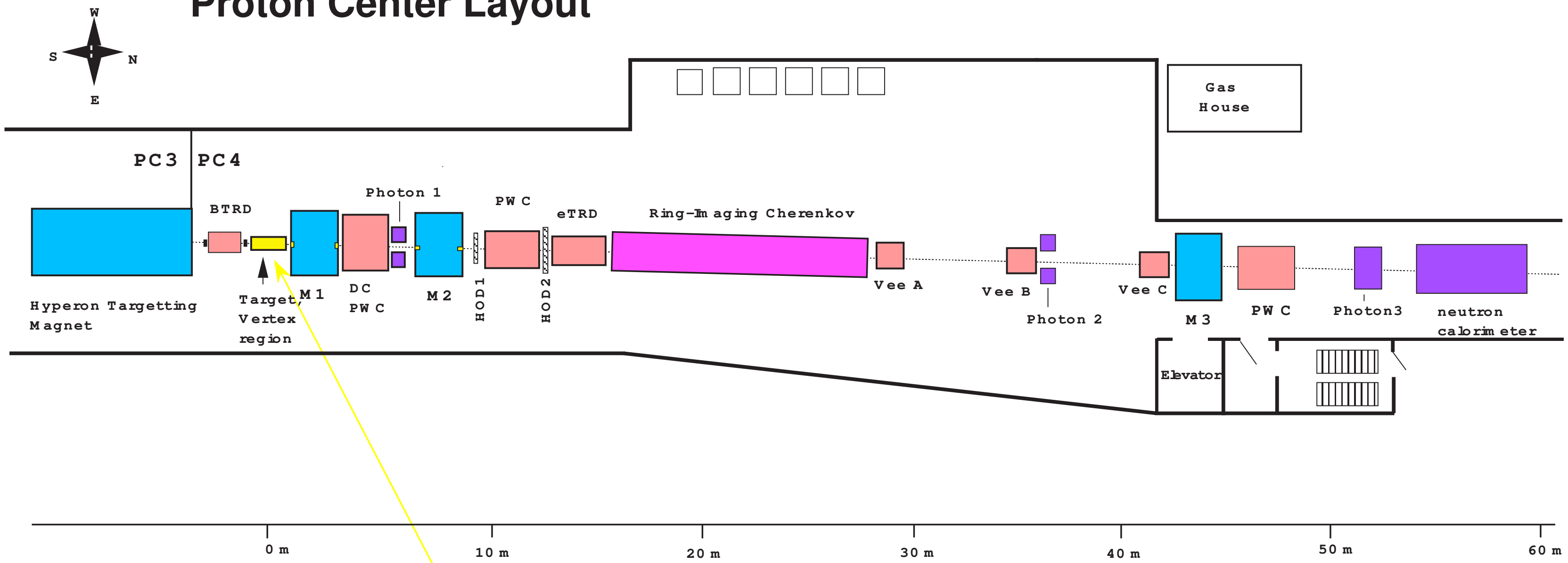
- 600 GeV/c negative Beam: 50 % π^- / 50 % Σ^-
- 570 GeV/c positive Beam: 92 % protons
- RICH Counter for definite identification of π, K, proton
- precision momentum resolution ($\delta p/p \approx 0.5\,\%$ at $100 - 300\,\mathrm{GeV}/c$)
- precision vertex resolution (primary: 270 μm; secondary: 560 μm)

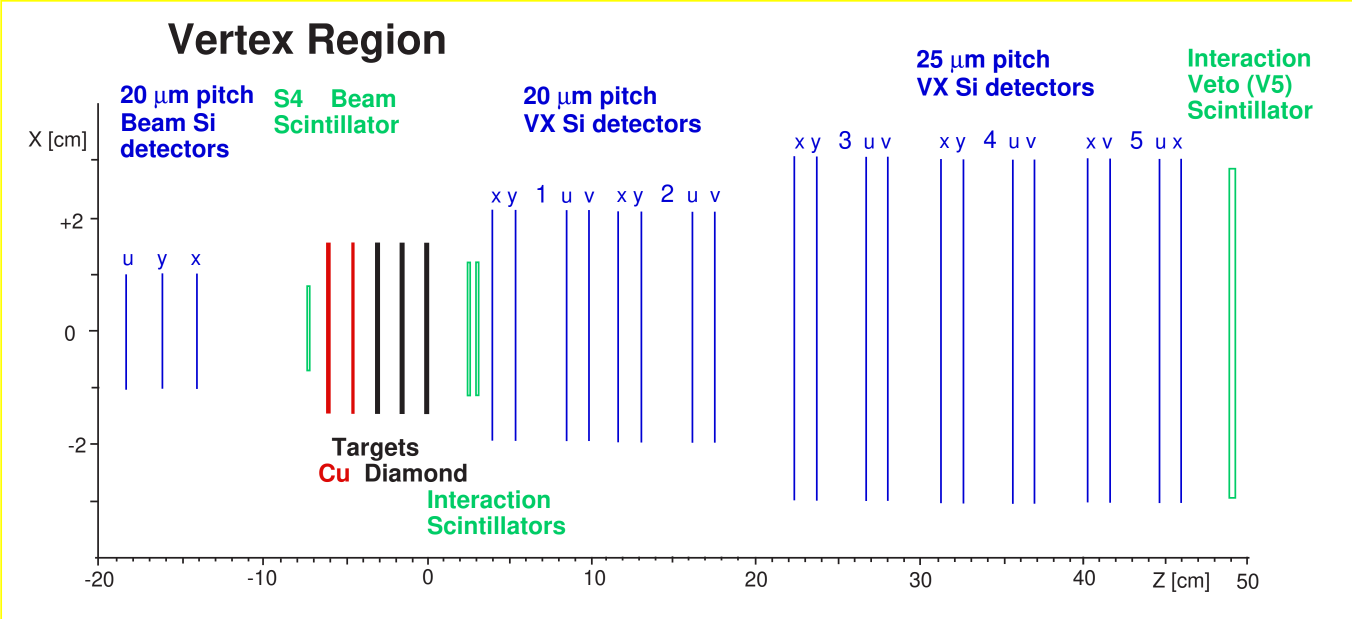
SELEX Apparatus

3 Segment Forward Spectrometer ($x_F > 0.1$)

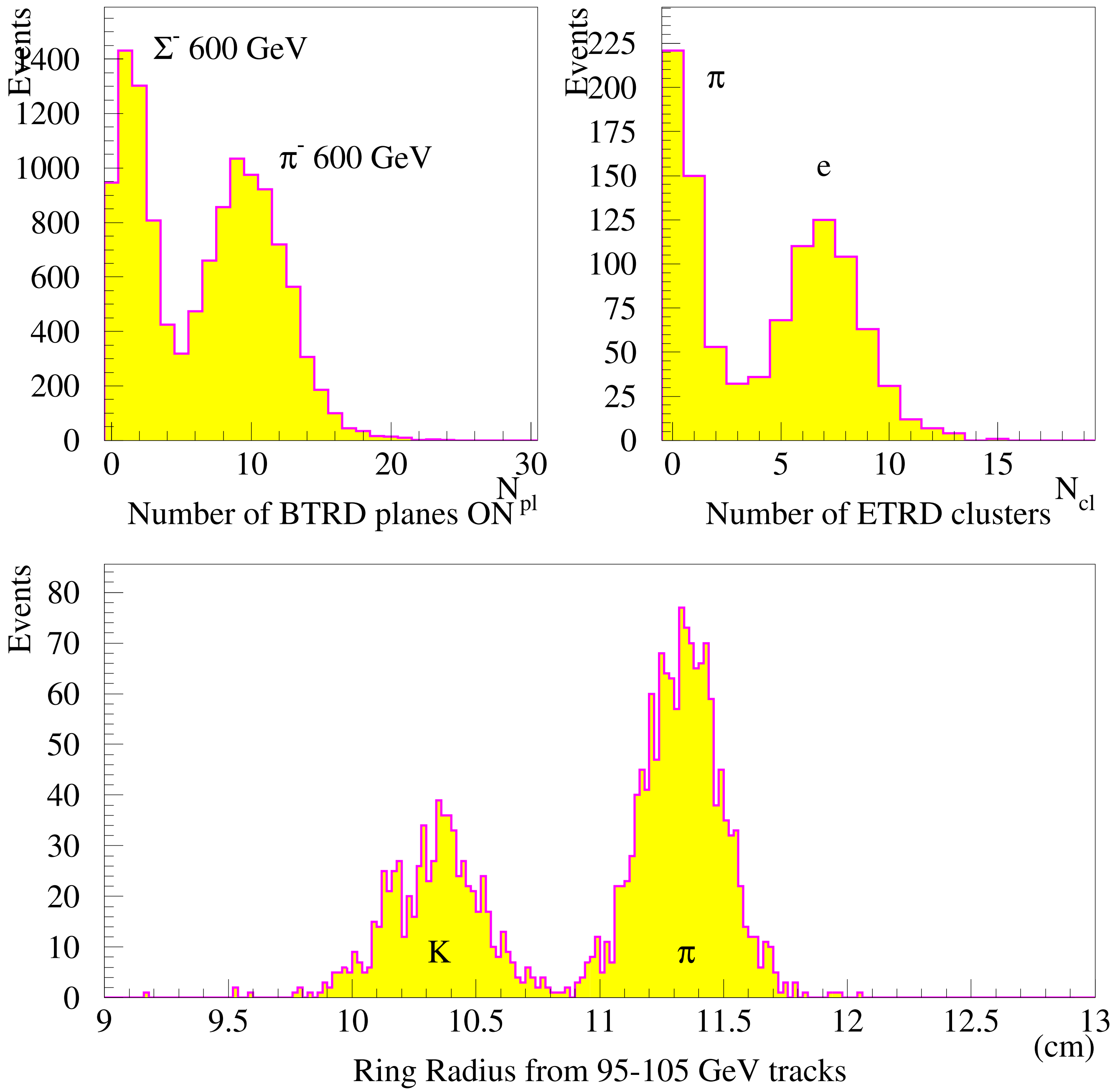
- 74000 Strip Silicon system, $4\,\mu$m transverse position resolution at $600\,\mathrm{GeV}/c$
- Beam Tagging (Σ^-/π^-, p/π^+) with Beam TRD
- 3000 Phototubes RICH – $2\,\sigma$ K/π separation up to $165\,\mathrm{GeV}/c$
- Secondary e^- with Electron TRD for semileptonic decays
- Precise downstream tracking
  - 18 large silicon planes ($\sigma \sim 8\,\mu$m)
  - 26 PWC planes ($\sigma \sim 0.6 - 1\,$mm)
  - 3×24 Vector Drift chambers ($\sigma \sim 100\,\mu$m)
- 3 lead glass photon detectors

Selex (E781)
Proton Center Layout





SELEX Particle ID detectors



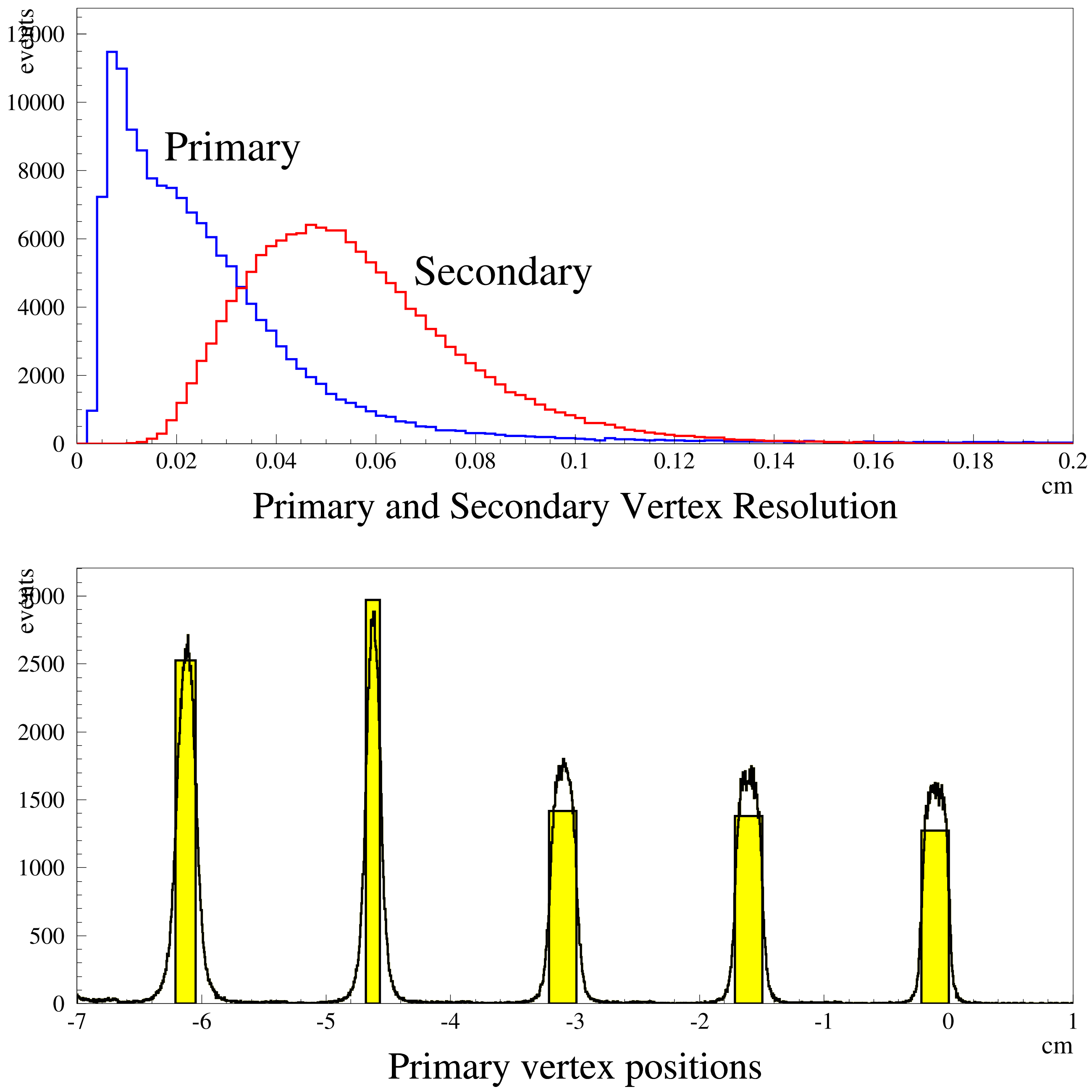
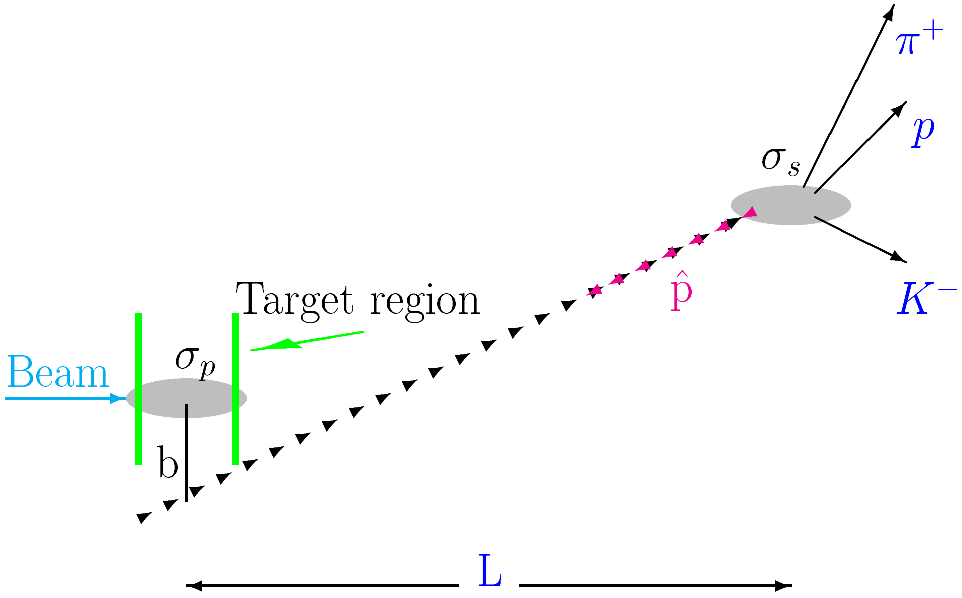


Fig. 3: Vertex resolution

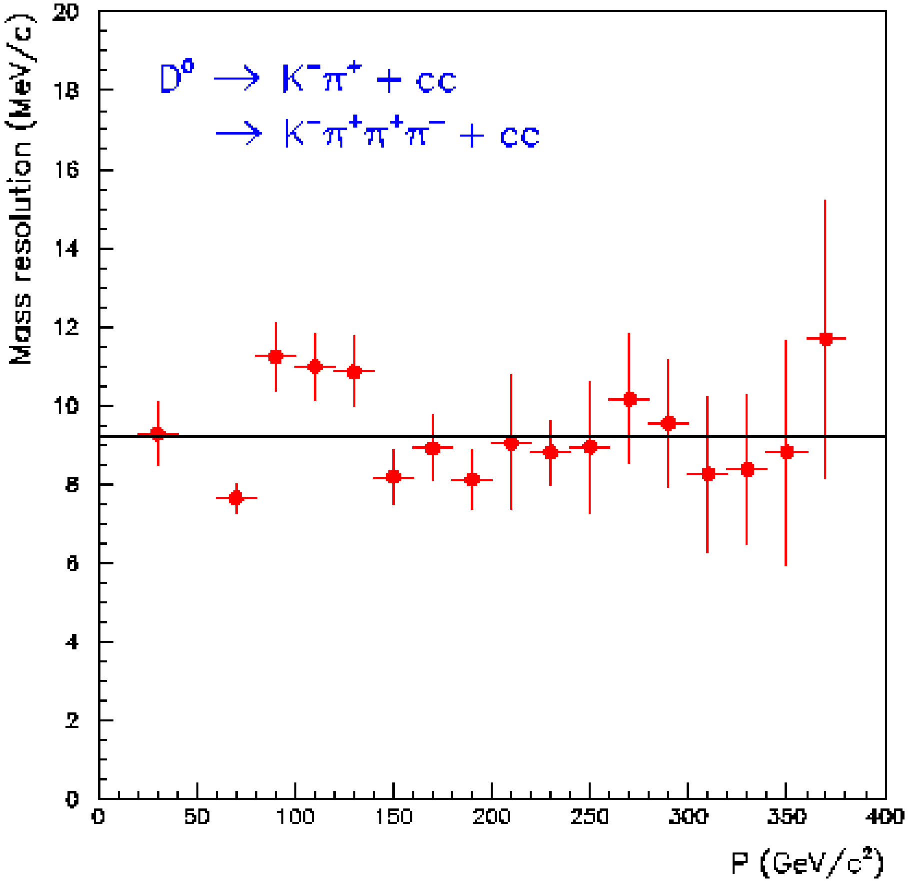
Charm Selection

- vertex driven with definite RICH identification of p, K required



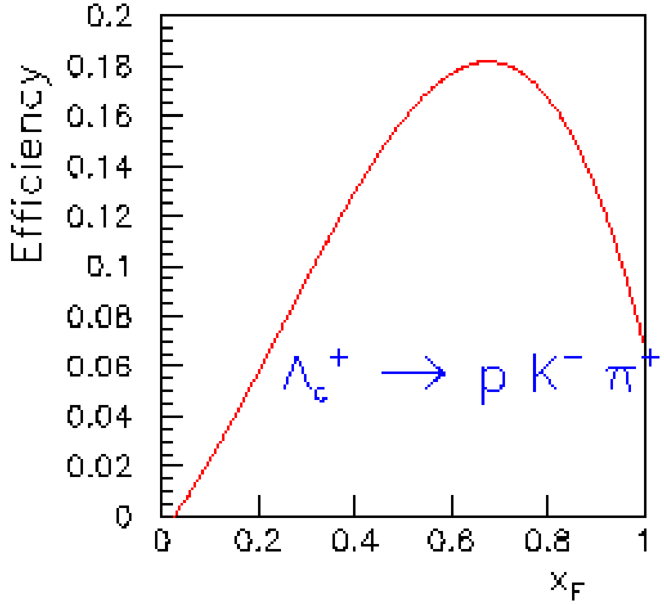
- Good secondary vertex ($\chi^2/dof < 5$)
- Longitudinal separation (L) between the vertices bigger than $8\,\sigma$ ($\sigma^2 = \sigma_p^2 + \sigma_s^2$)
- Charm track points back to primary vertex (pointback $= (\mathrm{b}/\sigma_{\mathrm{b}})^2 < 12$)
- K, p identified by the RICH: $\mathcal{L}(K) > \mathcal{L}(\pi)$, $\mathcal{L}(p) > \mathcal{L}(\pi)$
- No secondary vertices in material

Mass Resolution



- $\Delta M \sim 9$ MeV (constant in momentum)

Acceptance



- Acceptance for Particle and Anti-particle identical (Difference $< 3\,\%$)
- Acceptance still high at large x_F
- Acceptance flat in p_t

Charm Lifetimes

Experimental goal is to measure lifetime hierarchies for mesons and baryons to:

- test calculation of $1/m_Q$ terms in HQET expansion
- compare strength of W-exchange and W-annihilation terms
- compare Pauli suppression mechanisms in different hadrons

Features of SELEX Lifetime Analysis Method

- apply strong PID requirements to minimize overlapping states
- use real data to establish acceptance correction function
- check systematics by using several decay modes, different production targets
- Use reduced proper time $t_R = t - 8\,\sigma/(\beta\gamma)$
- $\sigma_{t_R} \sim 20\,\mathrm{fs} \Rightarrow$ use binned likelihood analysis
- Analyze D^0 lifetime to verify methodology

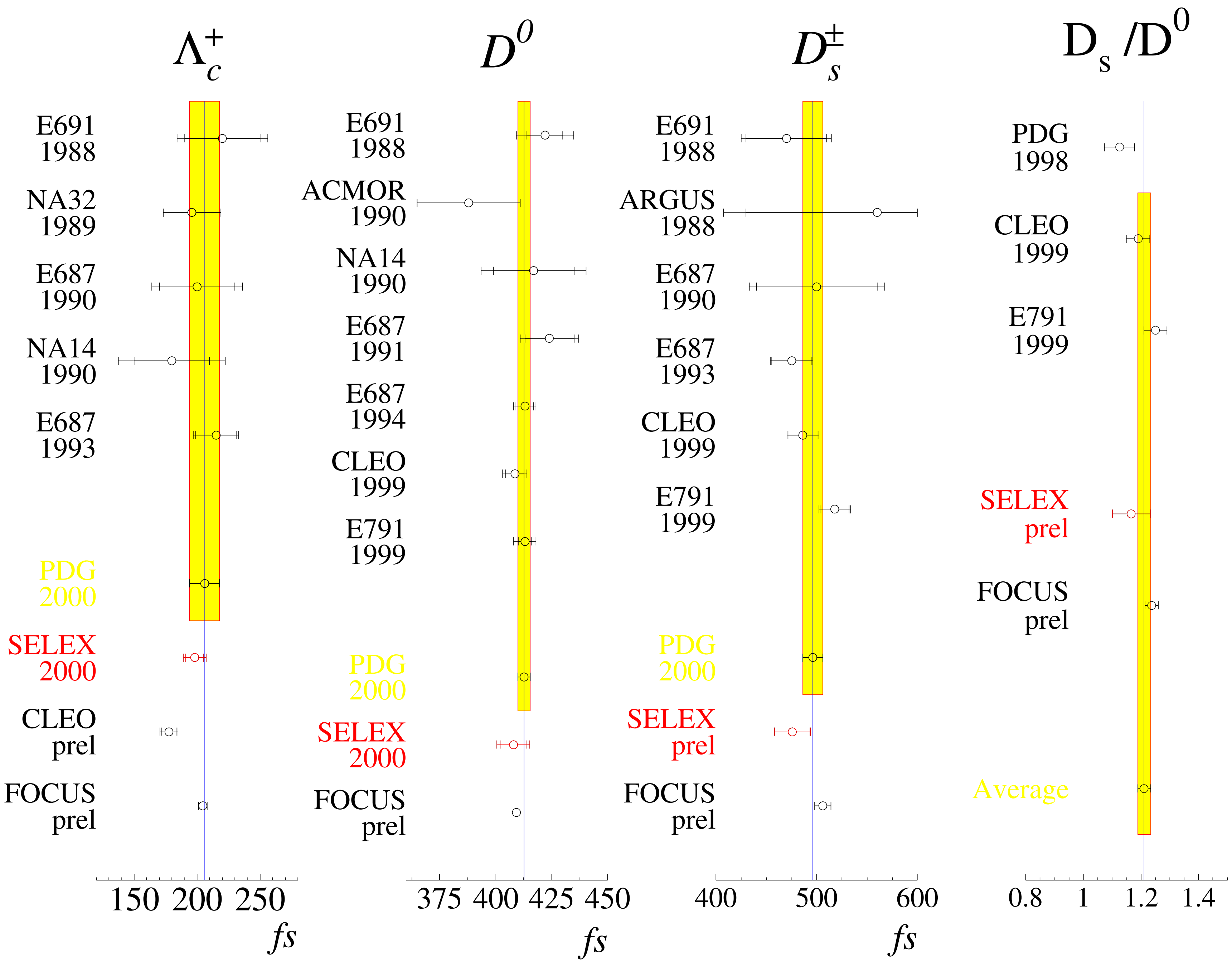
SELEX Lifetime Results

- Final results for Λ_c^+, D^0, ($D^\pm$) (Submitted to PRL, hep-ex/0010014)
- Preliminary for D_s and τ_{D_s}/τ_{D^0}

Decay Mode	τ (fs)	Events
$D^0 \to K^-\pi^+$, $K^-\pi^+\pi^-\pi^+$ +cc	407.9 ± 6.0	10210 ± 125
$\Lambda_c^+ \to pK^-\pi^+$	198.1 ± 7.0	1630 ± 45
$D^0 \to K^-\pi^+$	416 ± 12	2470 ± 57
$\overline{D}^0 \to K^+\pi^-$	416 ± 10	3420 ± 65
$D^0 \to K^-\pi^+\pi^-\pi^+$	399 ± 16	1950 ± 63
$\overline{D}^0 \to K^+\pi^-\pi^+\pi^-$	400 ± 14	2360 ± 66
average	410.3 ± 6.3	
χ^2/dof	0.49	
Target	Λ_c^+ τ (fs)	D^0 τ (fs)
1 Copper	198 ± 20	394 ± 13
2 Copper	198 ± 22	422 ± 14
3 Diamond	229 ± 25	413 ± 15
4 Diamond	178 ± 14	412 ± 14
5 Diamond	202 ± 16	413 ± 16
average	195.2 ± 8.2	410.1 ± 6.4
χ^2/dof	0.88	0.55

	Λ_c^+ $\Delta\tau$(fs)	D^0 $\Delta\tau$(fs)
acceptance	5.1	3.8
mass reflections	1.3	
background systematics	-	1.0
second charm in event	< 1.0	< 1.0
other	< 1.5	< 1.5
total (quadrature)	5.6	4.3

	Lifetime	Stat. Err.	Sys. Err.
$\Lambda_c^+ \to pK^-\pi^+$	198.1 fs	7.0 fs	5.6 fs
$D^0 \to K\pi$	416 fs	8 fs	–
$D^0 \to K\pi\pi\pi$	402 fs	10.5 fs	–
D^0	407.9 fs	6.0 fs	4.3 fs
$D^\pm \to K\pi\pi$	1070 fs	36 fs	–
$D_s \to \phi\pi$	474 fs	22 fs	–
$D_s \to K^\star K$	478 fs	33 fs	–
D_s	475.6 fs	17.5 fs	4.4 fs



Λ_c^+
E691 1988
NA32 1989
E687 1990
NA14 1990
E687 1993
PDG 2000
SELEX 2000
CLEO prel
FOCUS prel
150 200 250
fs
D^0
E691 1988
ACMOR 1990
NA14 1990
E687 1991
E687 1994
CLEO 1999
E791 1999
PDG 2000
SELEX 2000
FOCUS prel
375 400 425 450
fs
$D_s^\pm$
E691 1988
ARGUS 1988
E687 1990
E687 1993
CLEO 1999
E791 1999
PDG 2000
SELEX prel
FOCUS prel
400 500 600
fs
D_s/D^0
PDG 1998
CLEO 1999
E791 1999
SELEX prel
FOCUS prel
Average
0.8 1 1.2 1.4

Charm Hadroproduction

Charm hadroproduction is major challenge to factorized pQCD analysis

- quark-level QCD process is charm/anti-charm symmetric
- hadronization depends on local color field environment
- some experiments observe significant production asymmetries in some cases

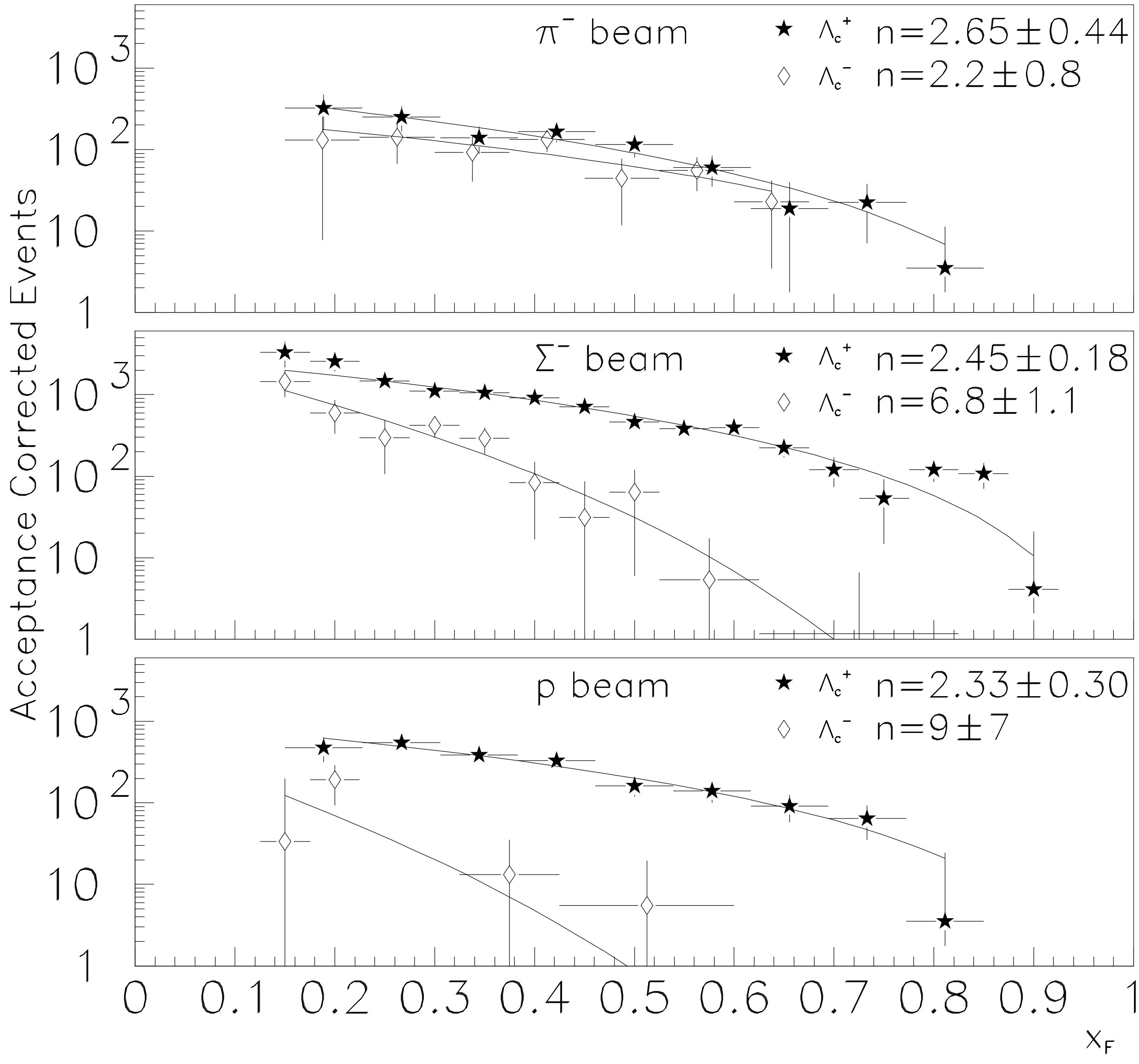
SELEX compares π^-, Σ^-, and p production in same apparatus
Clear systematic differences between pion and baryon beams emerge

Possible Phenomenology

Two classes of models for asymmetries: color-drag (leading particle effect) and intrinsic charm
Predictions differ:

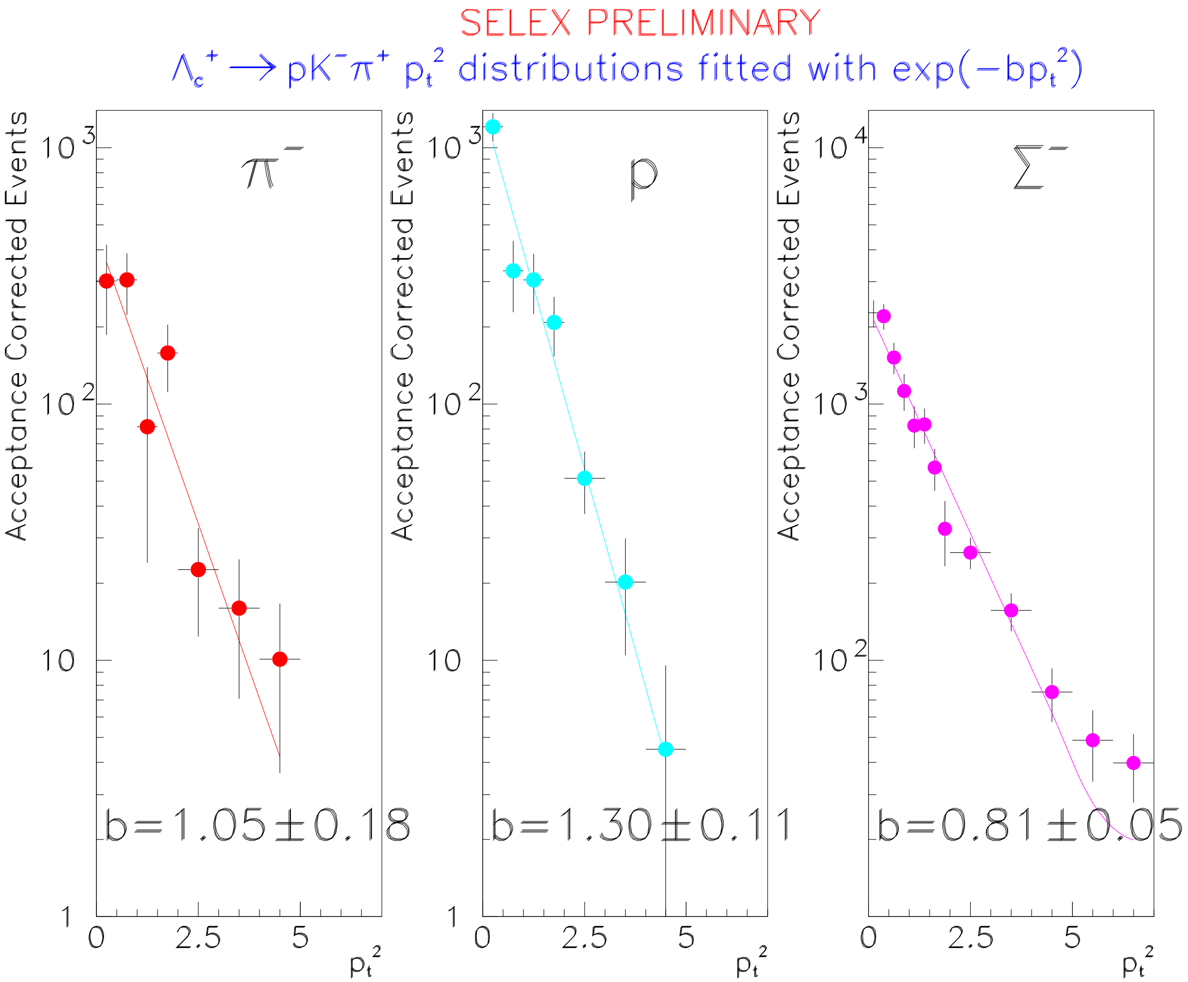
- color-drag effects are more pronounced at high x_F and don't depend on p_T
- intrinsic charm effects occur at low p_T, become apparent at large x_F

SELEX Measurements for Λ_c



- Λ_c production is very hard for all beam particles
- Striking contrast in $\overline{\Lambda_c}$ production between π^- beam (valence anti-quark) and baryon beams.
- Large-x_F structure in Σ^- data suggest Pythia-style color drag

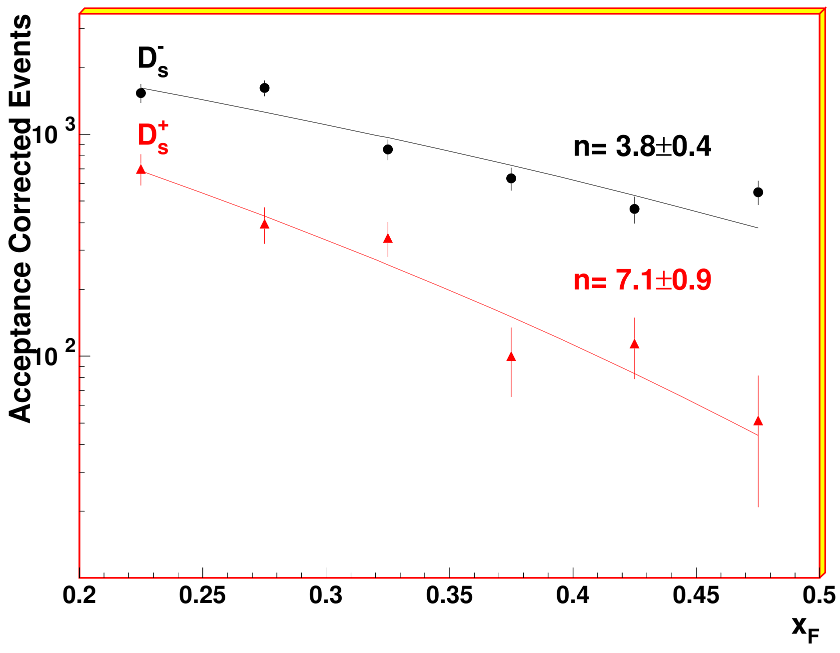
SELEX Measurements for Λ_c (cont.)



- Σ^- production data show expected deviation from Gaussian behavior slightly earlier than corresponding D^+ spectra from π beams
- Forward gaussian slope ($p_T^2 \leq 4\,(\mathrm{GeV}/c)^2$) same for all beams

SELEX Measurements for D_s

x_F Distributions for Σ^- Beam

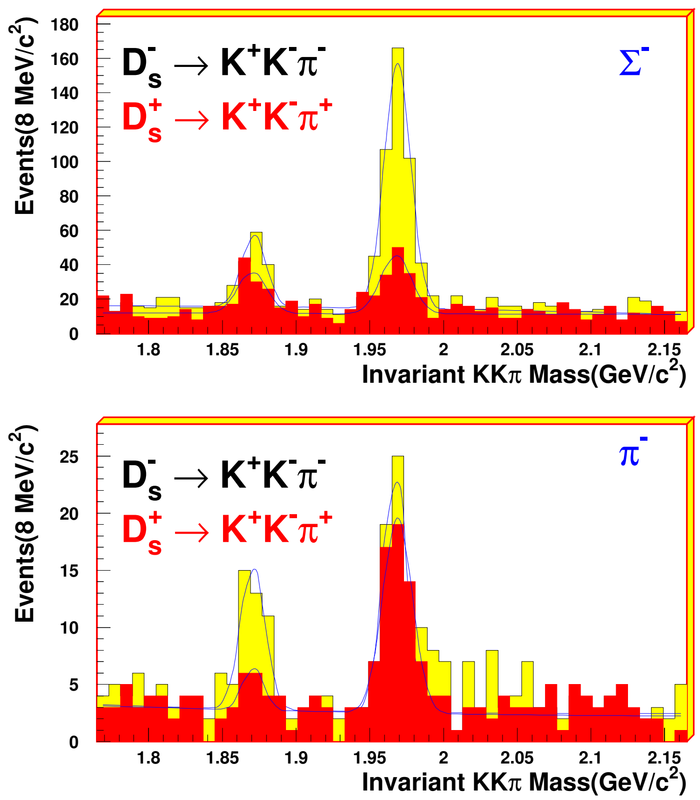


$$fit : (1 - x_F)^n$$

- Σ^- x_F distribution shows clear effect of valence quark
- no effect for the π^- beam

$\Longrightarrow$ Indication for color-drag effect

Raw Integrated Asymmetry

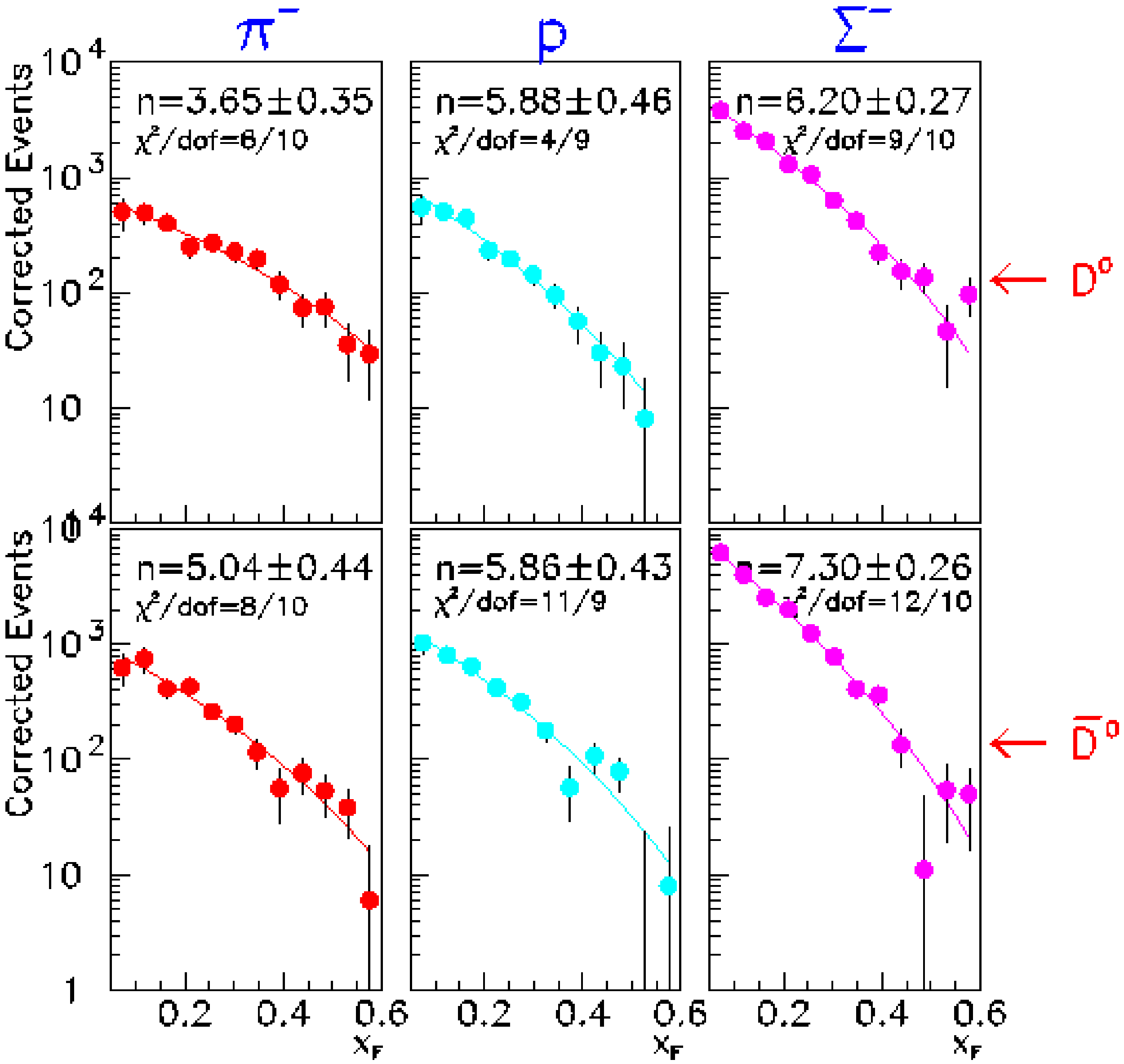


$$A \equiv \frac{N_{D_s^-} - N_{D_s^+}}{N_{D_s^-} + N_{D_s^+}}$$

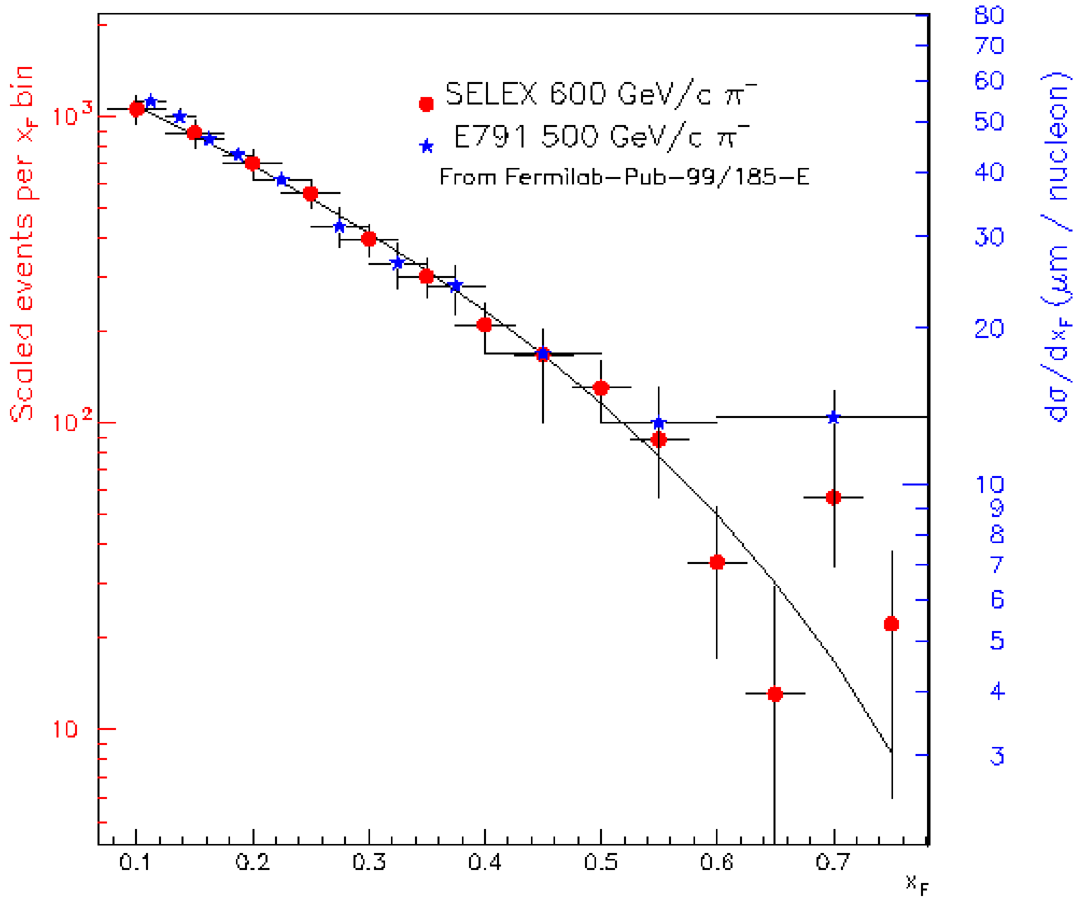
A($x_f > 0.2$)= 0.57 ± 0.07 Σ^-

A($x_f > 0.2$)= -0.08 ± 0.08 π^-

x_F Distributions for D^0 and $\overline{D^0}$

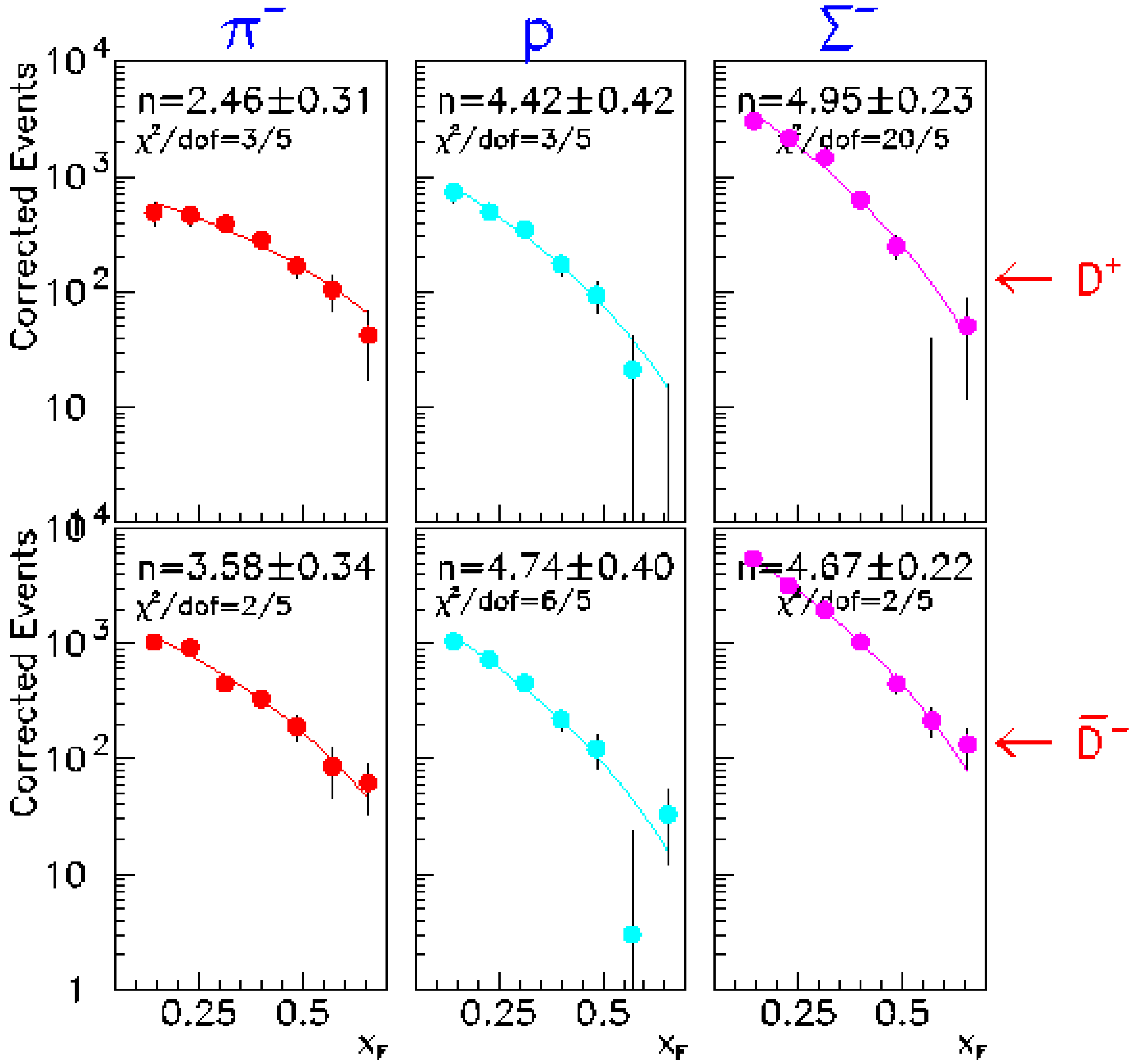


x_F Distribution for $D^0 + \overline{D^0}$ (π^- beam)

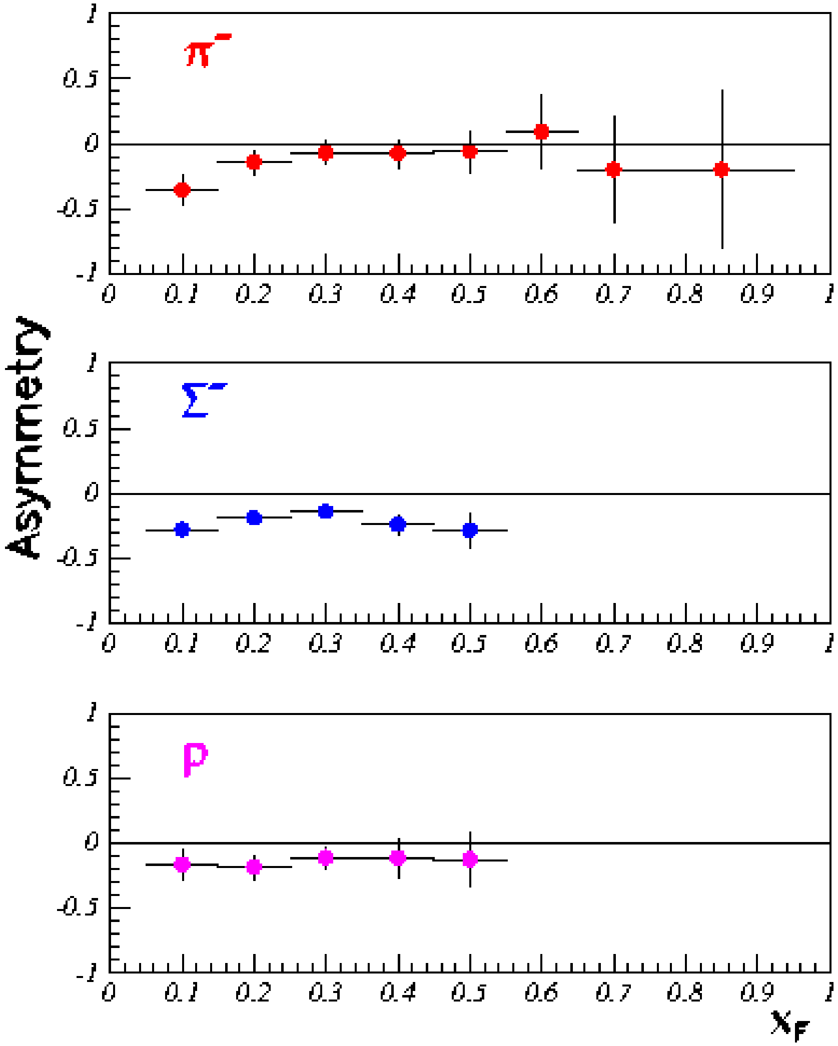


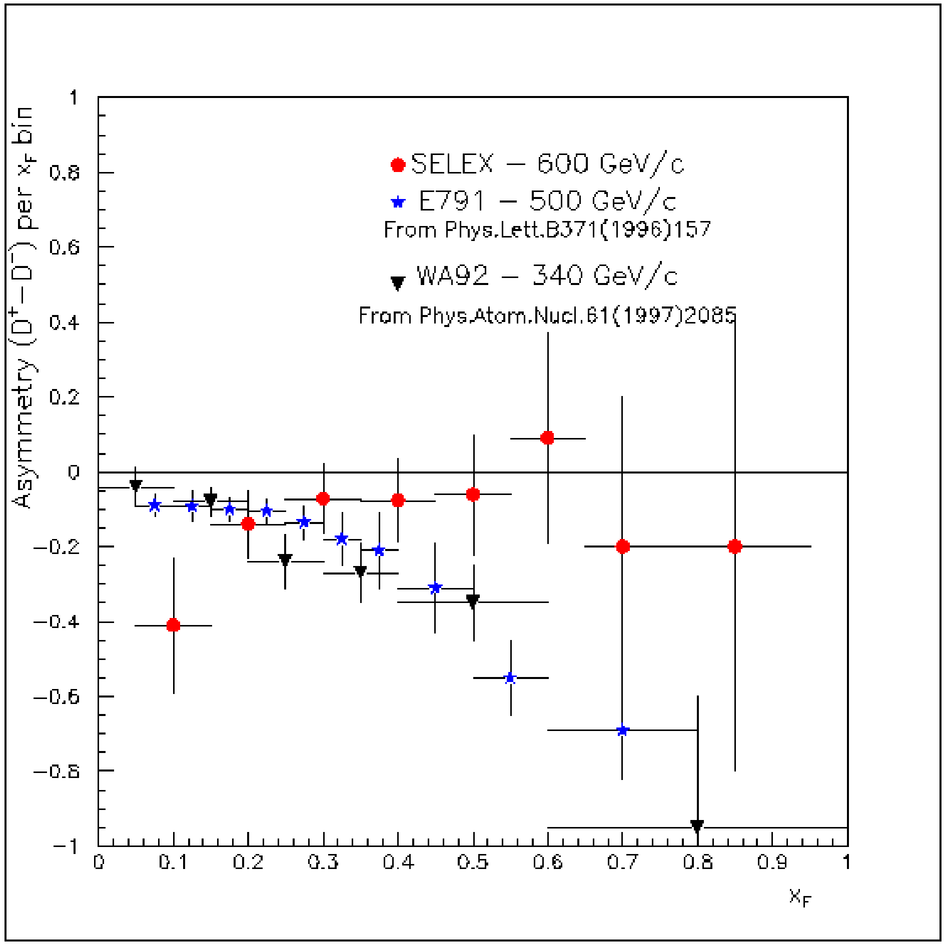
E791 Collaboration, Phys. Lett. B462 (1999) 225-236

x_F Distributions for $D^{\pm}$



$D^{\pm}$ Asymmetry



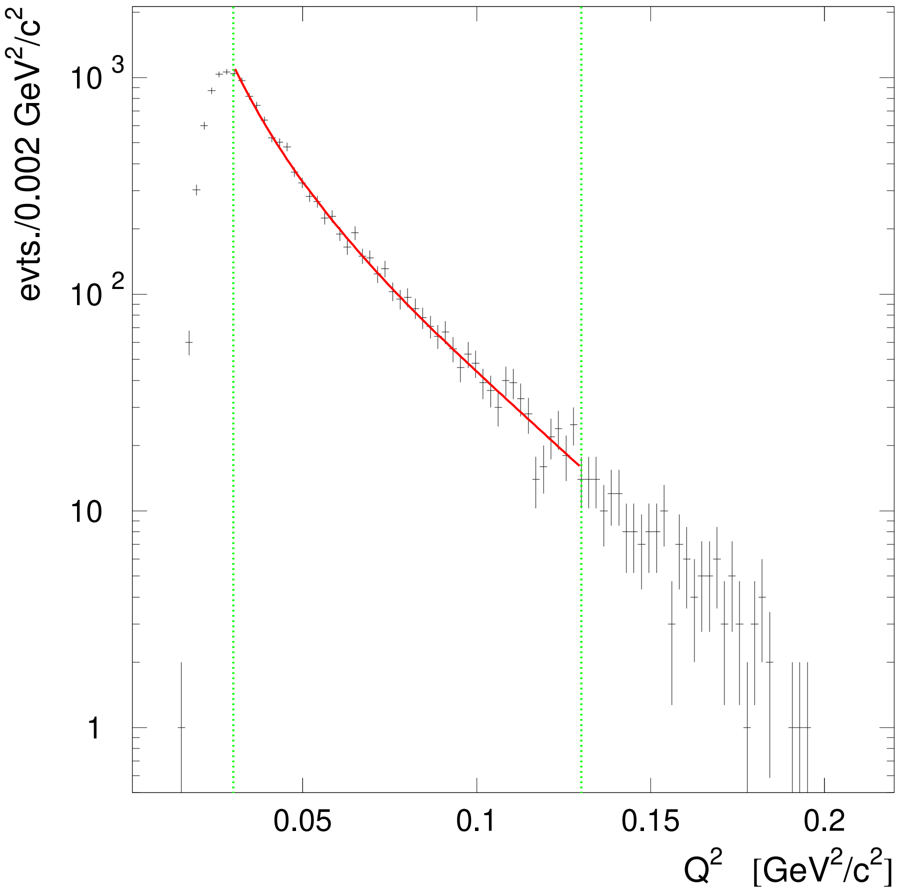


Charm Production Summary

SELEX has preliminary (nearly final) data for
$d\sigma/dx_F$, $d\sigma/dp_T$, and asymmetry
for
Λ_c, D^0, $D^\pm$, and $D_s^\pm$
with
Σ^-, π^-, and p beams

- charm $d\sigma/dx_F$ shows strong sensitivity to shared valence quark
- little support in SELEX data for "Intrinsic Charm"

Σ^- Charge Radius – Preliminary Results



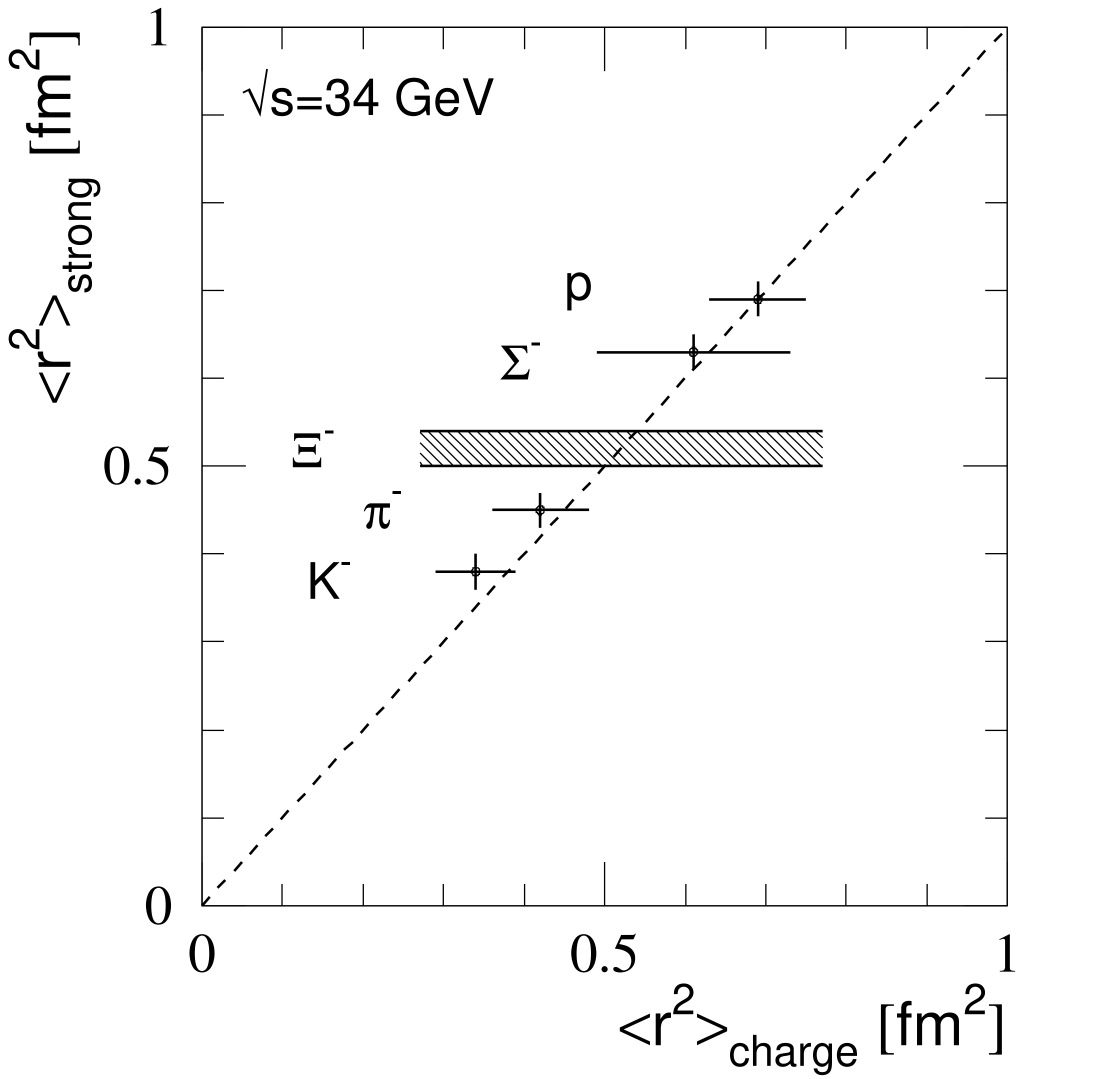
$$\frac{d\sigma}{dQ^2} = \frac{4\pi\alpha^2\hbar^2}{Q^4}\left(1 - \frac{Q^2}{Q^2_{\max}}\right) \cdot F^2(G_E, G_M, Q^2)$$

$$G_E(Q^2) = \frac{1}{\kappa - 1} G_M(Q^2) = \left(1 + \frac{1}{12} Q^2 <r^2_{ch}>\right)^{-2}$$

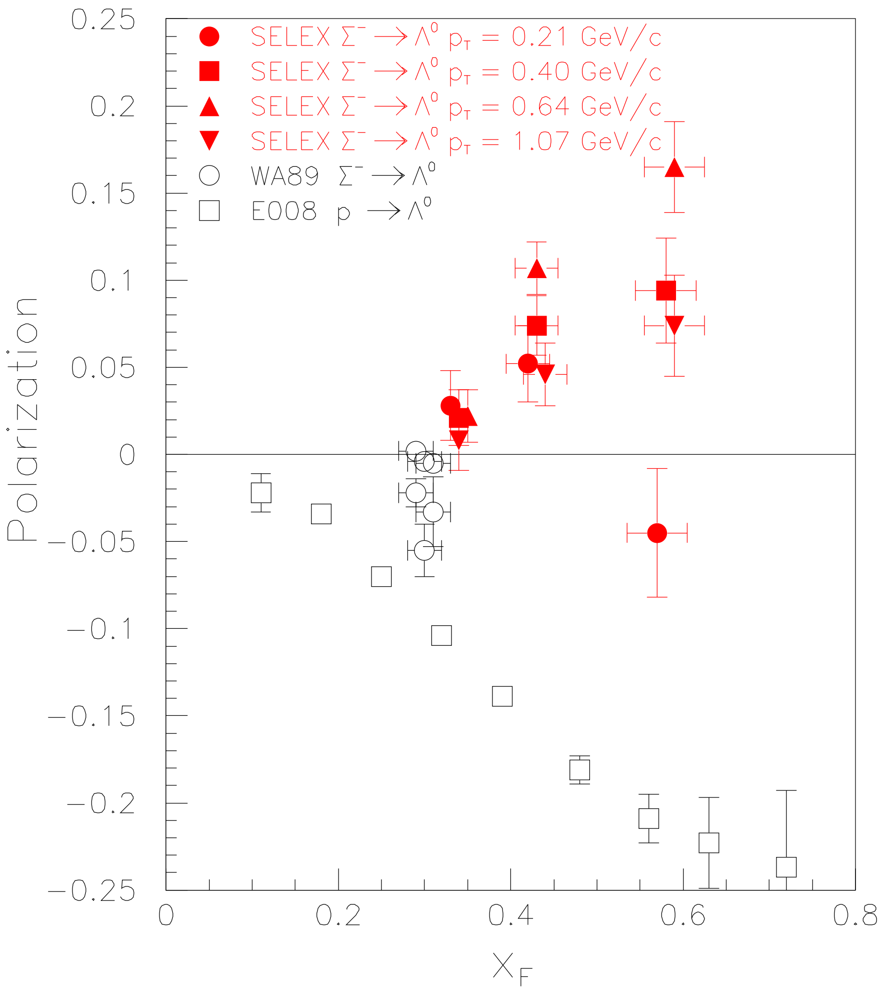
	SELEX $<r^2>$ [fm^2]	$<r^2>$ [fm^2]
Σ^-	$0.61 \pm 0.12 \pm 0.09$	0.91 ± 0.51 [a]
p	$0.69 \pm 0.06 \pm 0.06$	0.72 ± 0.01 [b]
π^-	$0.42 \pm 0.06 \pm 0.08$	0.44 ± 0.01 [c]

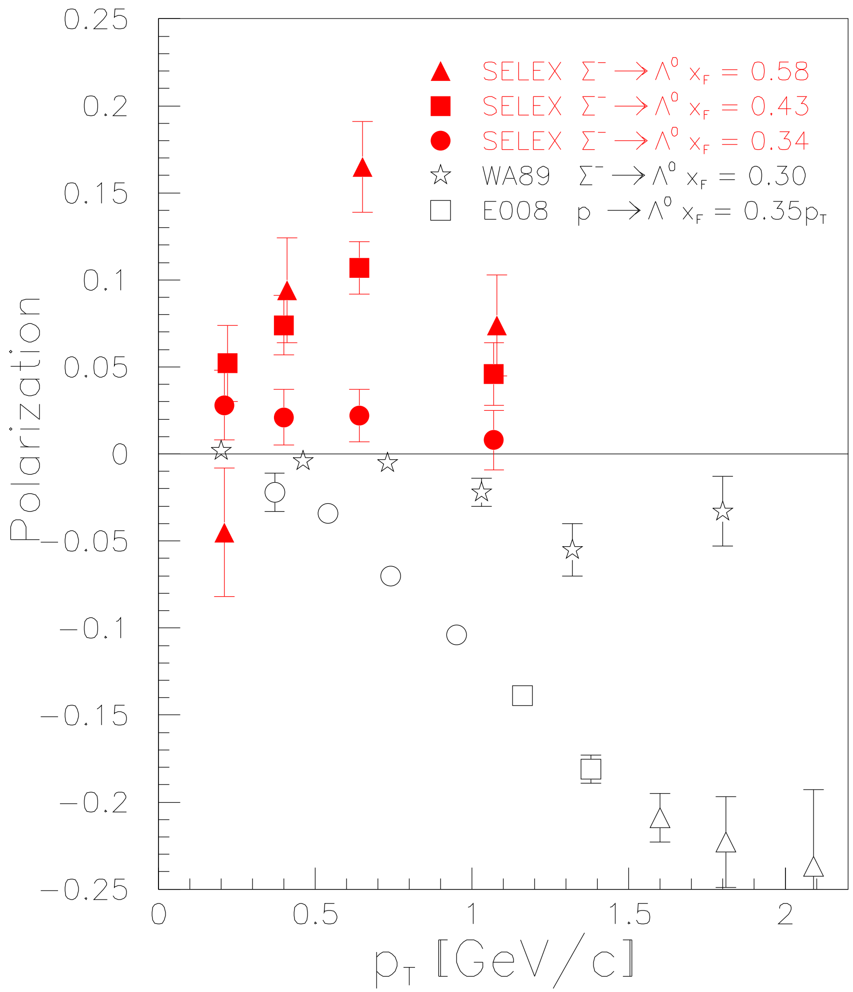
[a] WA89 Collaboration, Eur. Phys. J. **C8** (1999) 59
[b] Mergell et al., Nucl. Phys. **A596** (1996) 596
[c] NA7 Collaboration, Nucl. Phys. **A277** (1986) 168

Comparison Charge Radius – Strong Radius

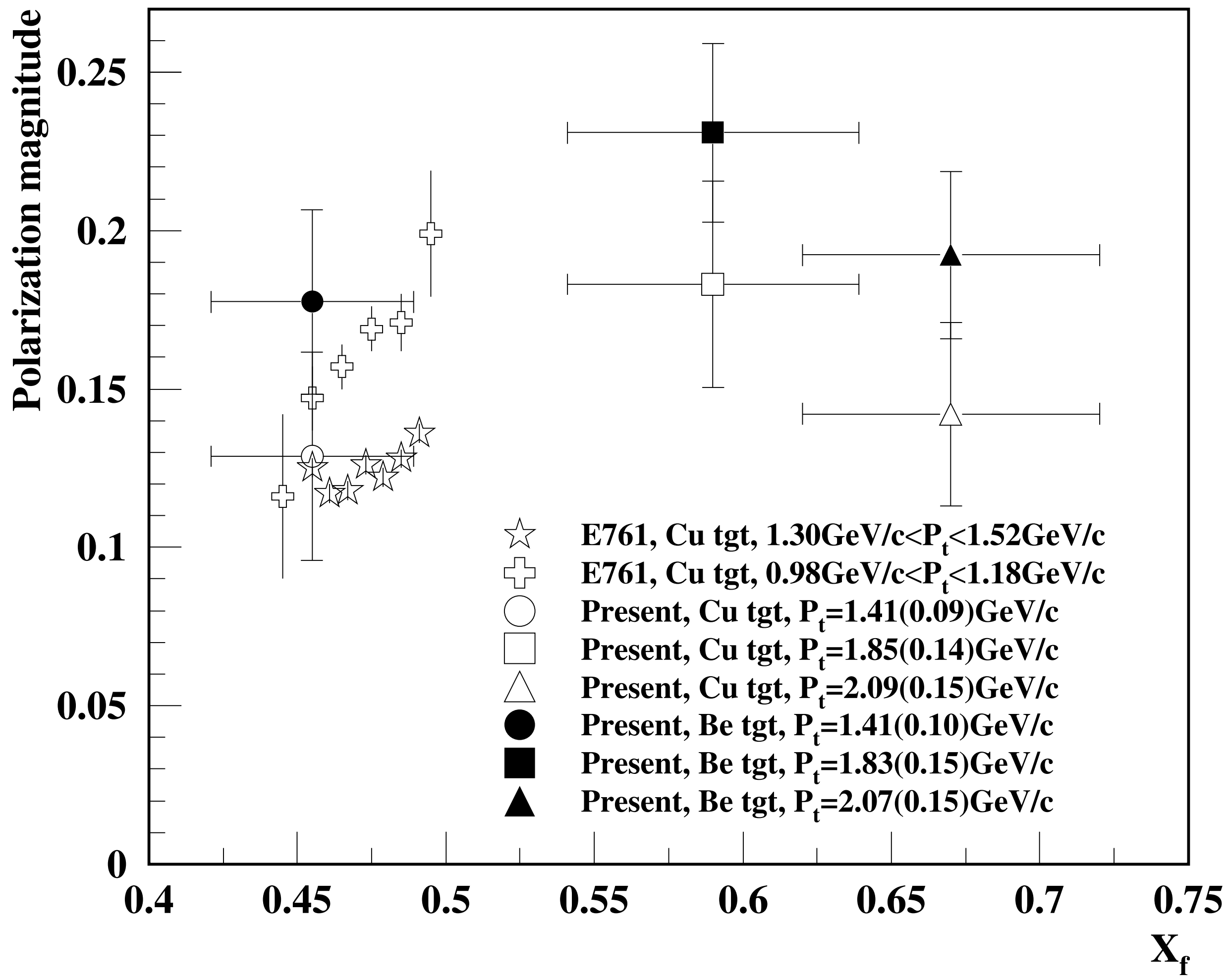


Polarization of Inclusively Produced Λ^0





Σ^+ Polarization



- X_F Dependence of the Σ^+ Polarization
- Σ^+ Polarization for Cu and Be Targets

Conclusion

- SELEX has most precise Λ_c lifetime measurement: $\tau(\Lambda_c) = (198.1 \pm 7.0 \pm 5.1)\,\mathrm{fs}$
- SELEX has preliminary $D_s^{\pm}$ lifetime measurement: $\tau(D_s^{\pm}) = (475.6 \pm 17.5 \pm 4.4)\,\mathrm{fs}$
- Analysis method validated with D^0 and D^+ lifetime
- SELEX has preliminary results on Λ_c, D_s, D^0, and $D^{\pm}$ production with Σ^-, π^- and p beams
- SELEX has measured the electromagnetic charge radius of the Σ^-
- New results on polarization