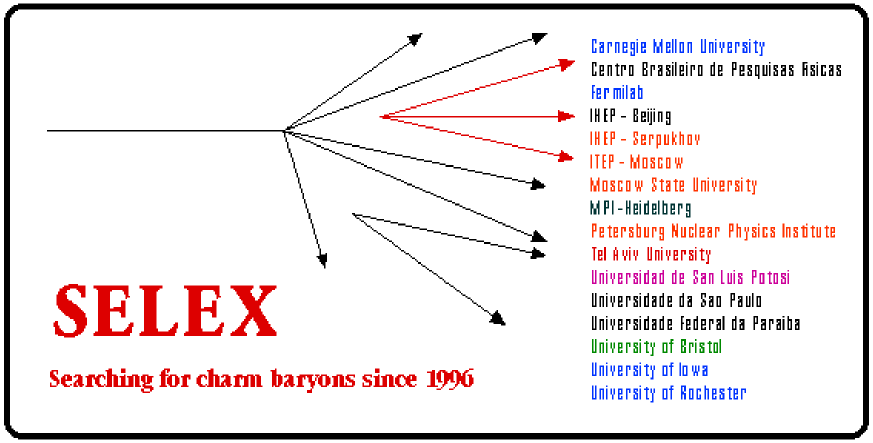

SELEX RICH Performance and Physics Results

RICH2002 Workshop, June 5-10, 2002
Jürgen Engelfried[1]
Instituto de Física
Universidad Autónoma de San Luis Potosí
For the SELEX RICH Group

Outline

- The Experiment
- Review of SELEX RICH Performance
- Physics Results obtained by SELEX
- Summary

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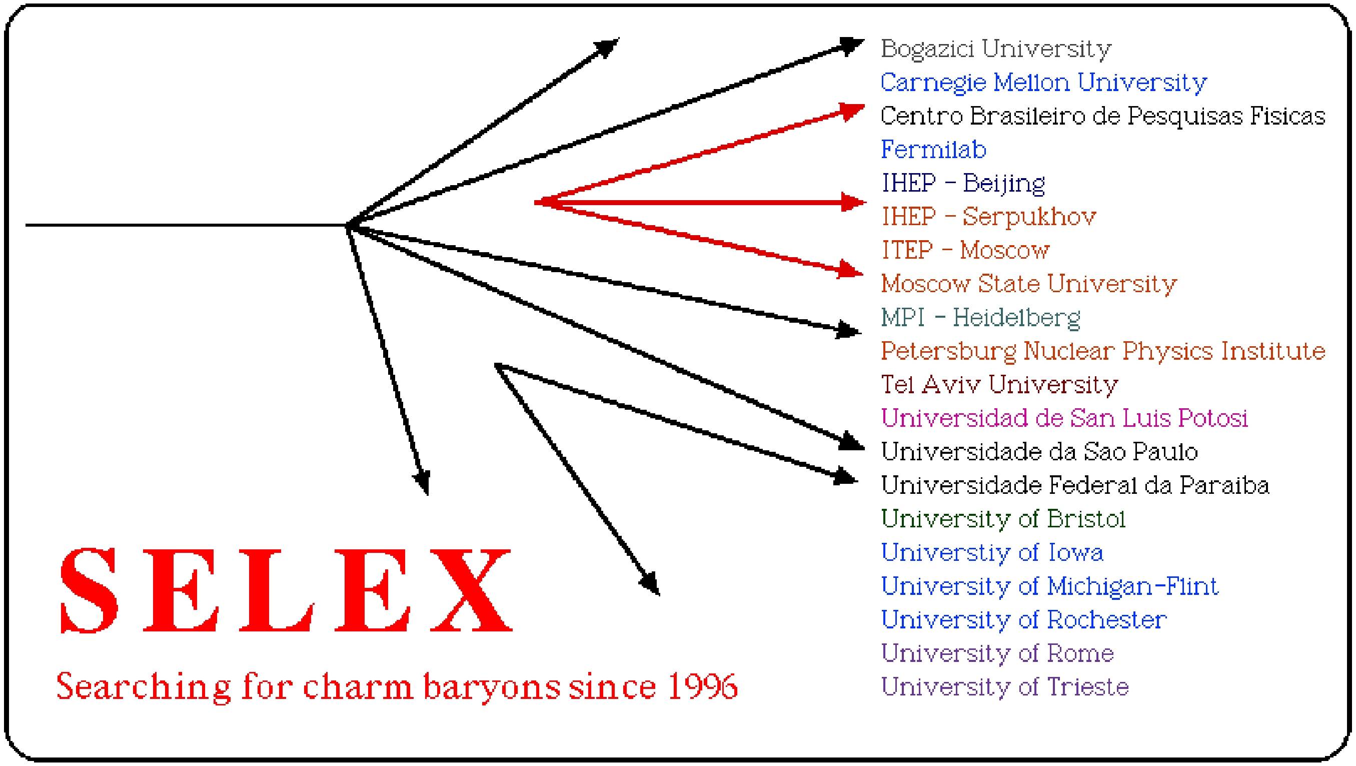


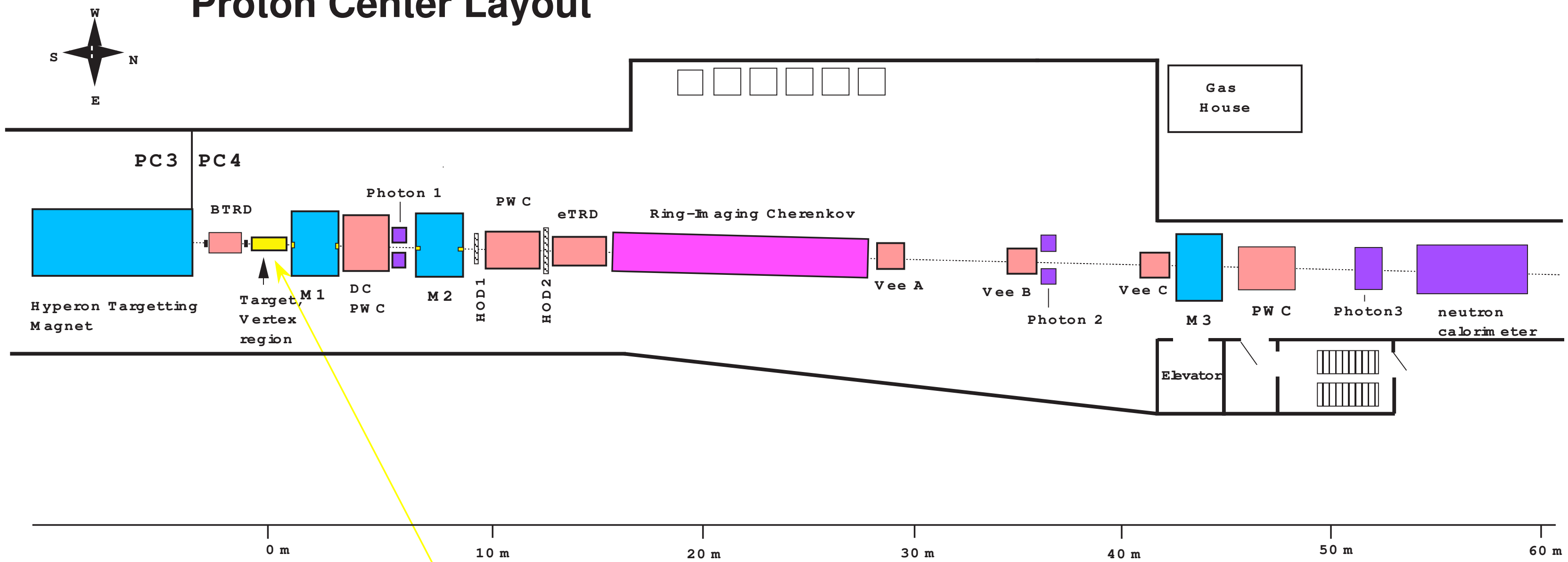
- 600 GeV/c negative Beam: 50 % π^- / 50 % Σ^-
- 570 GeV/c positive Beam: 92 % protons
- RICH Counter for definite identification of π, K, proton
- precision momentum resolution ($\delta p/p \approx 0.5\,\%$ at $100 - 300$ GeV/c)
- precision vertex resolution (primary: 270 μm; secondary: 560 μm)

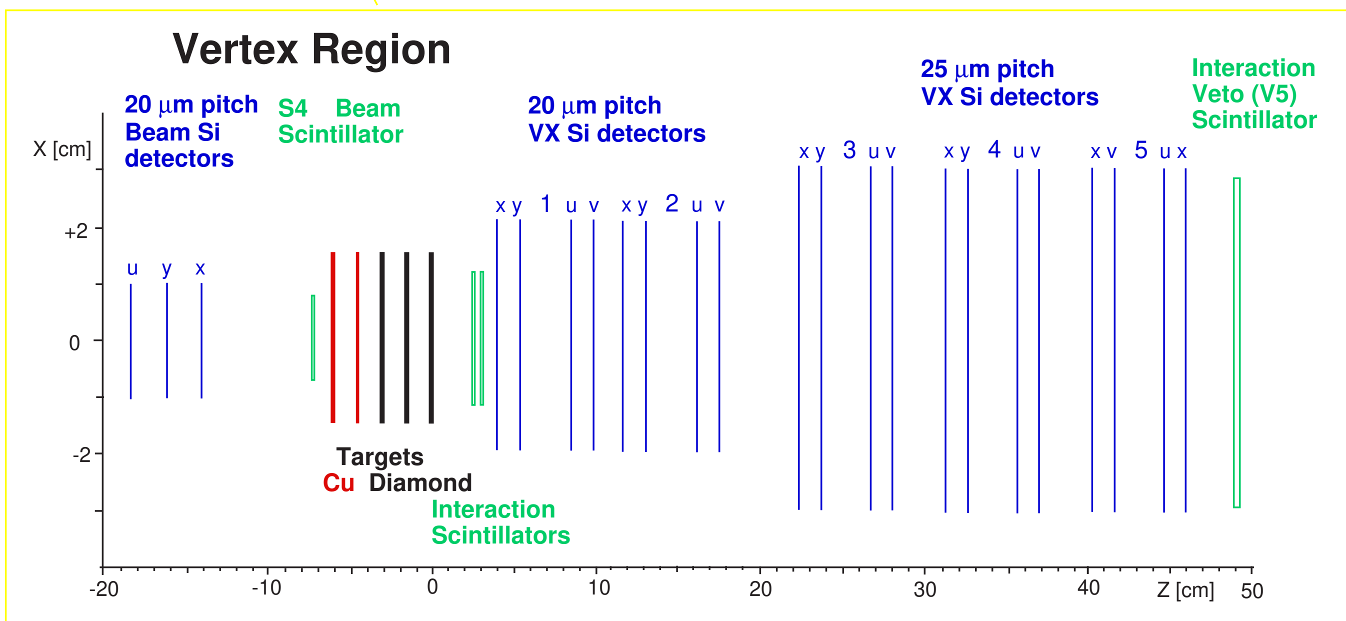
SELEX Apparatus

3 Segment Forward Spectrometer ($x_F > 0.1$)

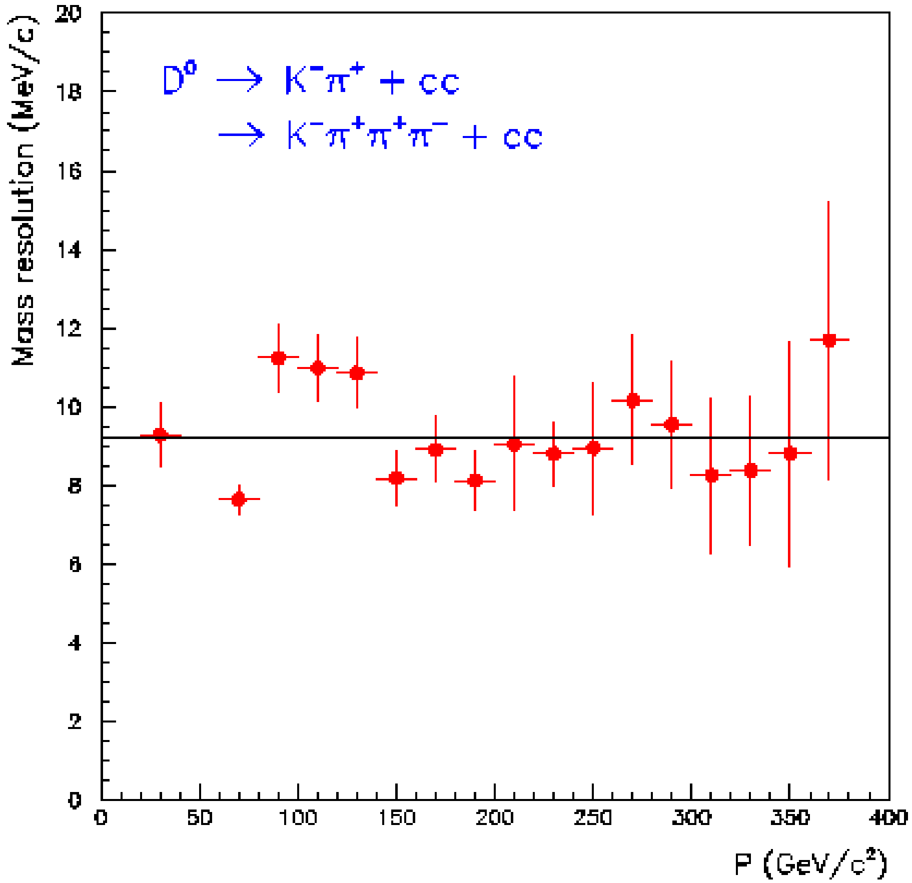
- 74000 Strip Silicon system, 4 μm transverse position resolution at 600 GeV/c
- Beam Tagging (Σ^-/π^-, p/π^+) with Beam TRD
- 3000 Phototubes RICH – 2 σ K/π separation up to 165 GeV/c
- Secondary e^- with Electron TRD for semileptonic decays
- Precise downstream tracking
  - 18 large silicon planes ($\sigma \sim 8\,\mu$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



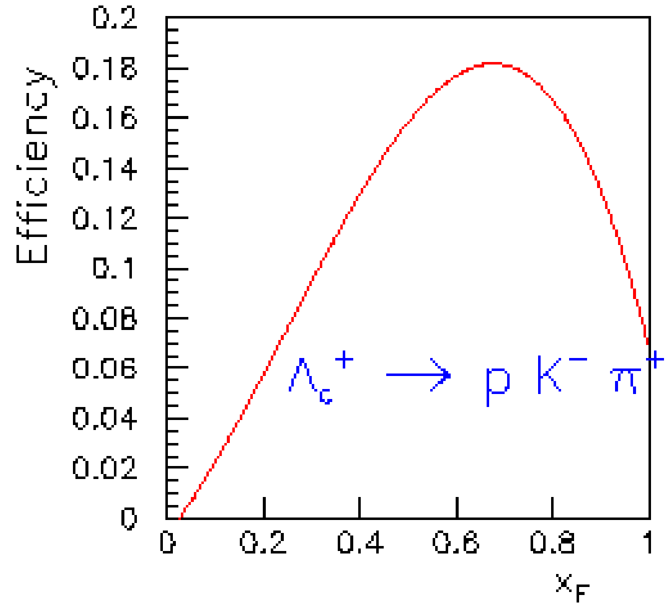


Mass Resolution



- $\Delta M \sim 9$ 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

Short History of SELEX

- Proposed in 1988
- 1990/91 Testbeam for Silicon Microstrips, RICH Prototype
- July 1996 – September 1997: Datataking
- 1998/9: First reconstruction pass over all data (8 months)
- 1999: First Publications submitted
- 2001: Second reconstruction pass over all data (8 months)

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Nuclear Instruments and Methods in Physics Research A 431 (1999) 53–69

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

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The SELEX phototube RICH detector

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Abstract

In this article, construction, operation, and performance of the RICH detector of Fermilab experiment 781 (SELEX) are described. The detector utilizes a matrix of 2848 phototubes for the photocathode to detect Cherenkov photons generated in a 10 m neon radiator. For the central region an N_0 of 104 cm^{-1}, corresponding to 13.6 hits on a $\beta = 1$ ring, was obtained. The ring radius resolution measured is 1.6%. © 1999 Published by Elsevier Science B.V. All rights reserved.

1. Introduction

The Fermilab experiment E781 (SELEX): a segmented large x_F Baryon spectrometer [1,2], which took data in the 1996/1997 fixed target run at Fermilab, is designed to perform high statistics studies of production mechanisms and decay physics of charmed baryons such as Σ_c, Ξ_c, Ω_c and Λ_c. The physics goals of the experiment require good charged particle identification to look for the different baryon decay modes. One must be able to separate π, K and p over a wide momentum range when looking for charmed baryon decays like $\Lambda_c^+ \to pK^-\pi^+$.

A RICH [3] detector with a 2848 phototube photocathode array has been constructed [4,5] to do this. The detector begins about 16 m downstream of the charm production target, with two analysis magnets with 800 MeV/c p_t-kick each in-between, and is surrounded by multi-wire proportional and drift chambers which provide particle tracking. The average number of tracks reaching the RICH is about 5 per event. First results from this detector can be found in Ref. [6].

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[1] Work supported by the US Department of Energy under contract NO. DE-AC02-76CHO3000.

[2] Deceased.

[3] Supported by the Russian Ministry of Science and Technology.

PII: S0168-9002(99)00043-1

SELEX RICH Vessel and Gas System

Vessel: 10.3 m long

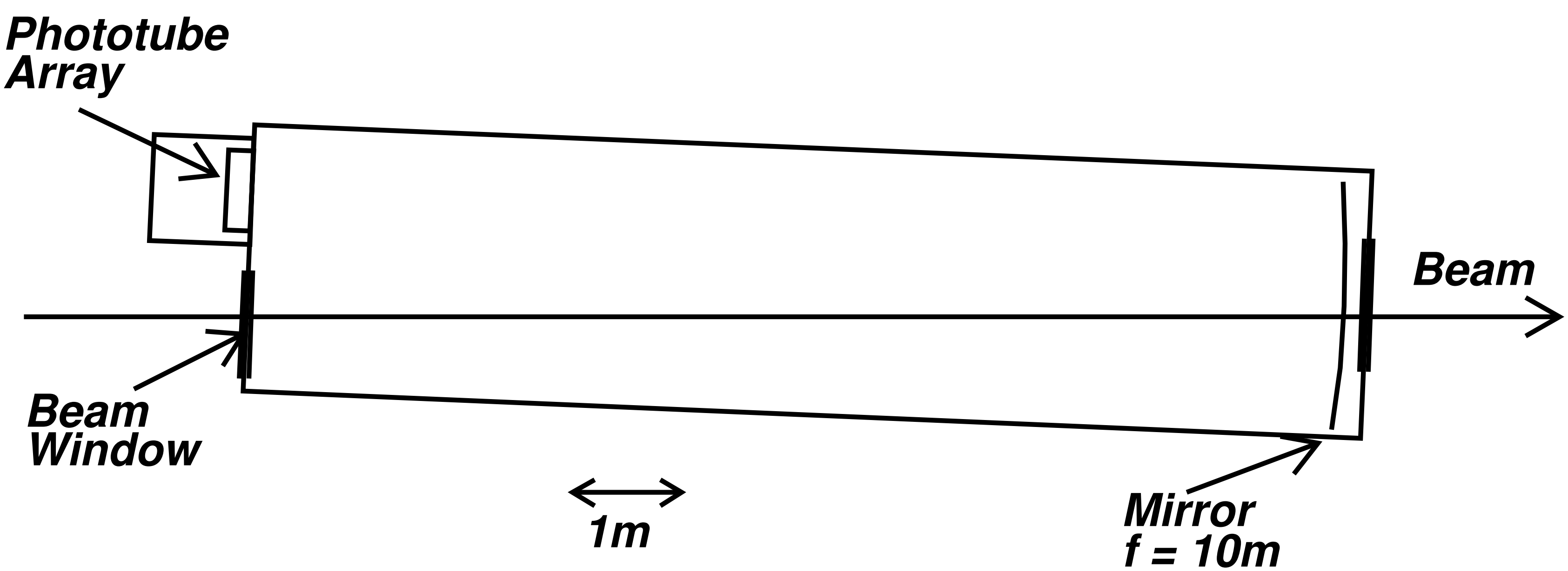
2.4 m diameter (50 m^3)

Gas: Neon @ 1 atm

closed volume ($\Rightarrow$ constant refractive index)

Filling:

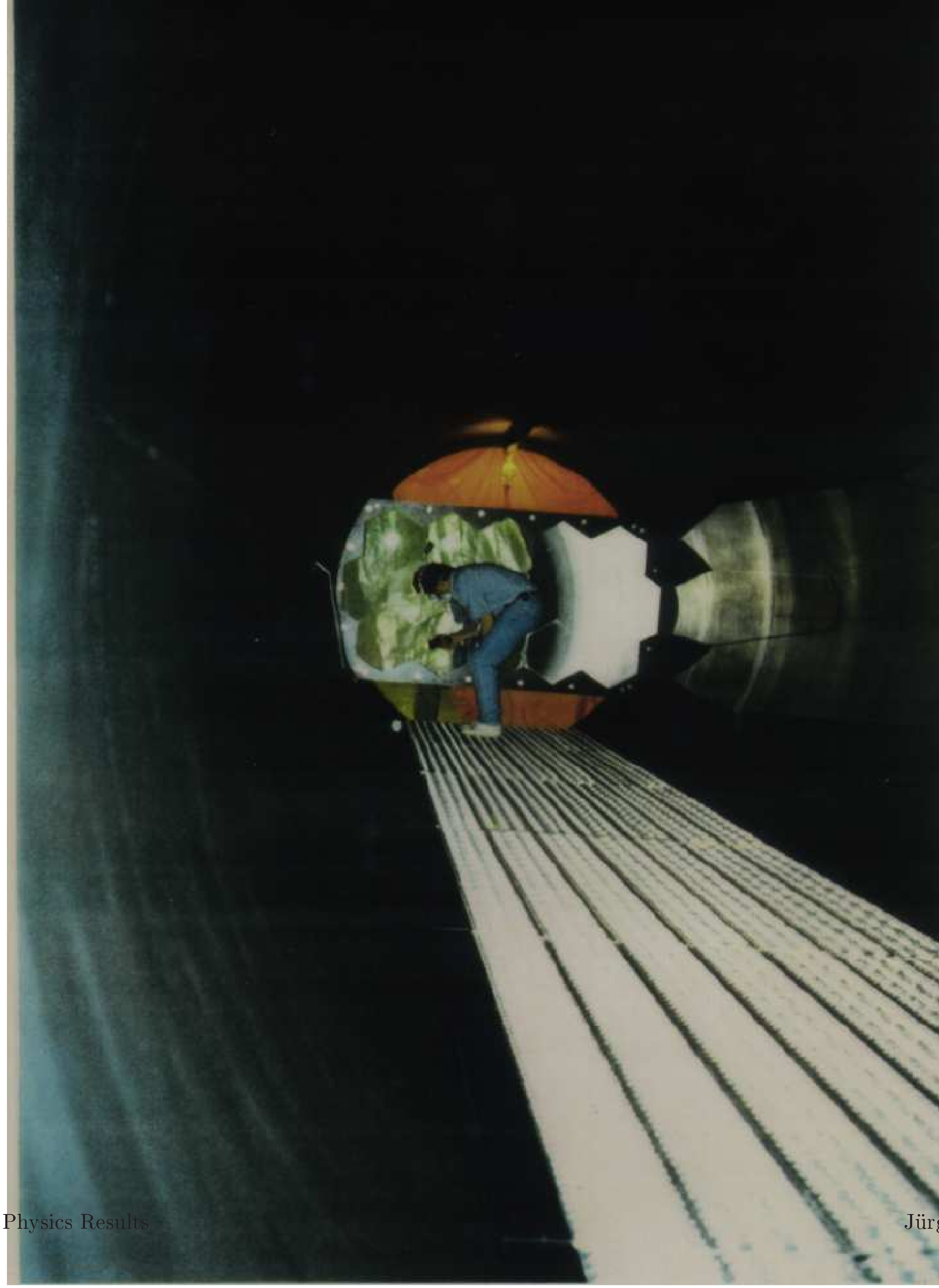
- purge with CO_2 ($\approx$ 1 day)
- freeze out CO_2, replace with Ne
- remove remaining O_2 and water
- started with 3 ppm O_2
- after 15 months: (20 ± 12) ppm



SELEX RICH Mirrors

Spherical, nominal 20 m Radius
16 hexagonal mirrors, 46 cm tip to tip

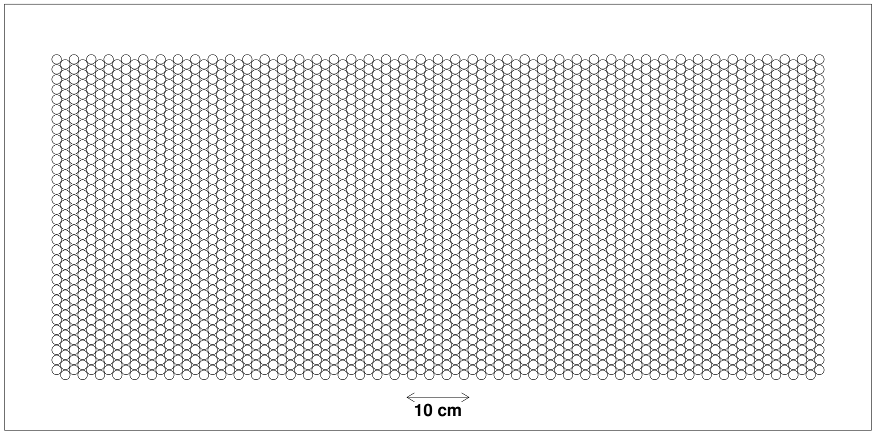
- Glass
  - low expansion glass (Schott Tempax), 10 mm thick.
  - Polished to 19.82 m $\pm$ 5 cm
  - Measured with Ronchi Method (NIMA 369 (1996) 69-78)
- Coating
  - Aluminum, with MgF_2 overcoating (Acton)
  - Reflectivity $> 85\,\%$ at 160 nm
- Mounting
  - 3 point mount
  - Ball bearing, double differential screw
  - Honeycomb panel with carbon fiber matrix
- Alignment
  - Theodolite with Laser in Center of Curvature
  - Vessel movable on wheels lateral to beam

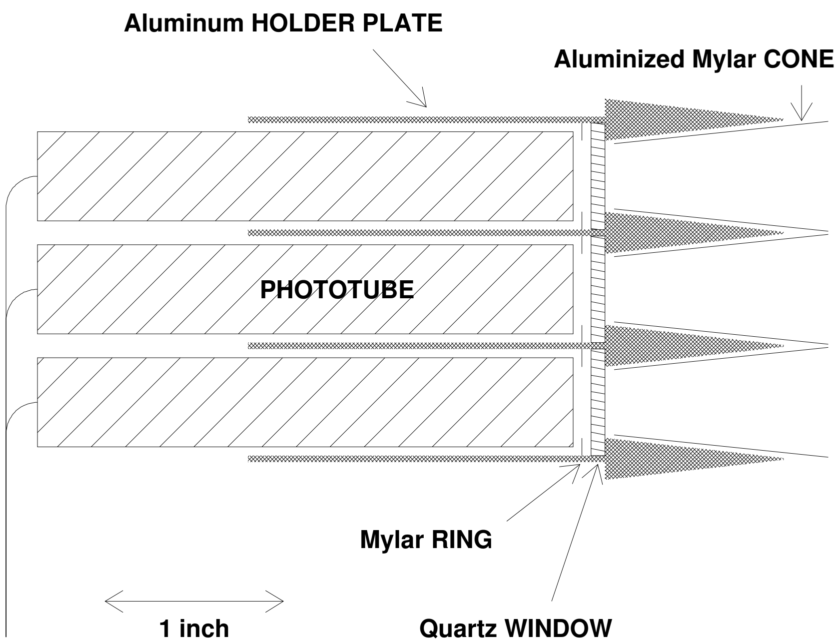


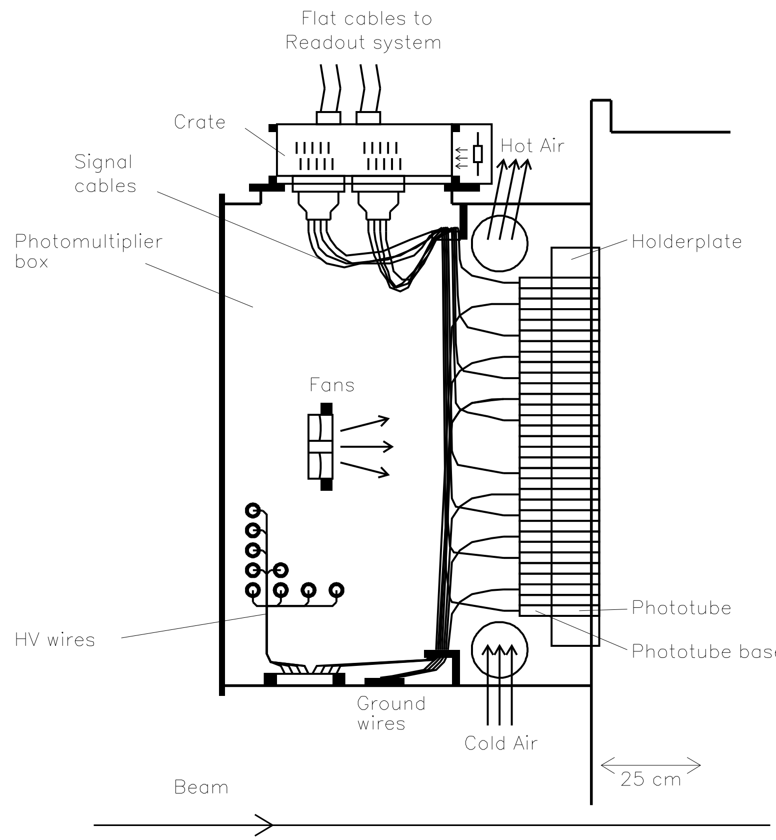
SELEX RICH Photon Detection

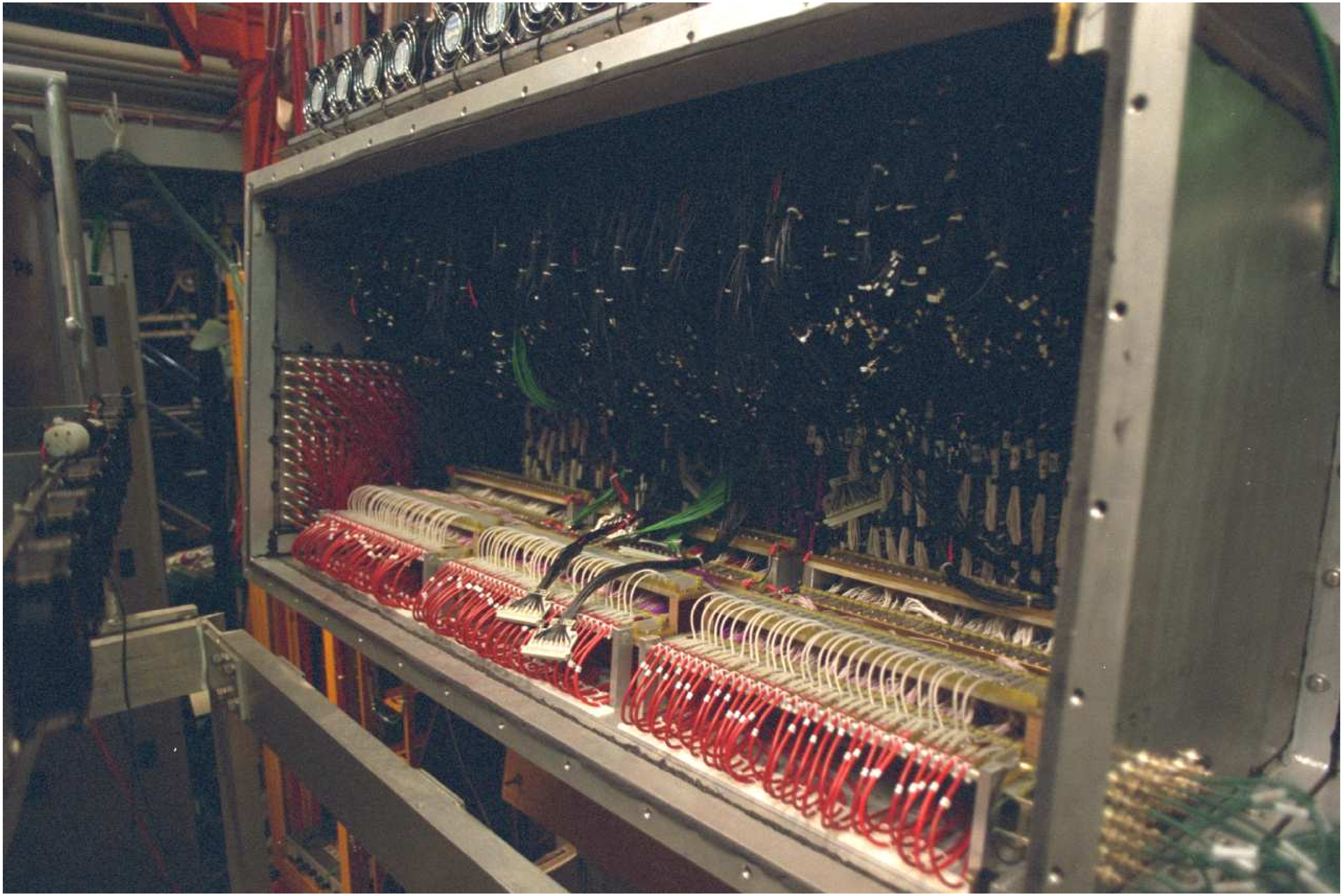
- Photomultiplier Holder
  - Aluminum plate, 2848 (89×32) holes
  - individual quartz windows as gas seal
  - aluminized Mylar Winston cones
- Photomultipliers
  - $\frac{1}{2}$" diameter, Photocathode 10 mm
  - 608 Hamamatsu R760
  - 2240 FEU60 (with wavelength shifter)
  - all PM measured to find operating voltage
  - groups of 32 run on same HV
- High Voltage
  - Operating Voltage 900 V...1900 V
  - 6 HV Supplies
  - Zener Box (á la "Berkeley Cow"), 96 outputs
- Crates with Hybrid Chips
  - Hybrids contain Amplifier, Discriminator, diff. ECL Driver
- Readout: CROS PWC System
  - Integration time 170 nsec

SELEX RICH PM Box



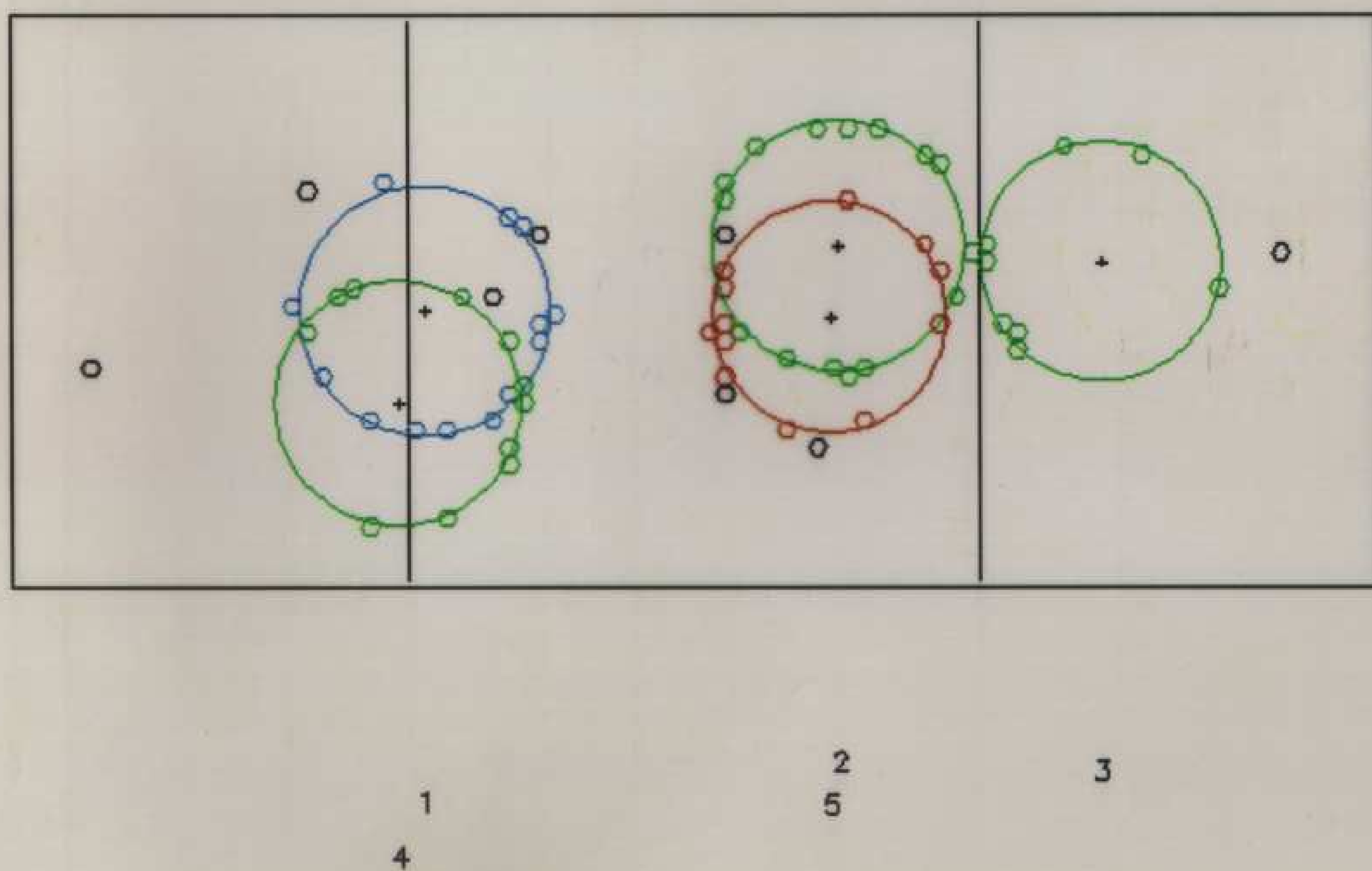






trk	momnt	pid	pckge	stat	gam	bckg	e	muon	pion	kaon	p	sigma
1	71.4	5	rich	8	-1.00	0.00	0.79	1.00	0.88	0.00	0.00	0.00
2	-136.8	9	rich	8	-1.00	0.00	0.88	0.96	1.00	0.00	0.00	0.00
3	-38.1	9	rich	8	-1.00	0.00	0.00	0.06	1.00	0.00	0.00	0.00
4	50.0	8	rich	8	-1.00	0.00	0.24	0.81	1.00	0.00	0.00	0.00
5	-107.7	12	rich	8	-1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00

RUN 1755 EVENT 10000030 TUBES: 67



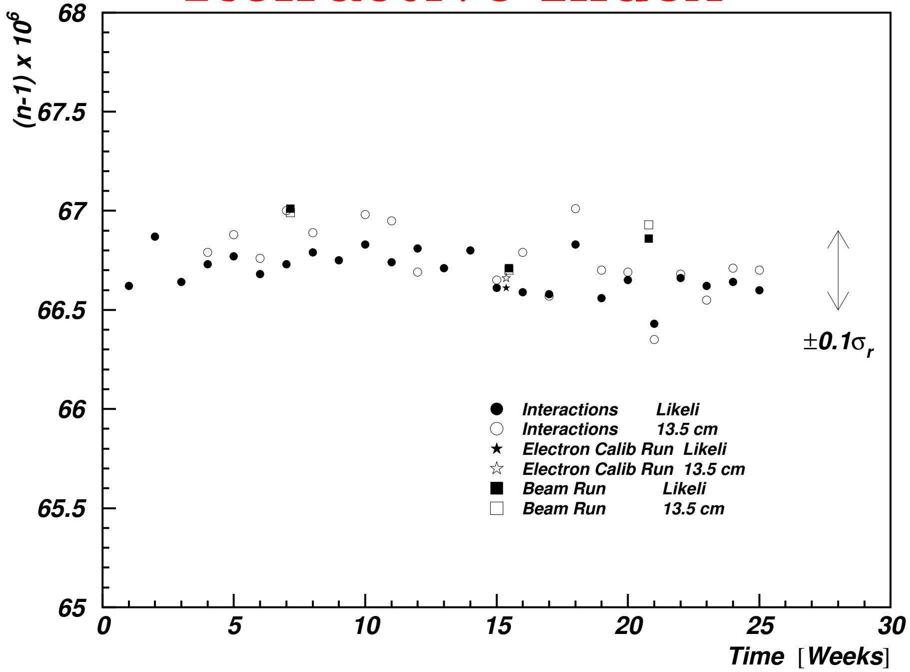
Particle Identification Algorithm[1]

- only discrete particle masses: e, μ, π, K, p, Σ, Ξ, Ω.
- Track parameter and momentum known
  $\Longrightarrow$ Calculate ring radius for each hypothesis
- "Compare" measured and expected rings for each hypothesis with a maximum likelihood method
- for identification, make cuts on likelihood ratios

[1] U. Mller et al.: Particle identification with the RICH detector in experiment WA89 at CERN. Nuclear Instruments and Methods A 343 (1994) 279-283

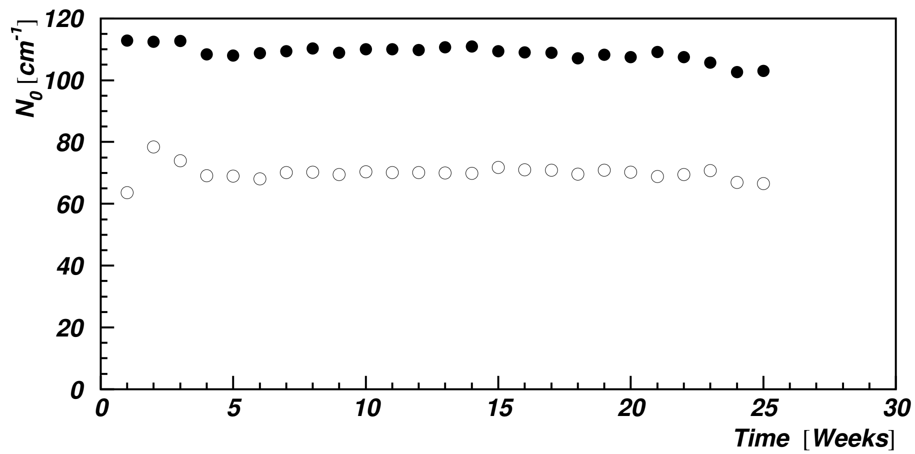
SELEX RICH Stability

Refractive Index

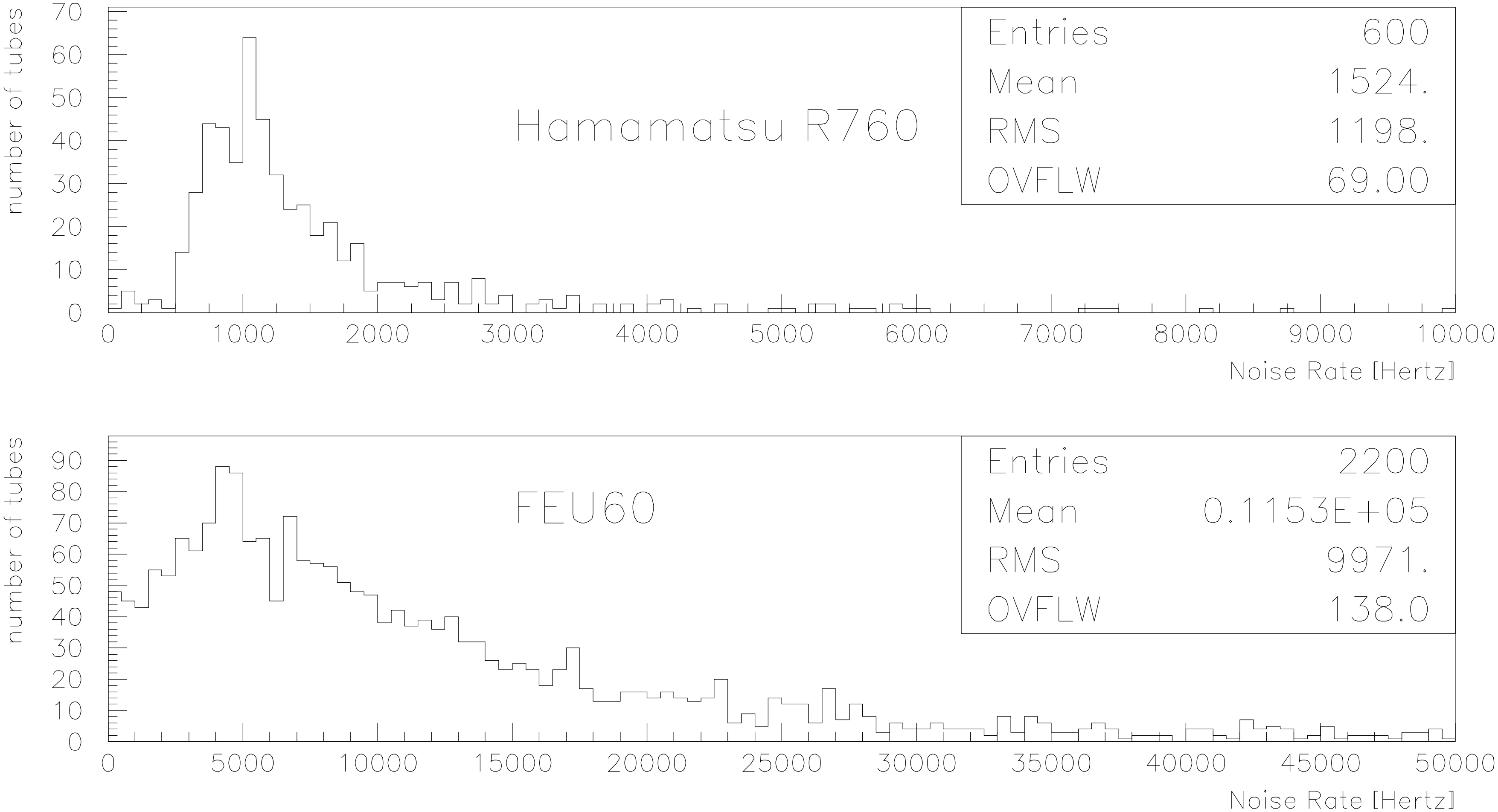


N_0

$$N_{\mathrm{ph}} = N_0 \cdot L \cdot \sin^2 \theta_c$$



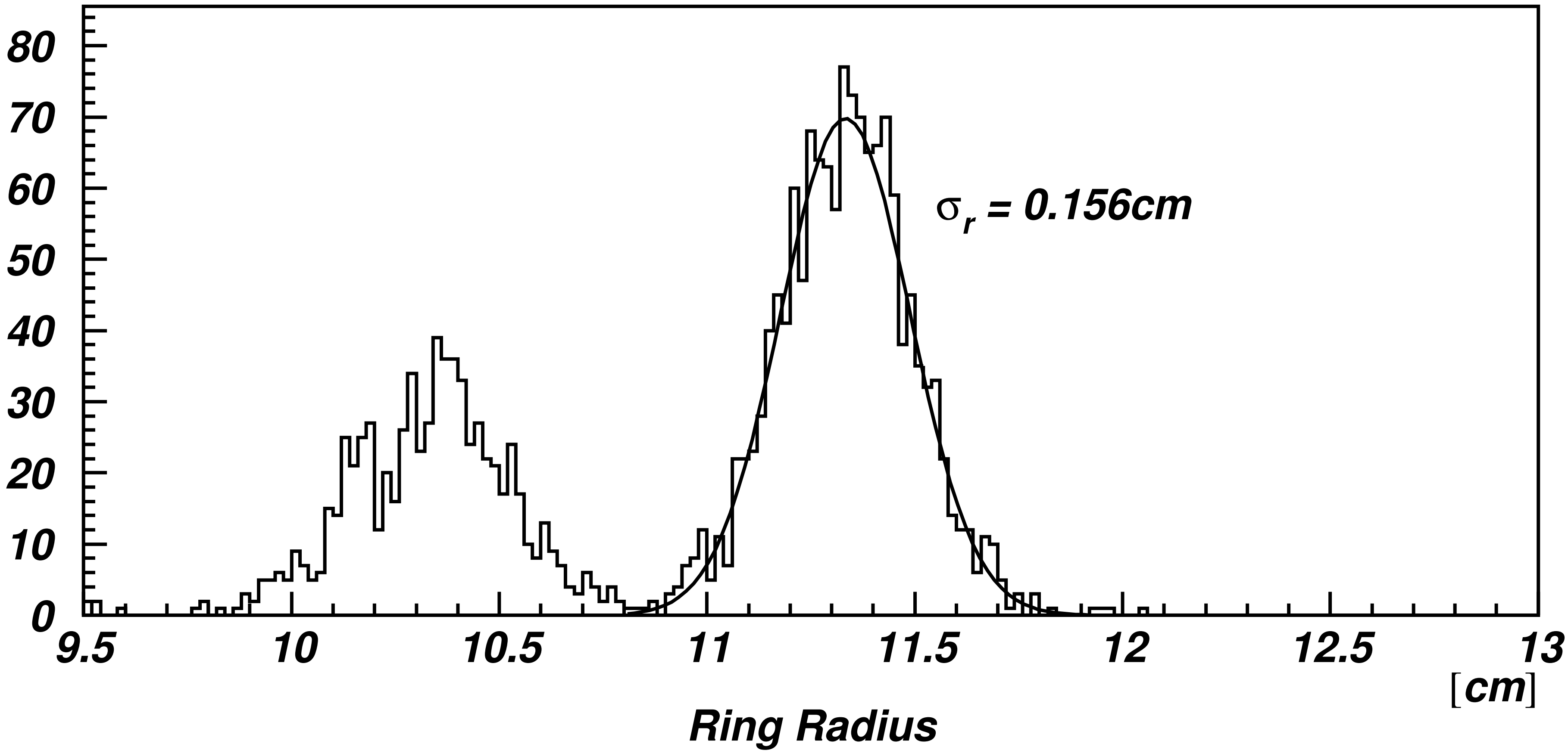
SELEX RICH: Noise Rates



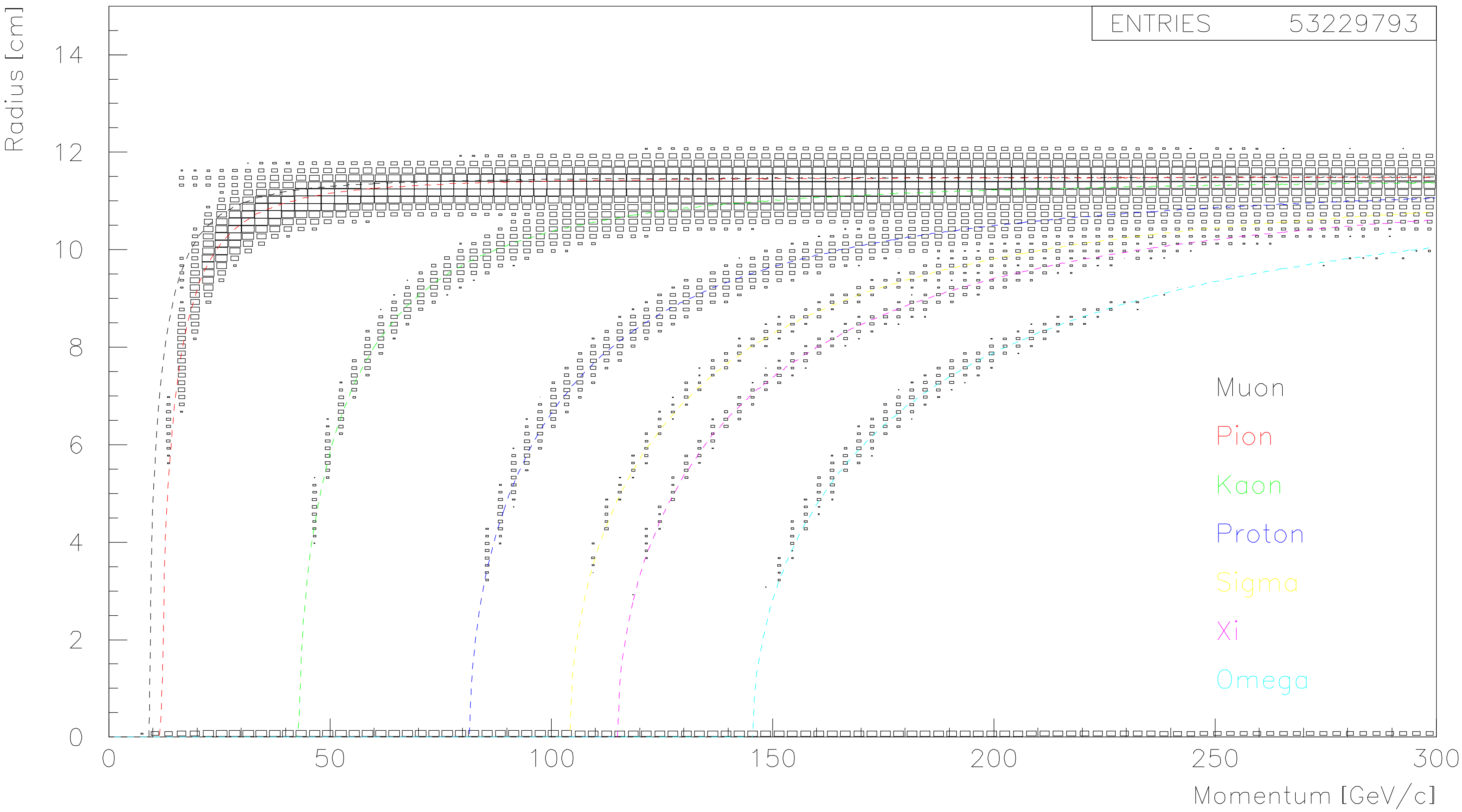
Gate length in SELEX: 170 nsec

SELEX RICH Separation

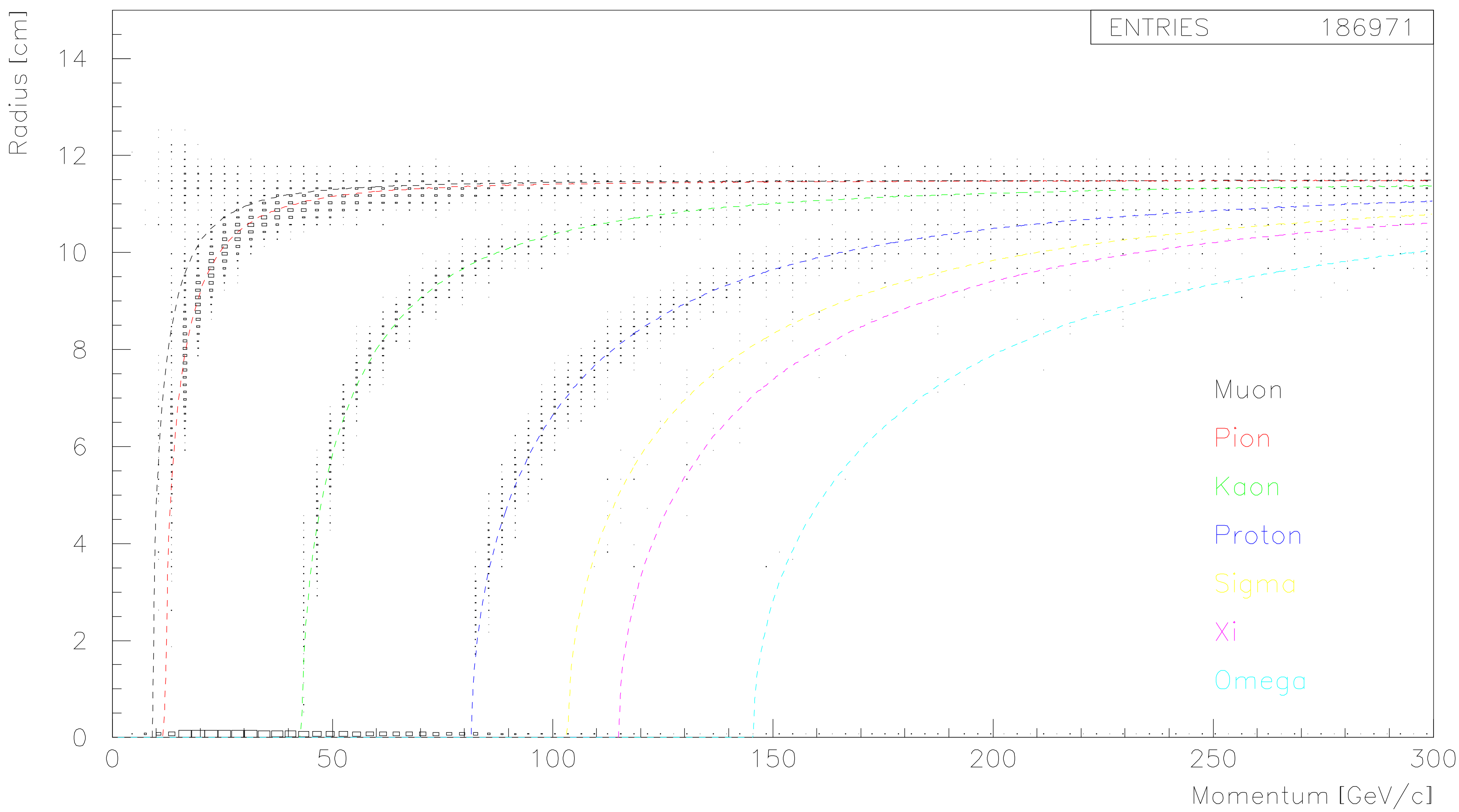
Momentum of particles: $95\,\mathrm{GeV}/c - 105\,\mathrm{GeV}/c$



SELEX RICH: Particle Id negative tracks

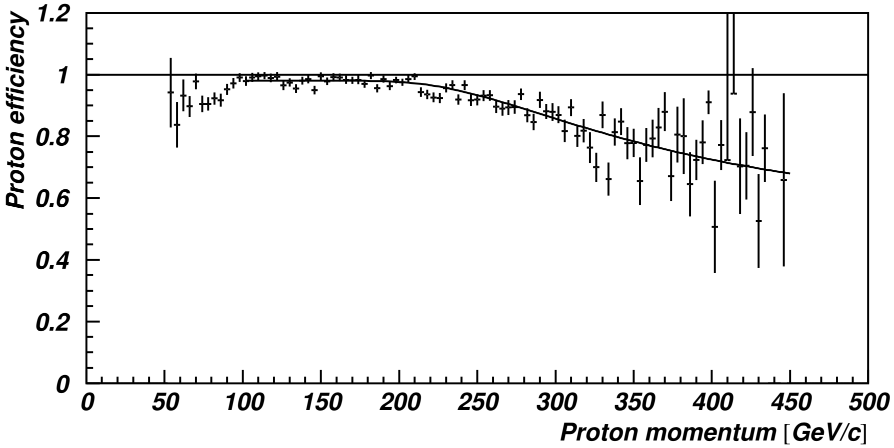


SELEX RICH: Particle Id positive tracks

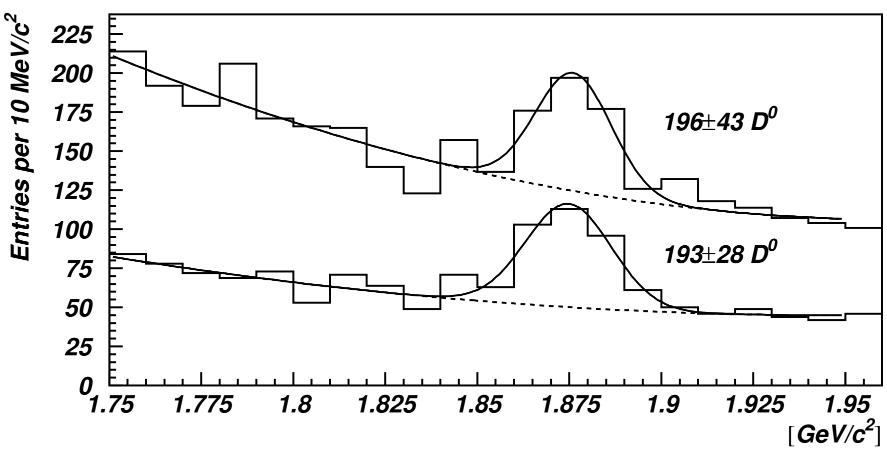


SELEX RICH Efficiencies

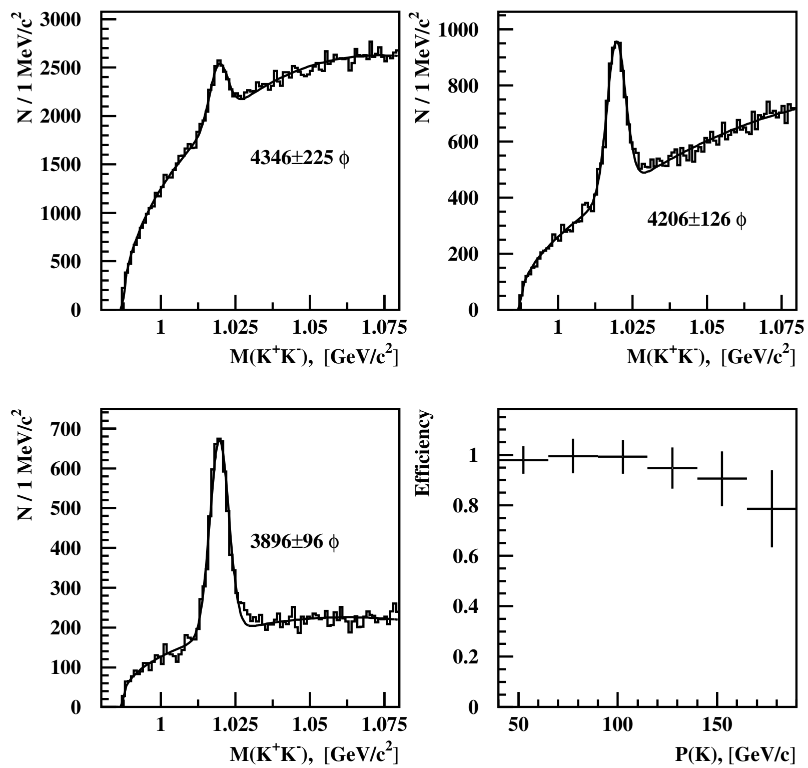
Protons



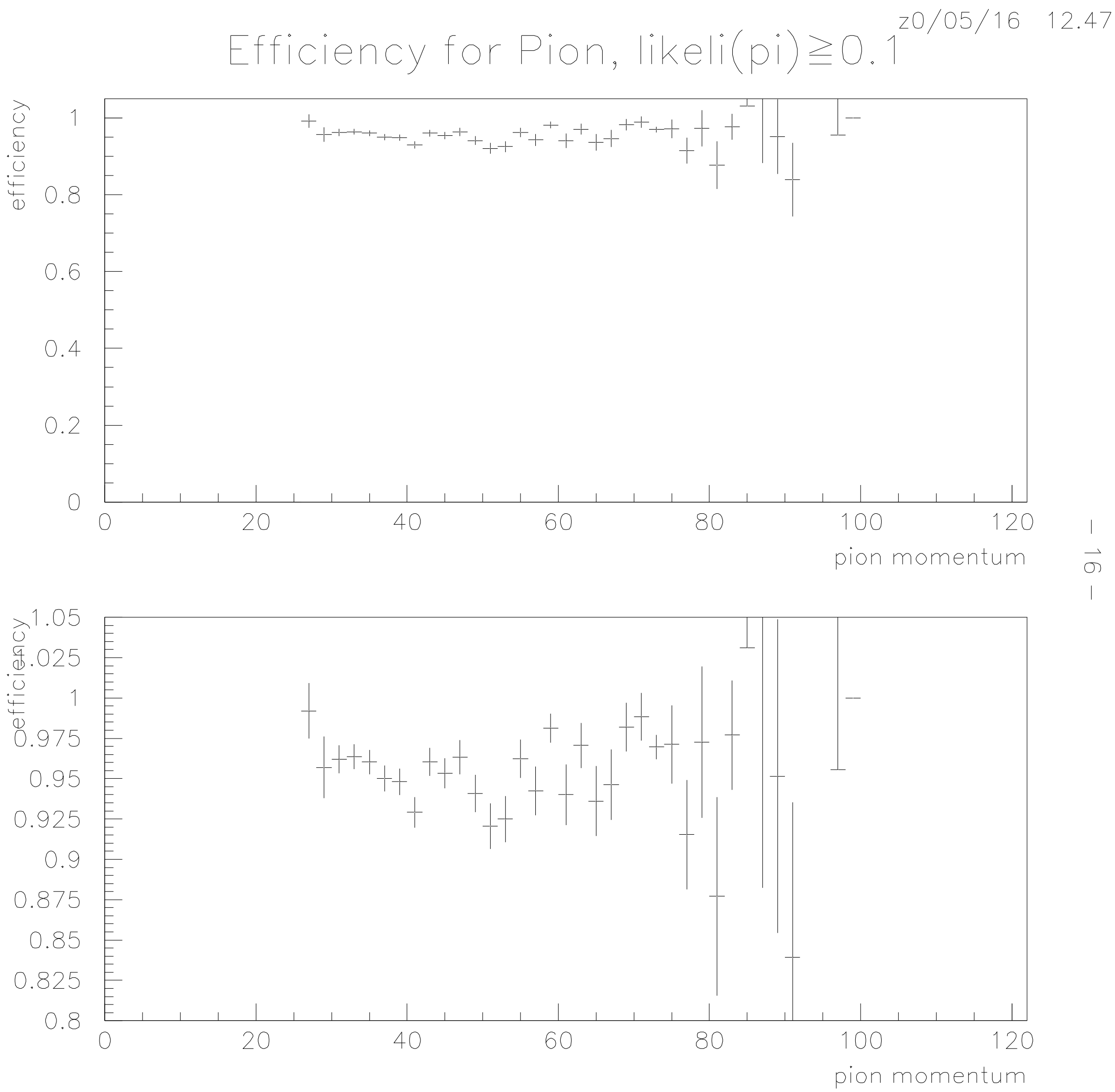
$D^0 \to K^{\mp}\pi^{\pm}$



Kaons

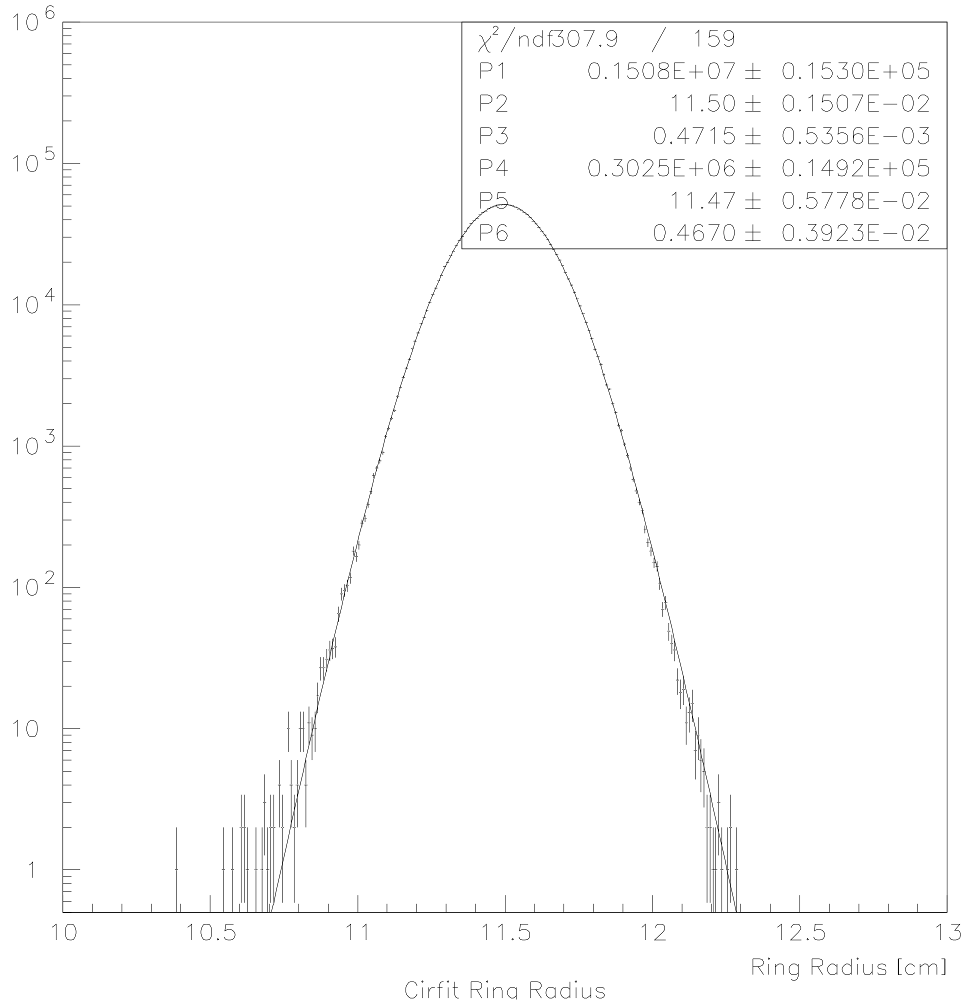


SELEX RICH Efficiency – Pions



How Gaussian is the response?

A Study with SELEX single beam tracks



Gaussian over nearly 5 orders of magnitude!

SELEX Publications

1. S.Y.Jun et al.: *Observation of the Cabibbo-suppressed decay* $\Xi_c^+ \to pK^-\pi^+$.
   Phys. Rev. Letter **84** (2000) 1857-1861.

2. U. Dersch et al.: *Total Cross Section Measurements wit* π^-, Σ^- *and Protons on Nuclei and Nucleons around* 600 GeV/c.
   Nucl. Phys. B 579 (2000) 277-312.

3. A. Kushnirenko et al.: *Precision measurements of the* Λ_c^+ *and* D^0 *lifetimes.*
   Phys. Rev. Letter **86** (2001) 5243-5246.

4. V. Molchanov et al.: *Radiative decay width of the* $a_2(1320)^-$ *meson.*
   Physics Letters **B521** (2001) 171-180.

5. I. Eschrich et al.: *Measurement of the* Σ^- *Charge Radius by* Σ^-*–Electron Elastic Scattering.*
   Physics Letters **B522** (2001) 233-239.

6. M. Iori et al.: *Measurement of the* D_s *lifetime.*
   Physics Letters **B523** (2001) 22-28.

7. F. Garica et al.: *Hadronic Production of* Λ_c *from* 600 GeV/c π^-, Σ^- *and* p *beams.*
   Accepted for publication in PLB, hep–ex/0109017.

8. A. Ocherashvili et al.: *First Measurement of* $\pi^- e \to \pi^- e\gamma$ *Pion Virtual Compton Scattering.*
   Submitted to Phys. Rev. C, hep–ex/0109003.

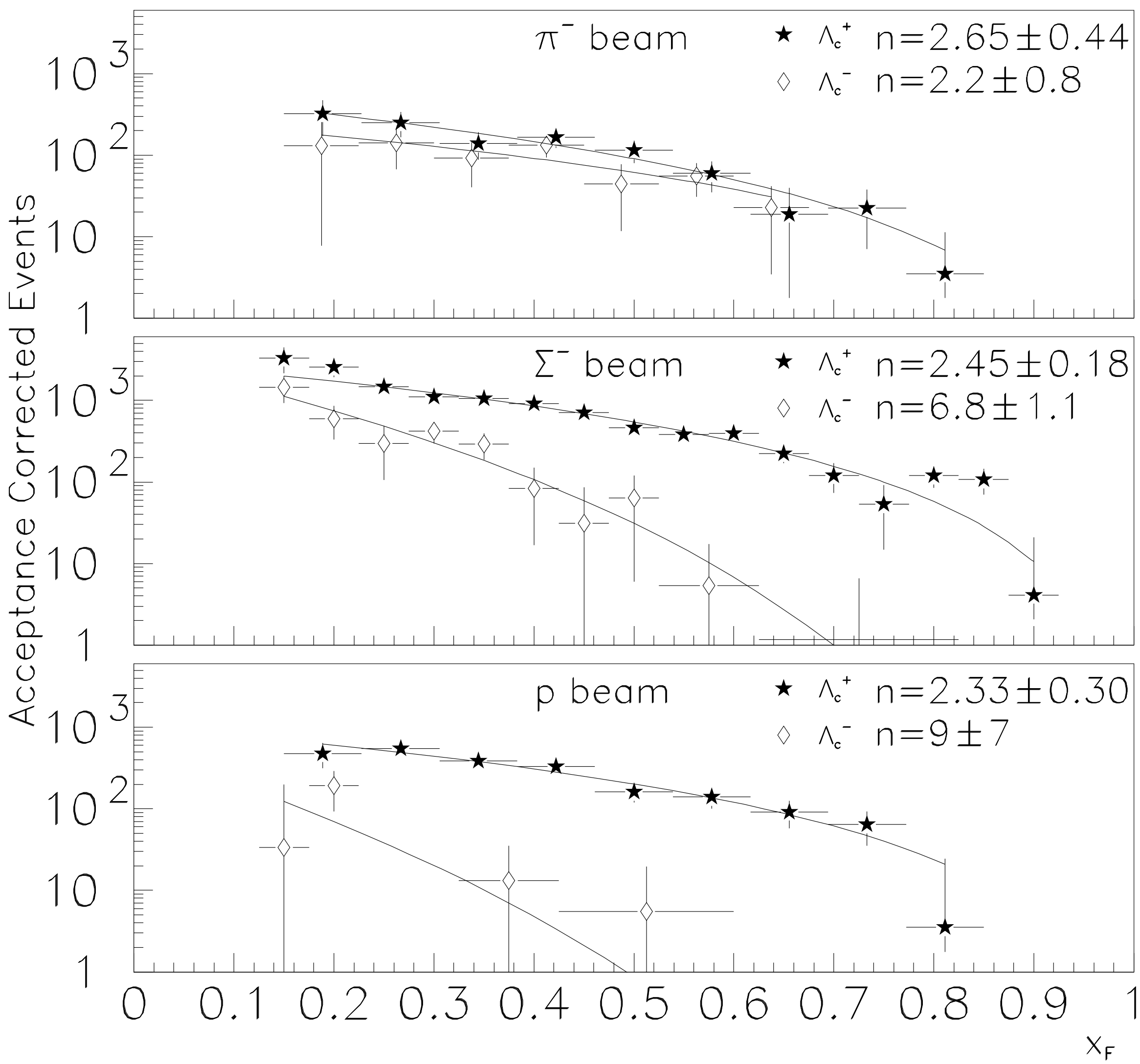
Charm Hadroproduction

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

Leading Charm Hadrons for π^-, Σ^- and p beams

	π^- $(\bar{u}d)$		Σ^- (sdd)		p (uud)	
	Leading	Non-Leading	Leading	Non-Leading	Leading	Non-Leading
D^0 $(c\bar{u})$	D^0	$\overline{D^0}$	–	D^0, $\overline{D^0}$	$\overline{D^0}$	D^0
$D^\pm$ $(c\bar{d})$	D^-, $D^{\star-}$	D^+, $D^{\star+}$	D^-, $D^{\star-}$	D^+, $D^{\star+}$	D^-, $D^{\star-}$	D^+, $D^{\star+}$
D_s $(c\bar{s})$	–	$D_s^\pm$	D_s^-	D_s^+	–	$D_s^\pm$
Λ_c (cud)	Λ_c^+, $\overline{\Lambda_c^+}$	–	Λ_c^+	$\overline{\Lambda_c^+}$	Λ_c^+	$\overline{\Lambda_c^+}$
Ξ_c^+ (csu)	$\overline{\Xi_c^+}$	Ξ_c^+	Ξ_c^+	$\overline{\Xi_c^+}$	Ξ_c^+	$\overline{\Xi_c^+}$
Ξ_c^0 (csd)	Ξ_c^0	$\overline{\Xi_c^0}$	Ξ_c^0	$\overline{\Xi_c^0}$	Ξ_c^0	$\overline{\Xi_c^0}$
Ω_c^0 (css)	–	Ω_c^0, $\overline{\Omega_c^0}$	Ω_c^0	$\overline{\Omega_c^0}$	–	Ω_c^0, $\overline{\Omega_c^0}$

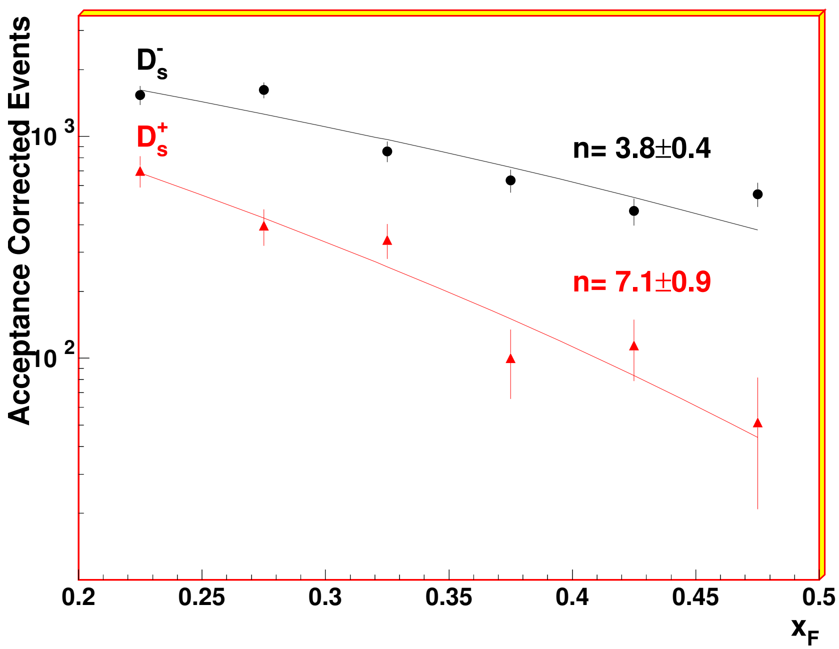
SELEX Measurements for Λ_c



- 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 D_s

x_F Distributions for Σ^- Beam

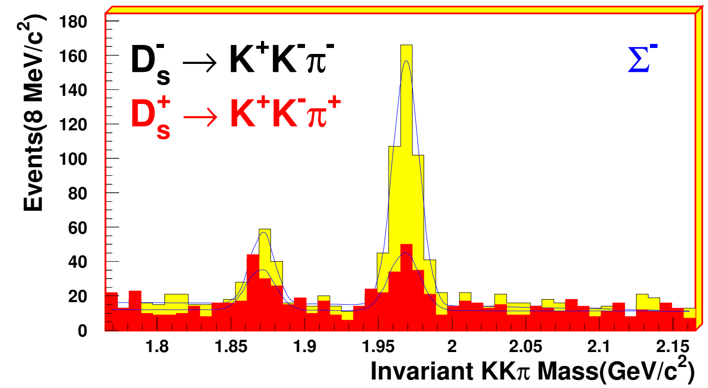


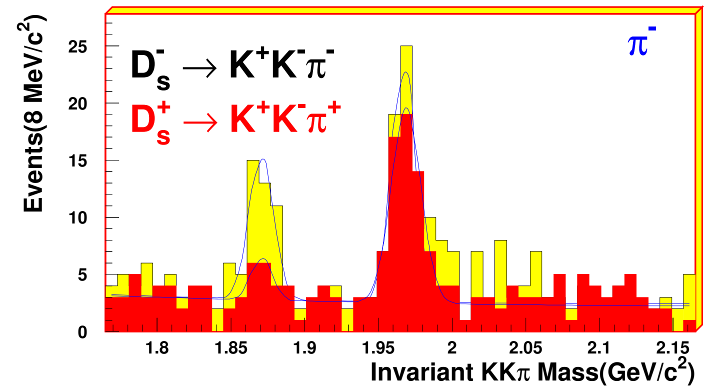
$$fit : (1 - x_F)^n$$

- 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



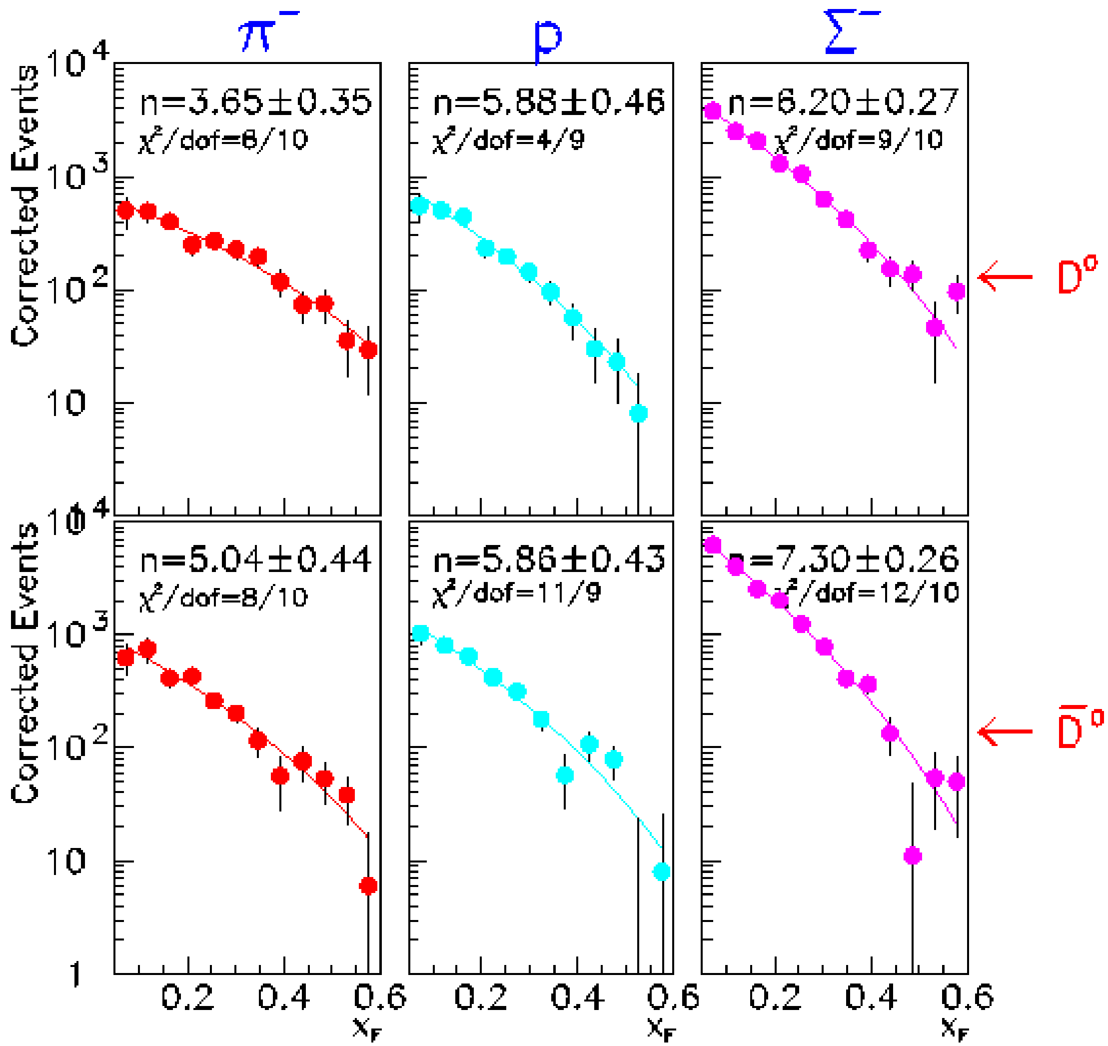


$$A \equiv \frac{N_{D_s^-} - N_{D_s^+}}{N_{D_s^-} + N_{D_s^+}}$$

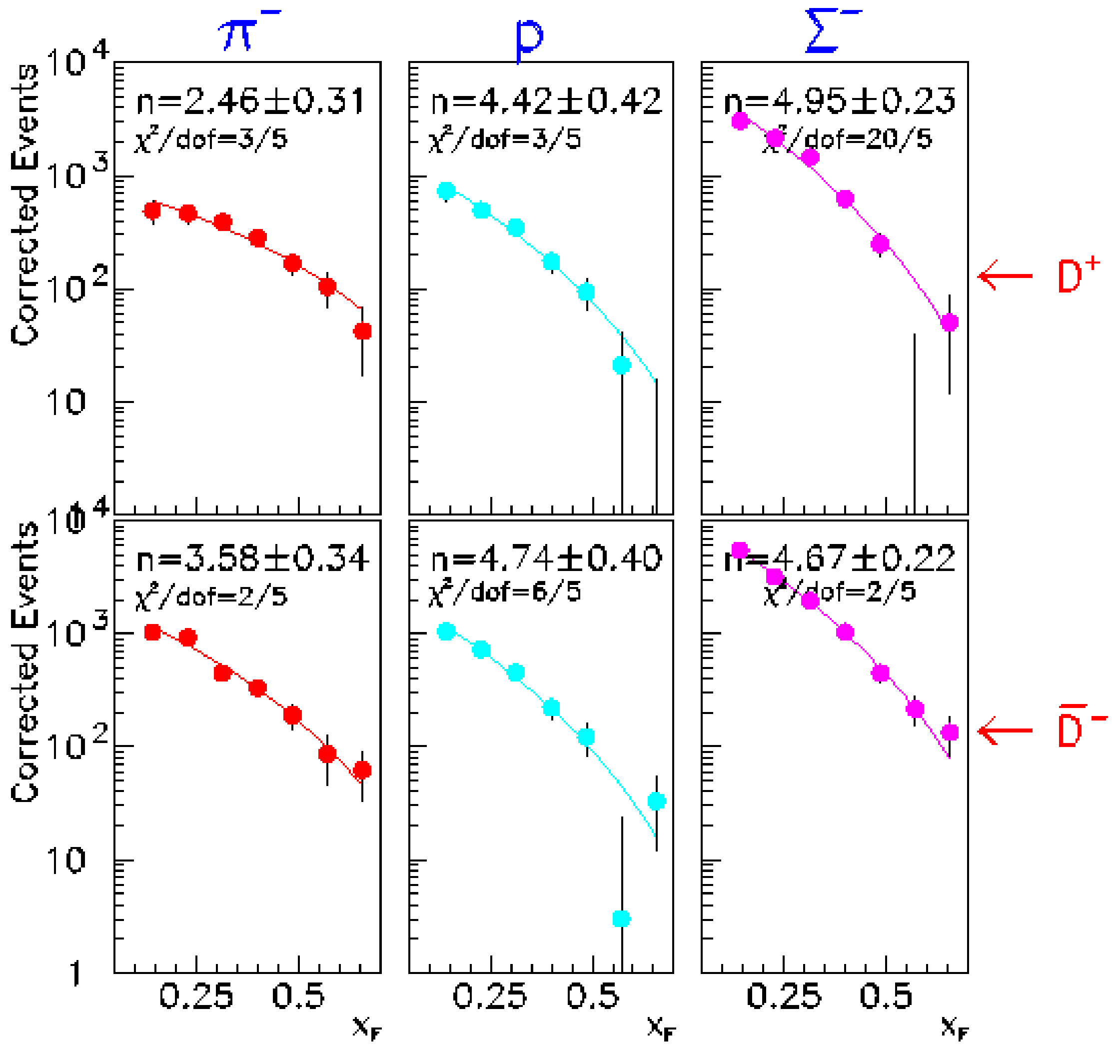
A($x_f > 0.2$)= 0.57 ± 0.07 Σ^-

A($x_f > 0.2$)= -0.08 ± 0.08 π^-

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



x_F Distributions for $D^{\pm}$



Charm Production Summary

SELEX has measurements for
$d\sigma/dx_F$, $d\sigma/dp_\perp$, and asymmetry
for
Λ_c, D^0, $D^\pm$, $D^{\star\pm}$, and $D_s^\pm$
with
Σ^-, π^-, and p beams

	π^- $(\bar{u}d)$		Σ^- (sdd)		p (uud)	
	Leading	Non-Leading	Leading	Non-Leading	Leading	Non-Leading
D^0 $(c\bar{u})$	D^0	$\overline{D^0}$	–	D^0, $\overline{D^0}$	$\overline{D^0}$	D^0
$D^\pm$ $(c\bar{d})$	D^-	D^+	D^-, $D^{\star -}$	D^+, $D^{\star +}$	D^-	D^+
D_s $(c\bar{s})$	–	$D_s^\pm$	D_s^-	D_s^+	–	
Λ_c (cud)	Λ_c^+, $\overline{\Lambda_c^+}$	–	Λ_c^+	$\overline{\Lambda_c^+}$	Λ_c^+	$\overline{\Lambda_c^+}$
Ξ_c^+ (csu)						
Ξ_c^0 (csd)						
Ω_c^0 (css)						

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

SELEX Charm Lifetime Results

- Λ_c^+, D^0, $(D^\pm)$: Phys. Rev. Letter **86** (2001) 5243-5246, hep-ex/0010014.
- D_s, τ_{D_s}/τ_{D^0}: Physics Letters **B523** (2001) 22-28, hep–ex/0106005.

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

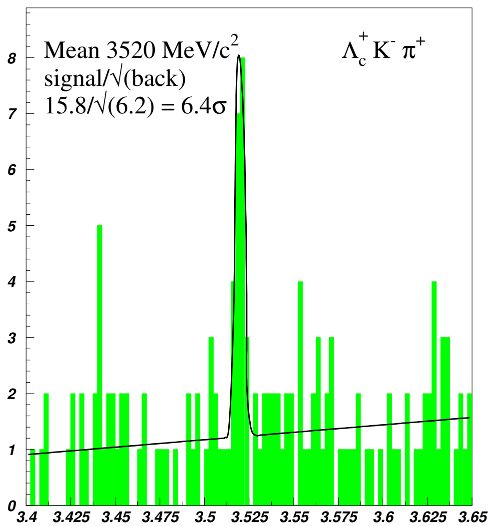
Features of SELEX Lifetime Analysis Method

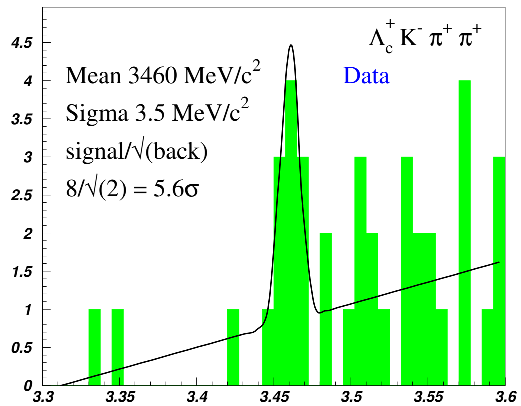
- apply strong PID requirements to minimize overlapping states
- use real data to establish acceptance correction function
- check systematics by using several decay modes, different production targets
- Use reduced proper time $t_R = t - 8\,\sigma/(\beta\gamma)$
- $\sigma_{t_R} \sim 20$ fs $\Rightarrow$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

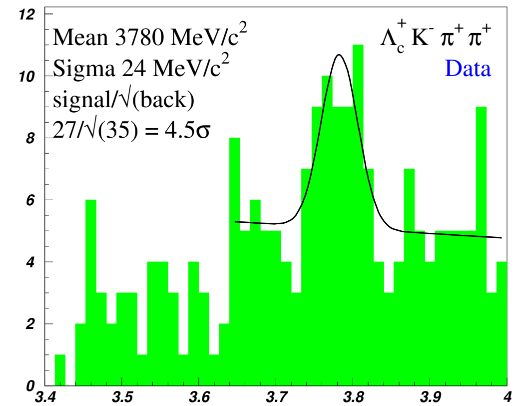
	Lifetime	Stat. Err.	Sys. Err.
$\Lambda_c^+ \to pK^-\pi^+$	198.1 fs	7.0 fs	5.6 fs
$D^0 \to K\pi$	416 fs	8 fs	–
$D^0 \to K\pi\pi\pi$	402 fs	10.5 fs	–
D^0	407.9 fs	6.0 fs	4.3 fs
$D^\pm \to K\pi\pi$	1070 fs	36 fs	–
$D_s \to \phi\pi$	474 fs	22 fs	–
$D_s \to K^\star K$	478 fs	33 fs	–
D_s	475.6 fs	17.5 fs	4.4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

	Λ_c^+ $\Delta\tau$(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

Selex has observed 3 significant high-mass peaks







- SELEX has preliminary but strong evidence for a family of high-mass states
- These states decay like doubly-charmed baryons
- The spectroscopy is not easy to understand
- The production rate is astoundingly high, but the double-charm world has seen a partner surprise from e^+e^- collisions.

It's difficult to avoid calling these states doubly-charmed baryons.

Papers in Preparation

- 8 Papers already published / submitted
- D^0, $D^\pm$ Production
- D_s Production
- Double Charm
- Beam Σ^+ Polarization
- Λ^0 inclusive Polarization
- Absorption Cross Sections
- Sigma(1385) in different channel

With this, the "first wave"
of Ph.D. thesis is over

Activities at this moment

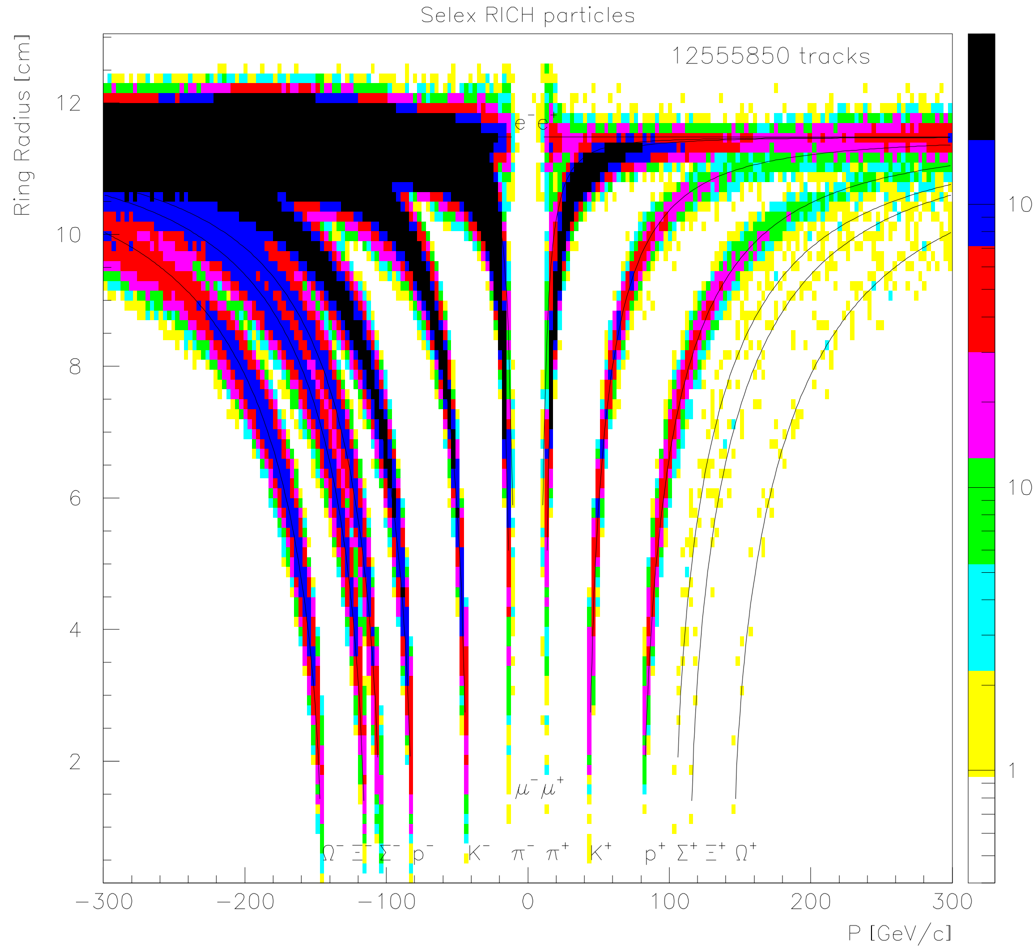
- Charm with γ and π^0 in final state
- reconstructing Ξ_c^+, Ξ_c^0, Ω_c^0 (decay channels with Hyperons)
- Resonances in $\Lambda_c^+ \to pK^-\pi^+$
- Semileptonic Λ_c decays
- Hyperon Production
- more Double Charm

Future Activities

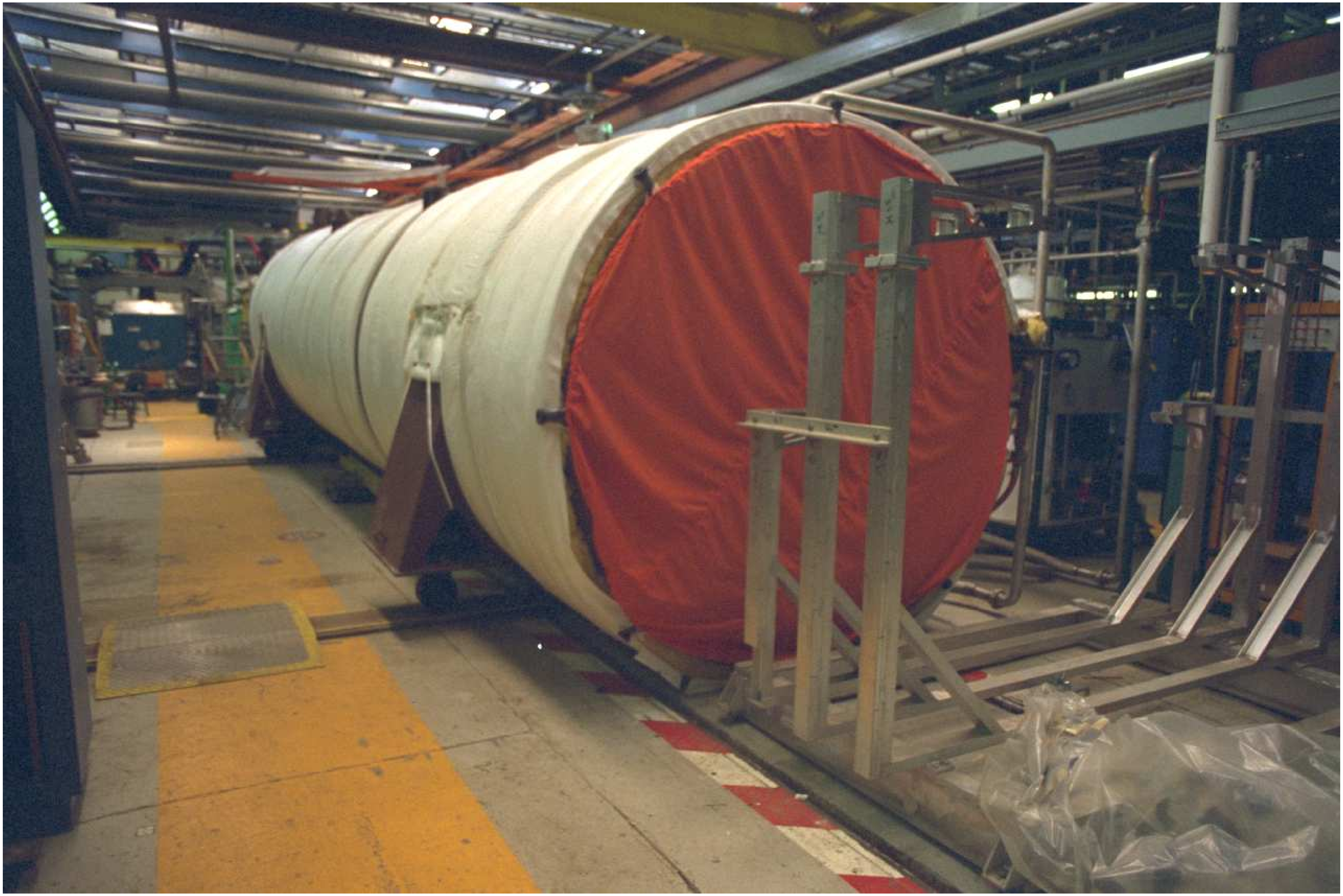
- Lifetime of Ξ_c^+, Ξ_c^0, Ω_c^0
- Production properties of Ξ_c^+, Ξ_c^0, Ω_c^0
- Double Charm
- Exotics
- Hyperon Production

Summary

- SELEX has 7 papers published, one submitted.
- SELEX RICH is essential Part in Physics Analysis
- SELEX RICH has
  - High Efficiency
  - Low Noise
  - Large Dynamic Range
- More Physics Results to come!



Additional transparencies



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NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH

Section A

Nuclear Instruments and Methods in Physics Research A 369 (1996) 69–78

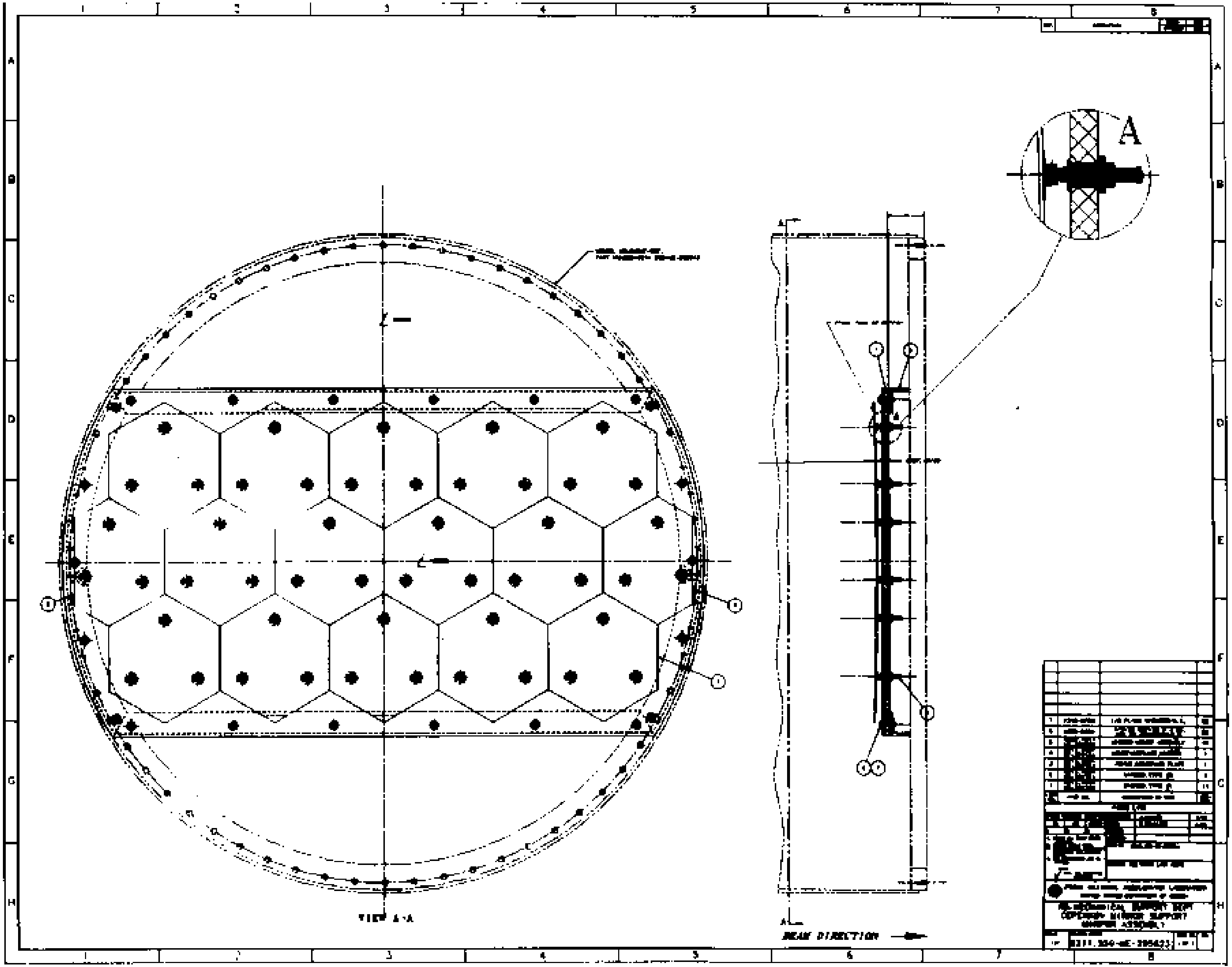
A method to evaluate mirrors for Cherenkov counters

Linda Stutte*, Jürgen Engelfried, James Kilmer

Fermi National Accelerator Laboratory[1], P.O. Box 500, Batavia, IL 60510, USA

Received 19 June 1995

ELSEVIER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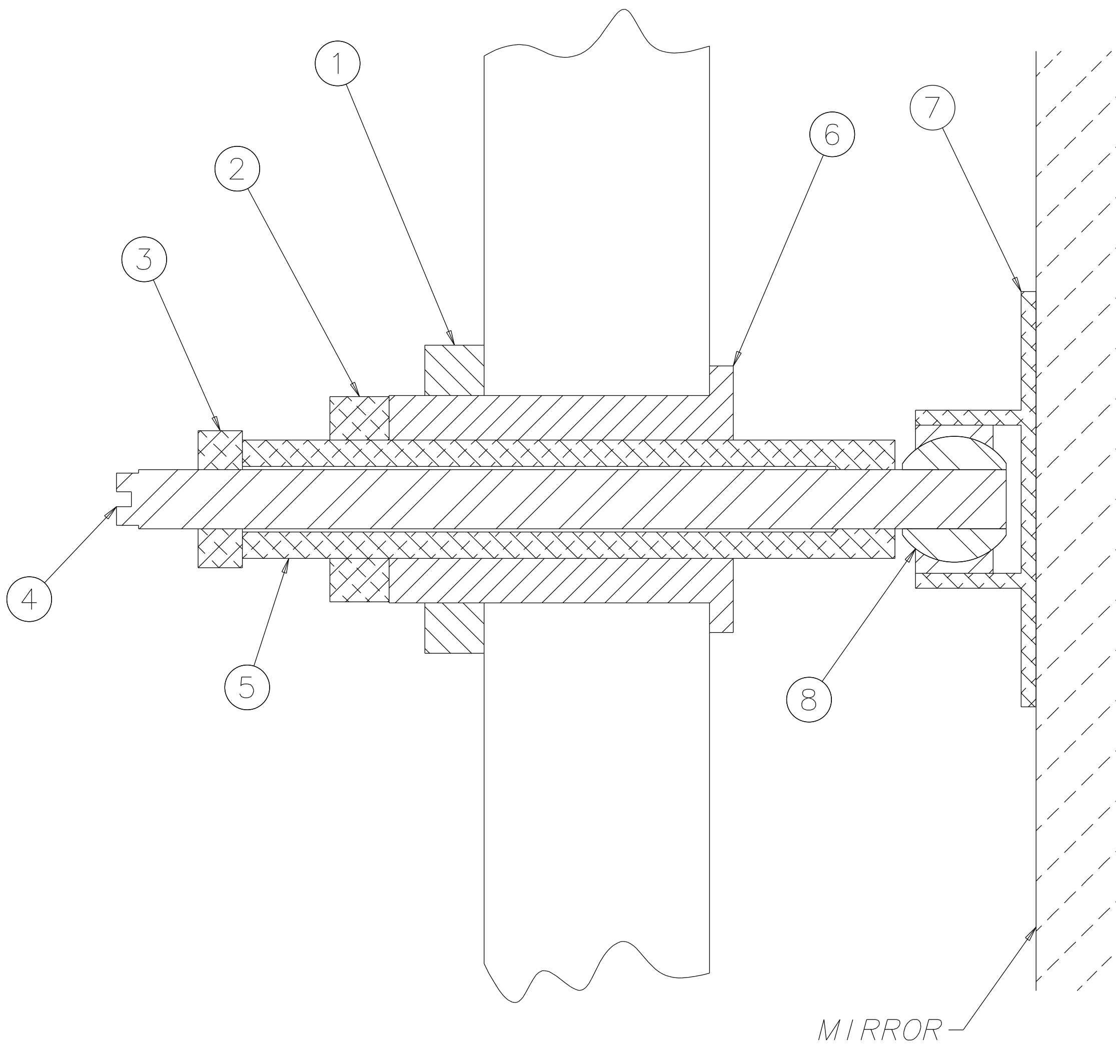
VIEW A-A
BEAM DIRECTION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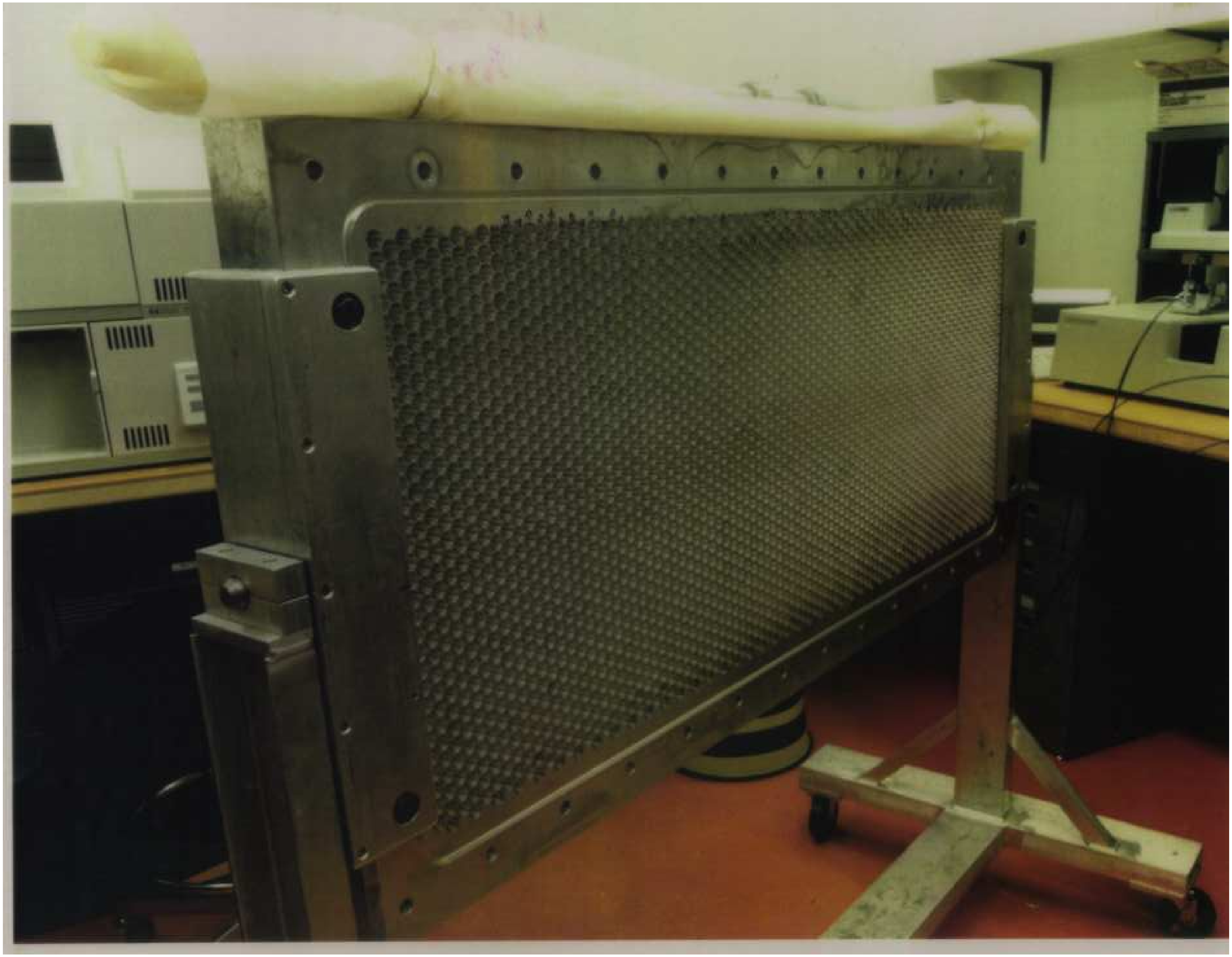
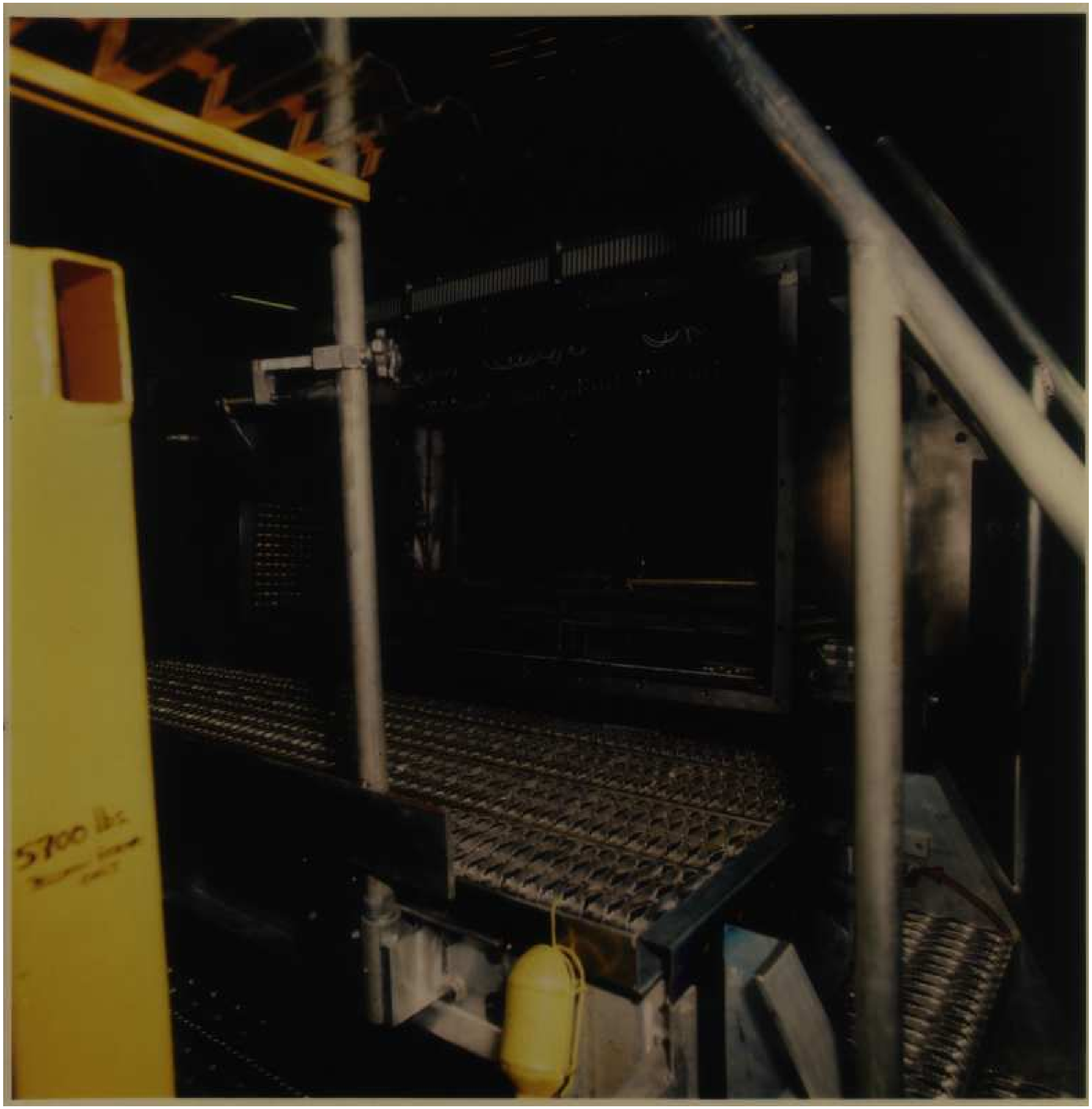
MIRROR

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Nuclear Instruments and Methods in Physics Research A 343 (1994) 279–283
North-Holland

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

Particle identification with the RICH detector in experiment WA89 at CERN **

U. Müller [a,*], J. Engelfried [b,1], S.G. Gerassimov [c,2], K. Martens [b], R. Michaels [c,3], H.-W. Siebert [b], G. Wälder [c]

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The RICH detector in the hyperon beam experiment WA89 at the CERN-SPS is used for identification of π, K and p/$\bar{p}$ out of Σ^-–N reactions. Methods for reduction of charged particle background in the detector are discussed. An algorithm for particle identification was developed and tested on a sample of $\Lambda \to p\pi^-$ decays. A separation of p and π with 90% efficiency and a rejection by a factor of 10 or more at a momentum of 150 GeV/c was achieved.

1. Introduction

We report on algorithms used for particle identification with the upgraded Omega RICH detector [1] in the hyperon beam experiment WA89 [2] at the CERN-SPS.

Cherenkov light is generated in a nitrogen radiator ($n - 1 = 290 \times 10^{-6}$) of length $L \approx 5$ m and detected in a set of five drift chambers, covering a total active surface of 3.6×0.75 m^2 with a maximum drift path of 41 cm. Photoelectrons are counted on 1280 wires with a pitch of 2.54 mm, equipped with multihit TDCs. The overall spatial accuracy is $\sigma = 2.8$ mm for single electrons, corresponding to an angular resolution of 0.56 mrad [3]. The counting gas is ethane saturated with TMAE at 30°C. Fig. 1 shows an on-line display of one event in the RICH of the 1991 beamtime. This display contains the signals observed in the chambers, the particle impacts extrapolated from the spectrometer, and the predicted rings for the mass hypotheses π, K, and p. Also the momenta and charges of the tracks are given. Cherenkov photon signals along the predicted rings are clearly seen. We also note two half-rings in the centre from an out-of-time beam particle or e^+e^- pair.

In the following, we present data analysis methods to reduce the background from charged tracks and other sources, and to identify particles with high efficiency and low probability of misidentification.

2. Background reduction

A charged particle traversing the drift chamber volume produces a few hundred electrons, which give a signal with high amplitude on several (typically three) adjacent wires. In addition, these large signals may produce electronic cross talk to neighbouring channels and signals due to δ rays or photon feedback. All these effects combined lead to a cluster of observed hits around the charged particle impact point.

In the raw data, information about a second discriminator threshold which is higher than the one used for single electron signals is available for each group of eight neighbouring wires [4]. This is used in the first step of background subtraction to suppress all hits with high amplitudes which may stem from a traversing charged particle.

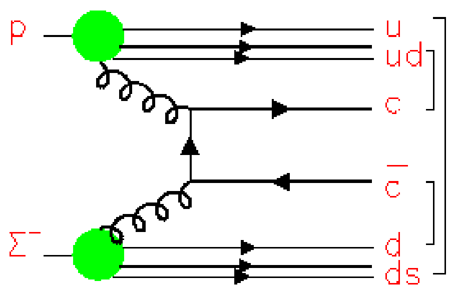
In the second step, clusters of at least four neighbouring hits are removed from the data. The distance for individual hits to be considered as neighbours has to be at most two wirespacings (0.508 cm) in the y direction and 1.0 cm in z (electron drift) direction. These numbers were tuned to give the best compro-

* Corresponding author.
** Work supported by the Bundesministerium für Forschung und Technologie under contract numbers 05 5HD15I, 06 HD524I, and 06 MZ5265 TP2.
[1] Now at Fermilab, Batavia, IL, USA.
[2] On leave from Lebedev Inst., Moscow, Russian Federation.
[3] Now at CEBAF, Newport News, VA, USA.

SSDI 0168-9002(93)E1168-W

Charm Hadroproduction

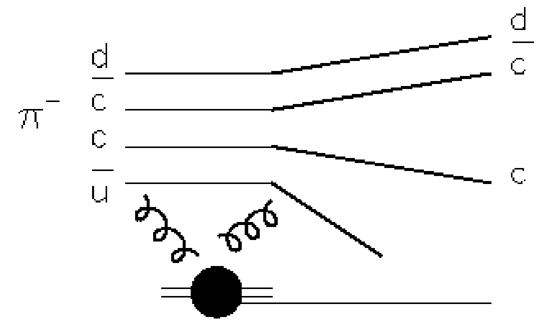
String Fragmentation Model[1]



- Production of $c\bar{c}$ pair is described by standard perturbation theory
- Partons of the hard interaction and the beam remnants are connected by strings (confining color field)
- Successive breakings of the color flux tube stretched between a cluster, when kinematically possible, will create light quark-antiquark pairs and hadrons will be produced

[1] T.Sjostrand

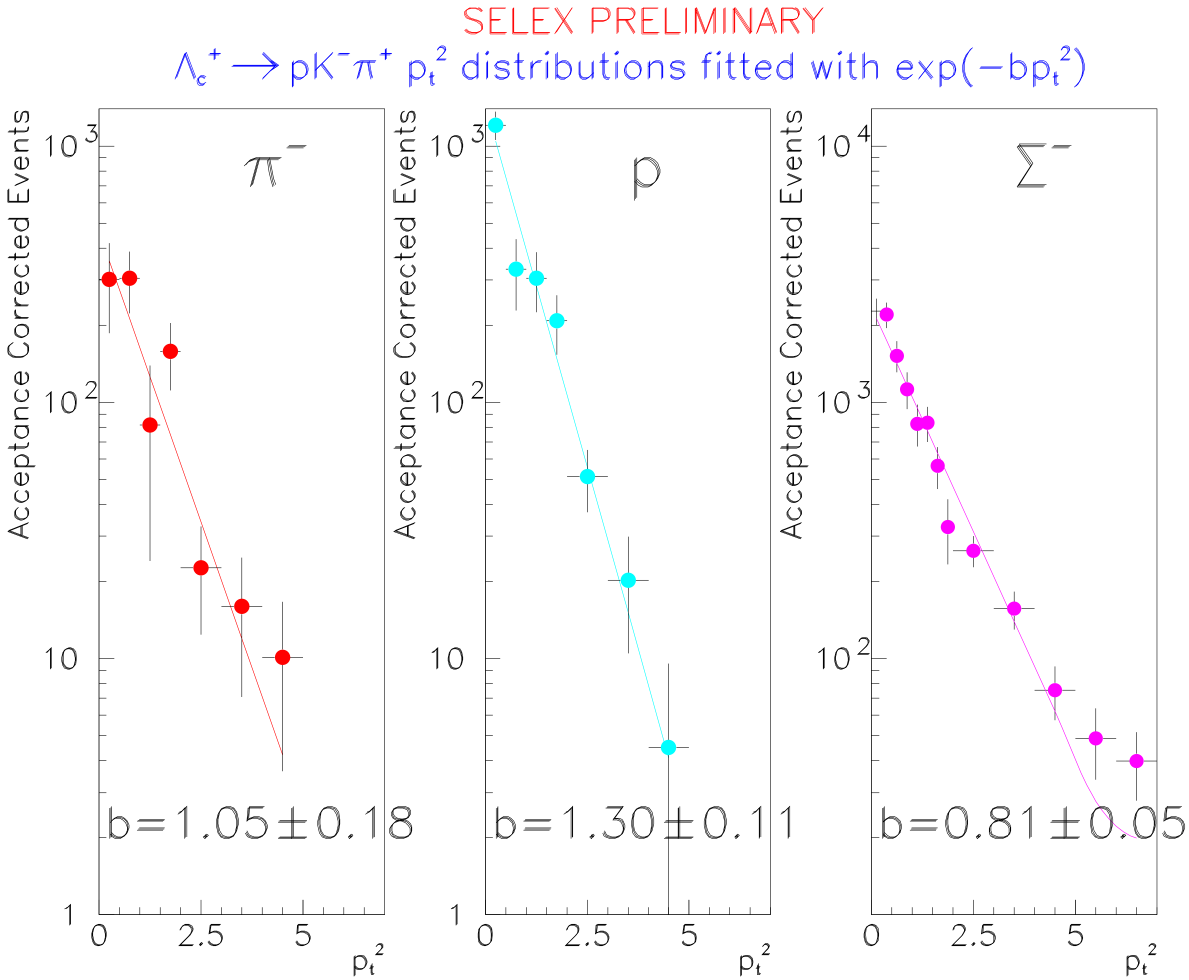
Intrinsic Charm Model[2]



- Virtual $c\bar{c}$ pair is in the sea of the incident particles
- $c\bar{c}$ coalesce with the beam quarks due to the similar rapidity
- Predictions: increasing asymmetry at high x_F and low p_t^2 region

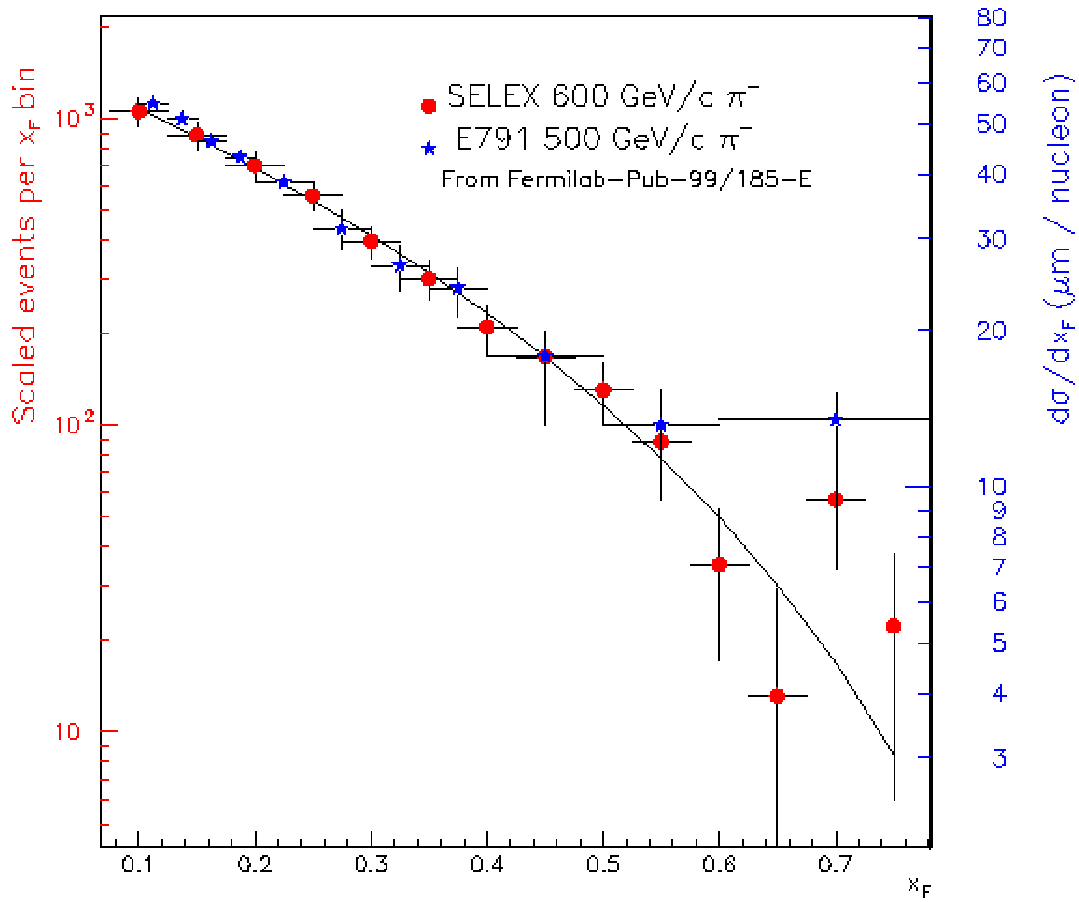
[2] S.J. Brodsky, R. Vogt

SELEX Measurements for Λ_c (cont.)

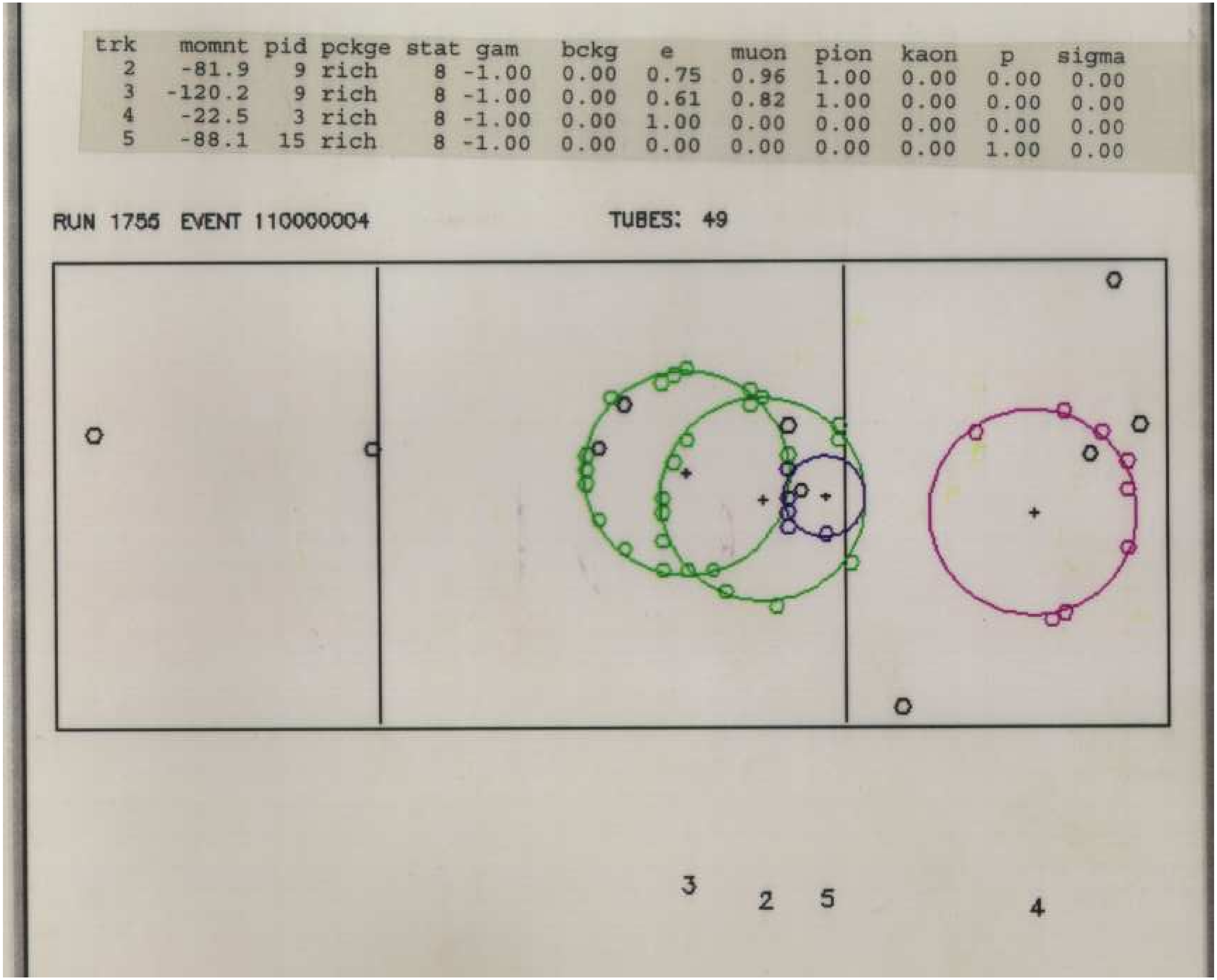


- Σ^- production data show expected deviation from Gaussian behavior slightly earlier than corresponding D^+ spectra from π beams
- Forward gaussian slope ($p_\perp^2 \leq 4\,(\mathrm{GeV}/c)^2$) same for all beams

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



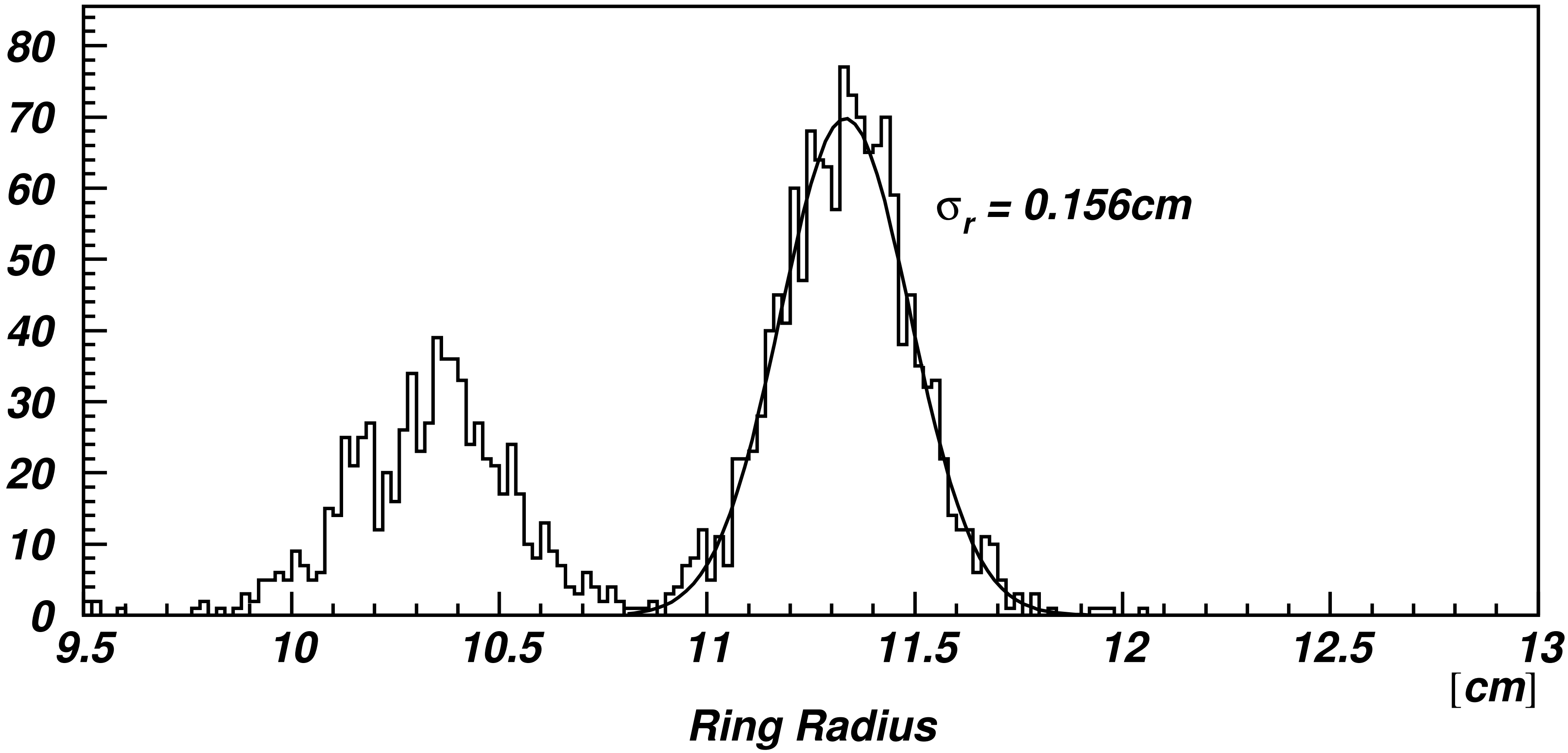
E791 Collaboration, Phys. Lett. B462 (1999) 225-236



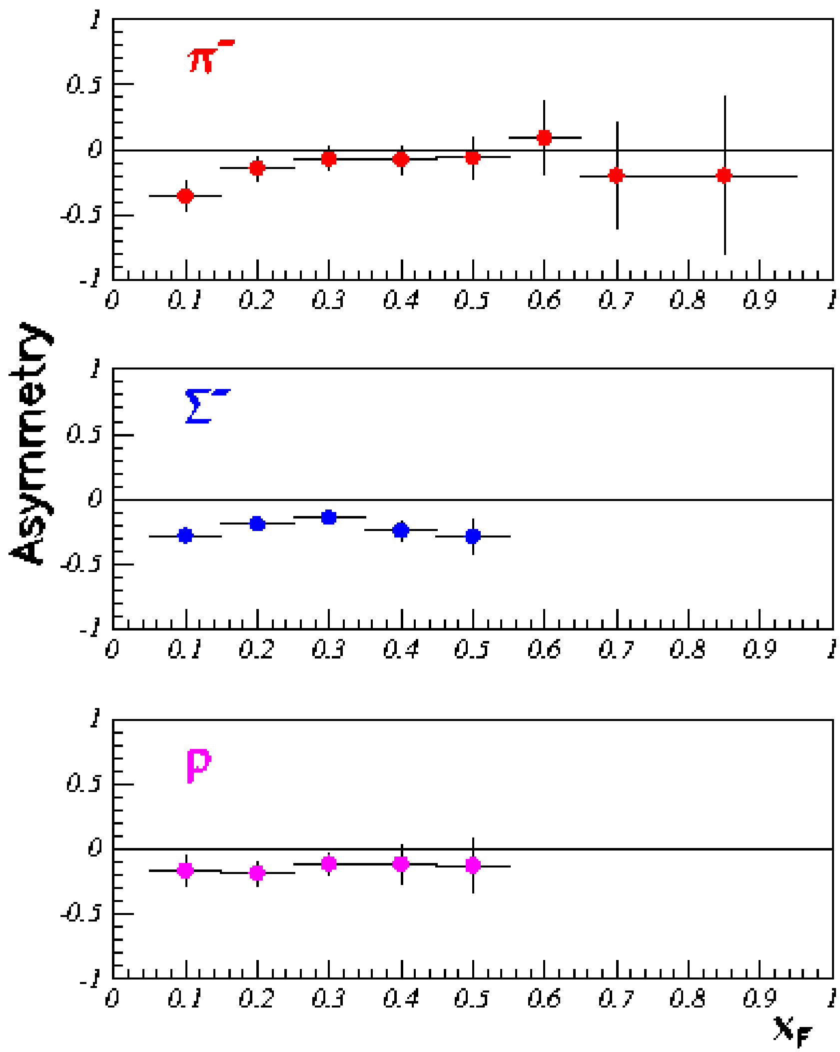
trk	momnt	pid	pckge	stat	gam	bckg	e	muon	pion	kaon	p	sigma
2	-81.9	9	rich	8	-1.00	0.00	0.75	0.96	1.00	0.00	0.00	0.00
3	-120.2	9	rich	8	-1.00	0.00	0.61	0.82	1.00	0.00	0.00	0.00
4	-22.5	3	rich	8	-1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
5	-88.1	15	rich	8	-1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00

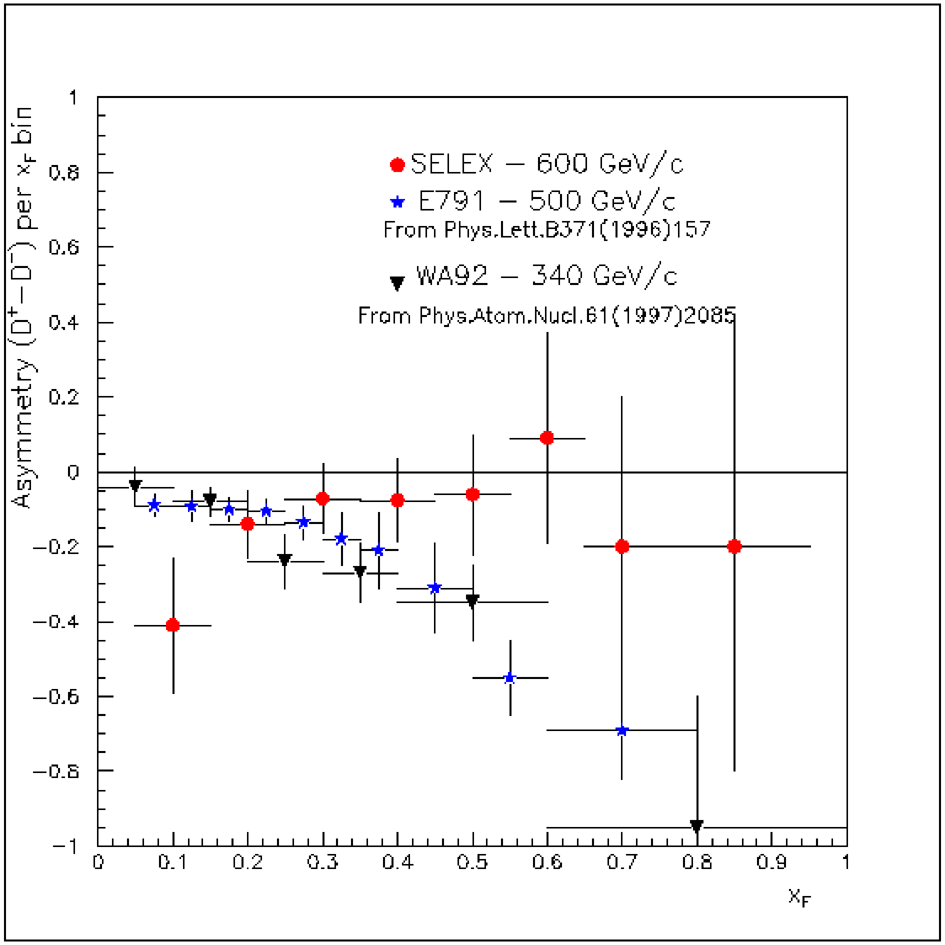
SELEX RICH Separation

Momentum of particles: $95\,\mathrm{GeV}/c - 105\,\mathrm{GeV}/c$



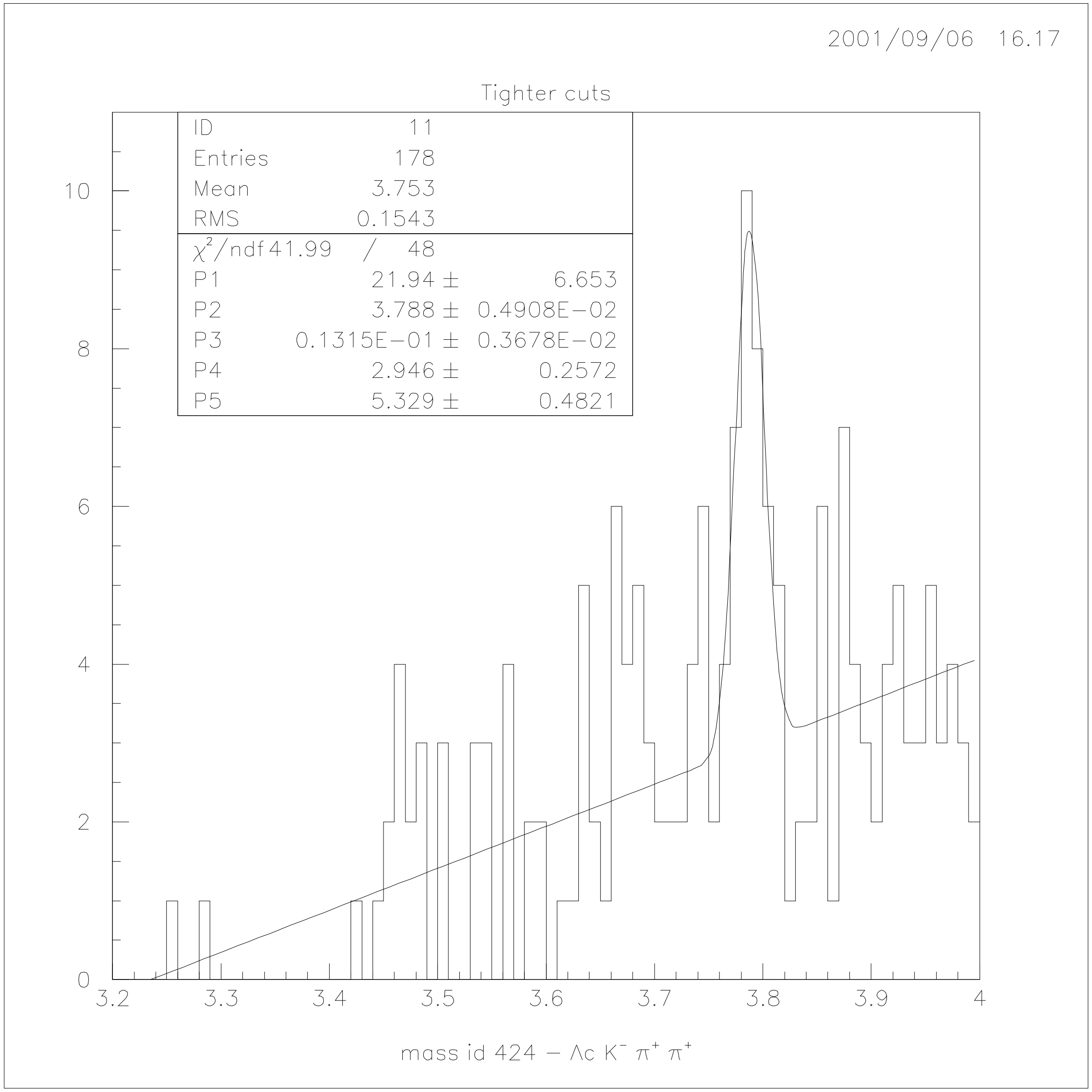
$D^{\pm}$ Asymmetry





Search for $(ccu)^{++}$ – Double Charm

- Masses predicted in the 1980's (Fleck&Richard, ...)
- Typical prediction: around 3.63 GeV/c, but ignores some effects.
- Cross section estimates: 0.01% to 10% of Λ_c cross section
- SELEX: search in $\Lambda_c^+ K^- \pi^+ \pi^+$
  - Λ_c^+ has to pass standard cuts
  - $K^- \pi^+ \pi^+$ without RICH requirement
  - $K^- \pi^+ \pi^+$ vertex: $1 \leq L/\sigma \leq 4$



Double Charm Background modes

Check other charge combinations:

- $\boldsymbol{\Lambda_c^+ K^- \pi^+ \pi^+}$, $Q = 2$
- $\Lambda_c^+ K^+ \pi^- \pi^+$, $Q = 2$
- $\Lambda_c^+ K^- \pi^- \pi^+$, $Q = 0$
- $\Lambda_c^+ K^+ \pi^- \pi^-$, $Q = 0$

No signal in other combination

Other experiments see anything?