Longitudinal spin transfer to Lambda at H1

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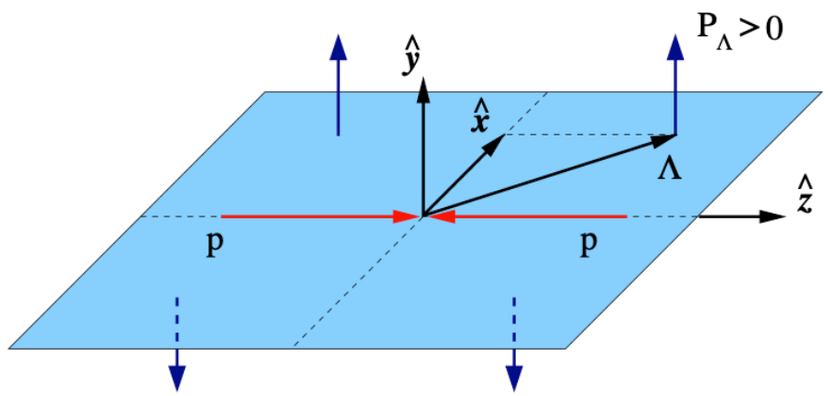
June 1, 2020

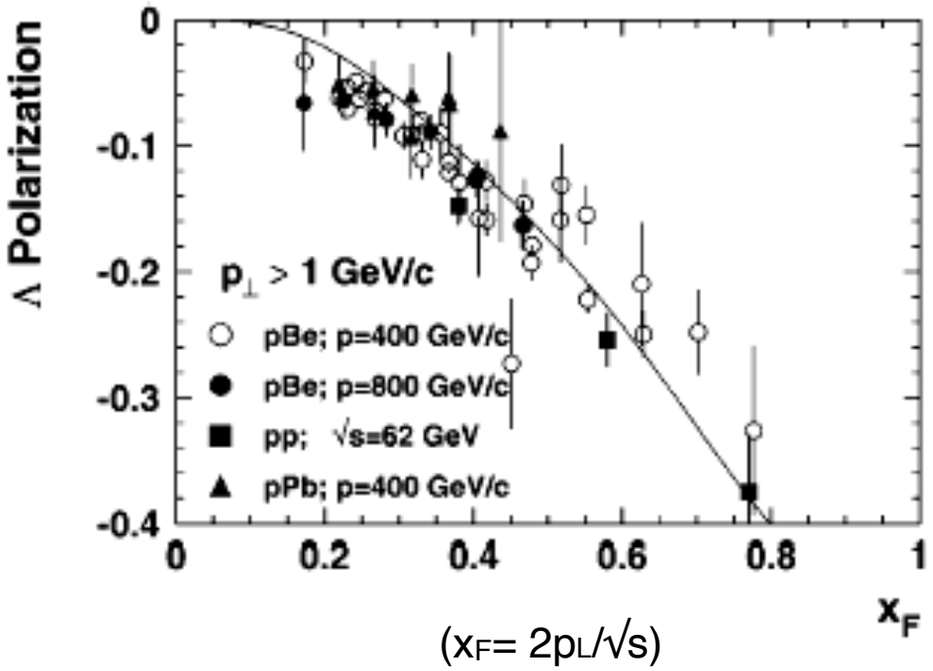
Why Lambda?

- Final state “polarimetry”
  - Self-analyzing weak decay: Lambda polarization can be measured from the angular distribution of its daughter particles, $\Lambda \to p\pi^-$(Br~64%) $\Lambda \to n\pi^0$ (Br~36%)

$$\frac{\mathrm{d}N}{\mathrm{d}\cos\theta^*} = \frac{\sigma\,\mathcal{L}\,A}{2}(1 + \alpha_{\Lambda(\bar{\Lambda})} P_{\Lambda(\bar{\Lambda})} \cos\theta^*)$$



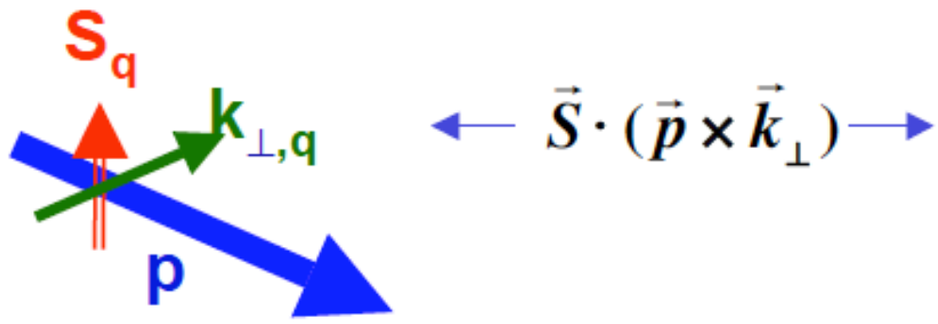
- Λ polarization plays an important role in spin physics
  - *Transverse polarization* in ***unpolarized*** pp, pA (G.Bunce et al 1976)
  - Study pol. fragmentation function and spin content of hyperon
  - Complementary to Kaon SIDIS, study spin structure of nucleon



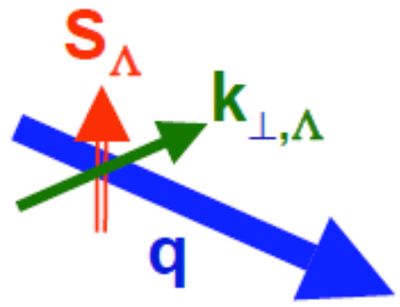
($x_F = 2p_L/\sqrt{s}$)

Theoretical Understanding

Polarizing distribution



Polarizing fragmentation



Quark pol.

Hadron pol.	U	L	T
U	f_1		$h_1^\perp$
L		g_{1L}	$h_{1L}^\perp$
T	$f_{1T}^\perp$	g_{1T}	$h_1, h_{1T}^\perp$

TMD PDFs

Quark pol.

Hadron pol.	U	L	T
U	D_1		$H_1^\perp$
L		G_{1L}	$H_{1L}^\perp$
T	$D_{1T}^\perp$	G_{1T}	$H_1, H_{1T}^\perp$

} Lambda

TMD FFs

Can not distinguish them in hadron-hadron reactions

But, lepton-hadron and e^+e^- can separate them.

Longitudinal Spin Transfer to Λ in ep

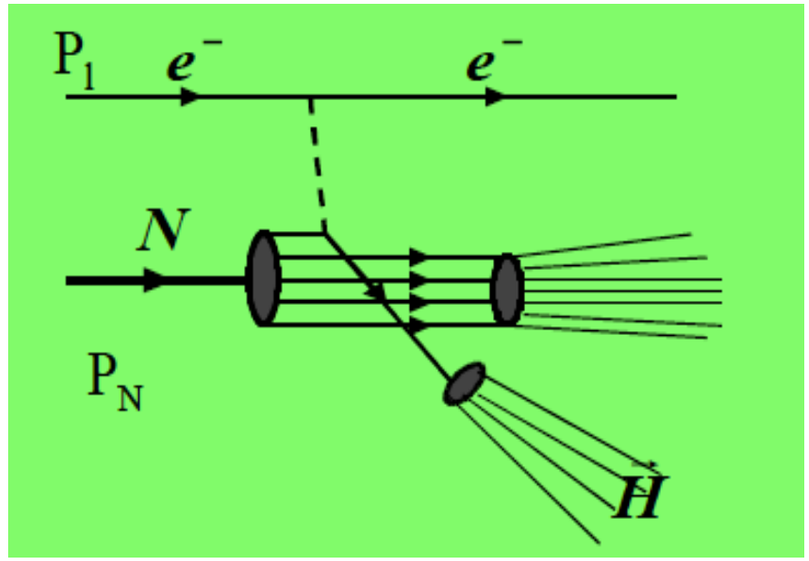
- Polarization of scattered quark:

pol. of lepton beam pol. of hadron beam

$$P_f = \frac{P_l D(y) q_f(x) + P_N \Delta q_f(x)}{q_f(x) + P_l D(y) P_n \Delta q_f(x)}$$

unpol. pdf pol. pdf

Depolarization factor: $D(y) = \frac{y(2-y)}{1-2y+y^2}$



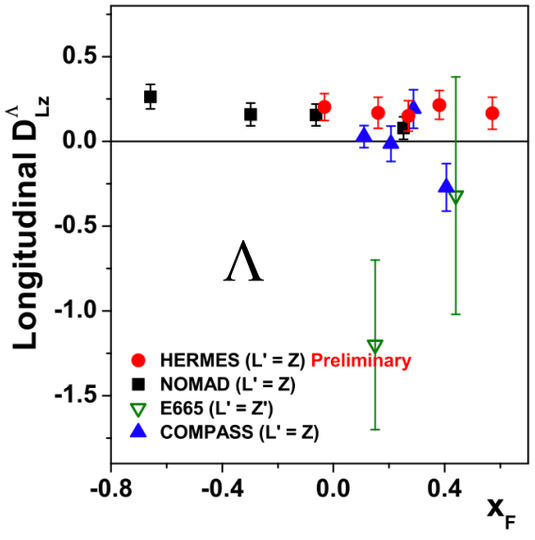
- Polarization of of Λ in the current region:

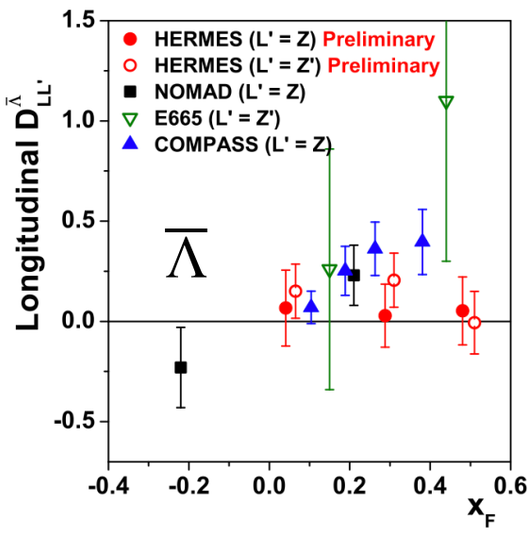
H1

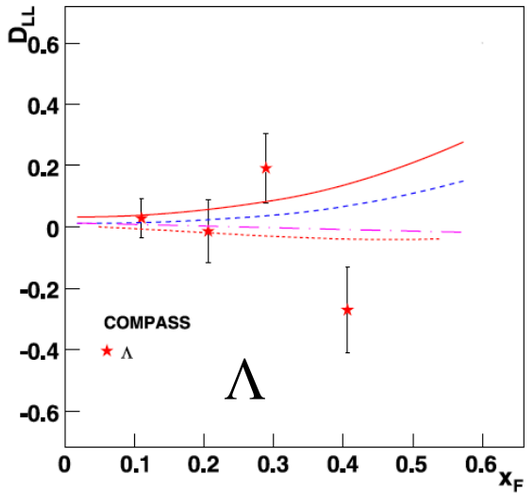
- $p_N = 0,\ P_l \neq 0:\quad P_\Lambda = P_l D(y) \frac{\Sigma_f e_f^2 q(x,Q^2) \Delta D_f^\Lambda(z,Q^2)}{\Sigma_f e_f^2 q(x,Q^2) D_f^\Lambda(z,Q^2)}$ → clean measurement of pol. FFs

- $p_N \neq 0,\ P_l = 0:\quad P_\Lambda = P_N \frac{\Sigma_f e_f^2 \Delta q(x,Q^2) \Delta D_f^\Lambda(z,Q^2)}{\Sigma_f e_f^2 q(x,Q^2) D_f^\Lambda(z,Q^2)}$ → pol. FFs and pol. PDFs

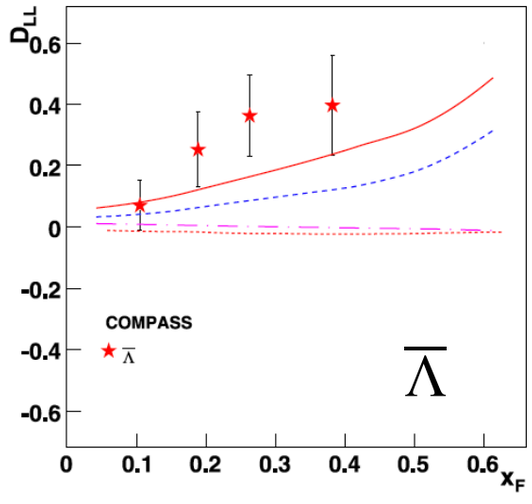
Existing measurements and projections





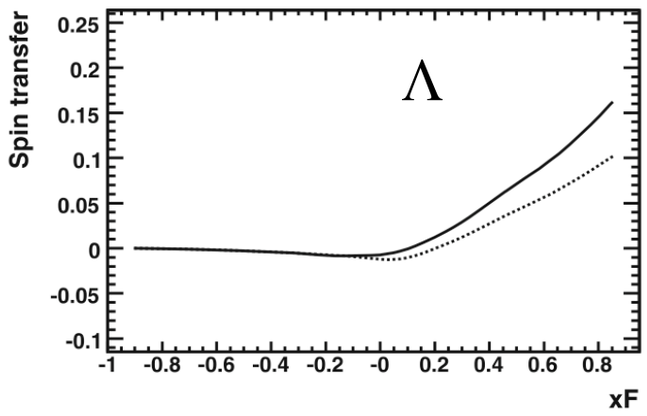


a)



b)

HERA Eur.Phys.J.C52:283-294,2007
J. Ellis, A. Kotzinian, D. Naumov, M. Sapozhnikov



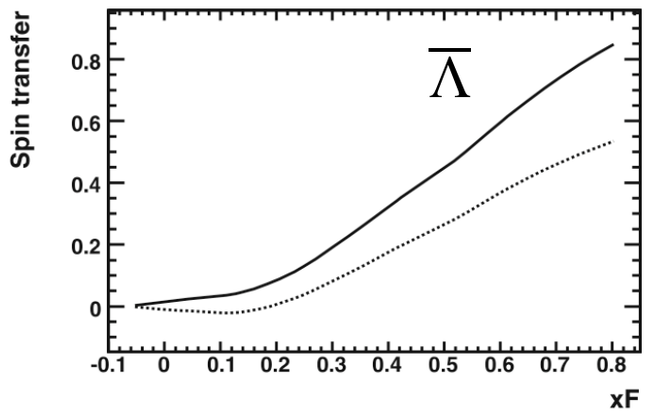
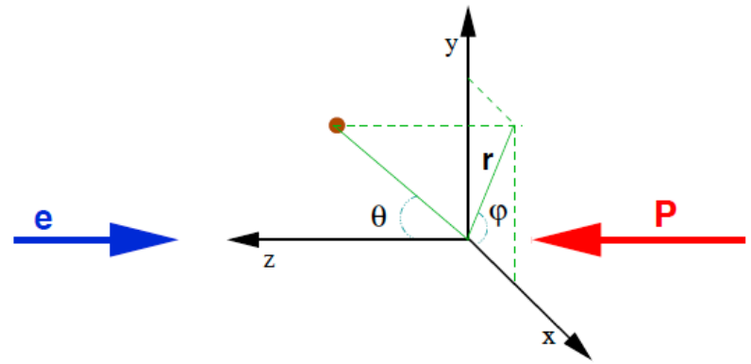


Fig. 11. The spin transfers to the Λ (*left*) and $\bar{\Lambda}$ (*right*) hyperons in the SU(6) (*solid line*) and BJ (*dashed line*) models, assuming GRV98 parton distribution functions, as functions of x_F, in the HERA kinematics

- Measured by many experiments
- HERA:
  - Better separation of current and target region
  - Broader kinematic coverage

H1 Detector



Forward Muon System

Central Muon System

Forward Tracker

$15^\circ < \theta < 165^\circ$

$150 < r < 850$ mm

Central Tracker

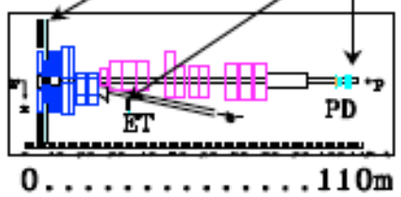
SIIIcon Tracker

$7^\circ < \theta < 25^\circ$

$120 < r < 800$ mm

Veto

Luml



$ep \to e'p'\gamma$

Had Spacal

Backward DC

PLUG TOF

LAr Calorlmeter

EM Spacal

Cu+Si

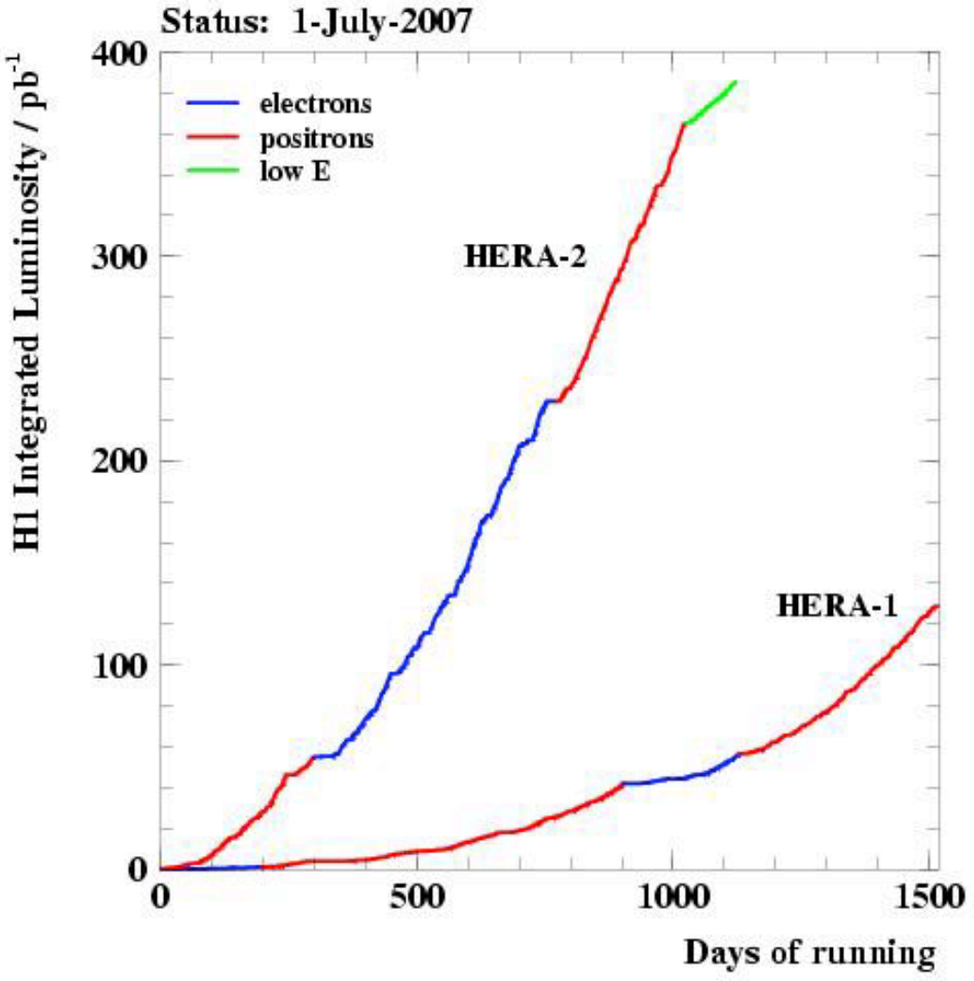
LAr + steel

50%/√E + 2%

LAr + Pb

11%/√E + 1%

H1 Data Set



Period	Run Period	Lumi $[pb^{-1}]$
$2004e^+$	367257-392213	50.61
$2004e^-$	398286-398679	0.15
$2005e^-$	399098-436893	102.93
$2006e^-$	444307-466997	57.73
$2006e^+$	468530-492541	92.54
$2007e^+$	492559-500611	48.02
HERA II	367257 - 500611	351.99

HERA II data

$e^+ + p$: 161 pb^{-1}

$e^- + p$: 191 pb^{-1}

Same physics for electron and positron

New H1 Data Structure

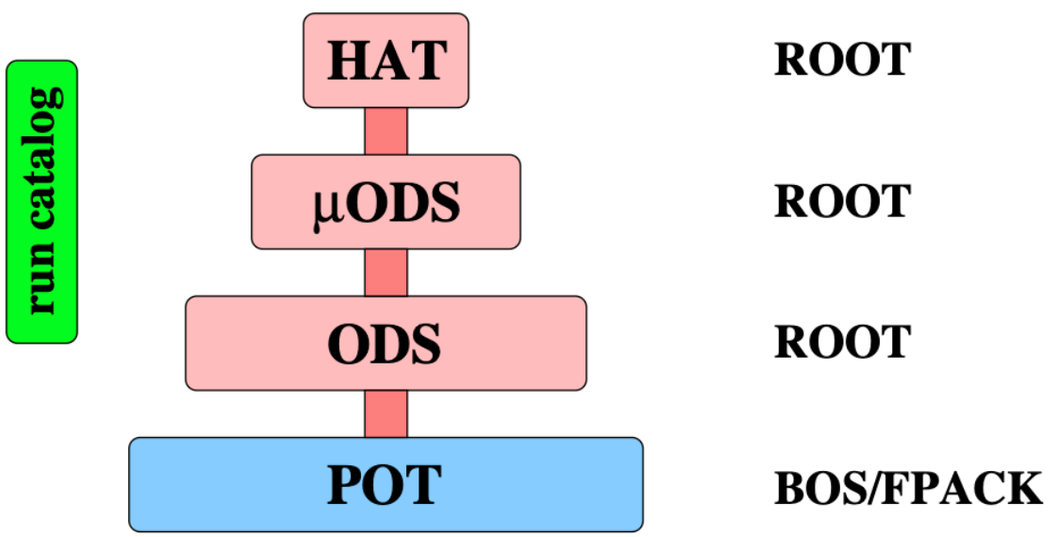


Figure 1: New H1 data storage model.

Table I: H1 data volumes after the luminosity upgrade in the year 2000.

storage level	event size (kB)	data volume (GB/year)
POT	200	10000
ODS	15	500
μODS	3	100
HAT	0.5	15

Ref: http://chep2000.pd.infn.it/short_p/spa_c078.pdf

The HAT (H1 Analysis Tag): a tag database for fast and dynamic data selection: contain about 100 kinematic event variables, e.g. Q2, x, y, beam Polarization

The microODS, which contains information on the particle level and their 4–vectors, e.g. electron candidates, jet properties, energy flow, PID probabilities, etc.

The ODS (Object data store) level contains all relevant information for physics analysis, e.g. tracks and clusters

The POT (production output tape) level contains the reconstructed and raw data.

HAT and uODS contains enough information at least for Lambda measurement.

Analysis Framework

- Read HAT and uODS files and save needed information to simpler/smaller analysis tree/ntuple

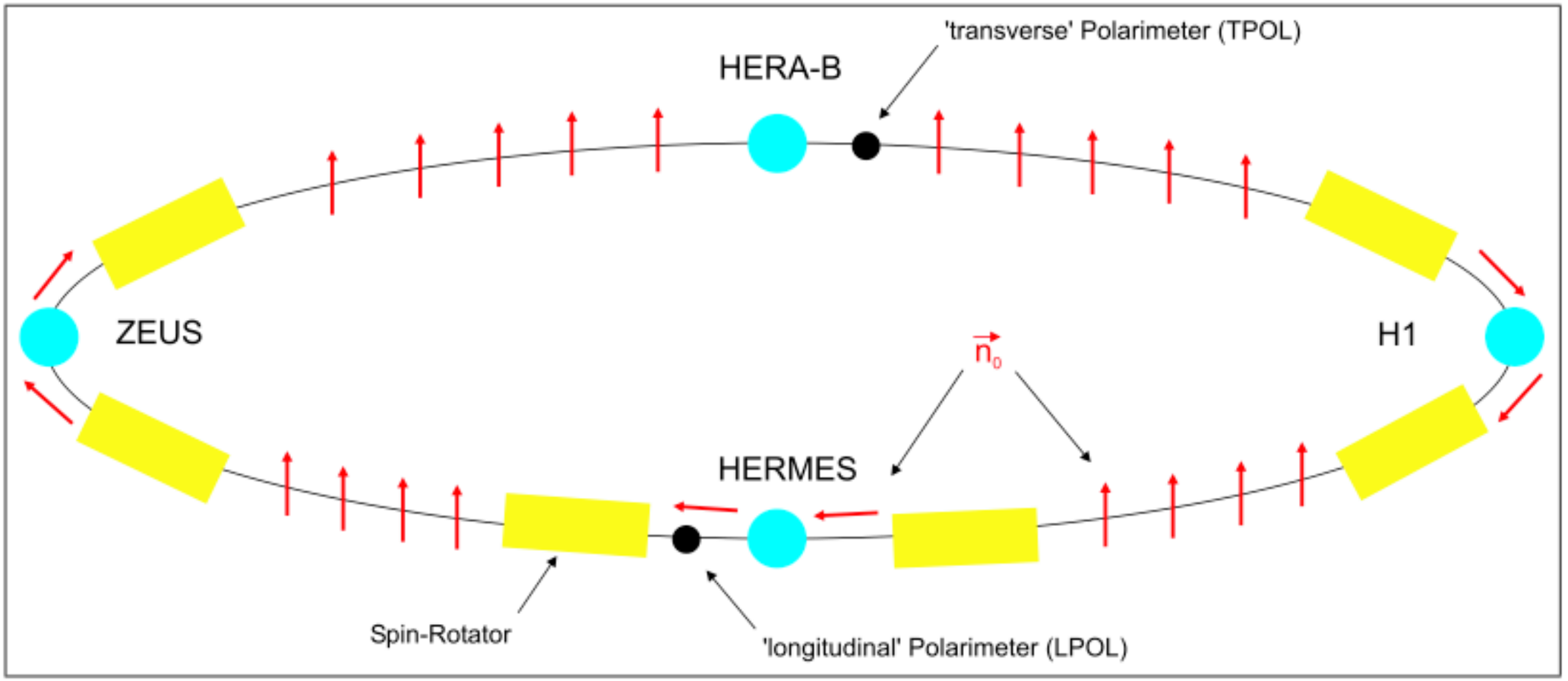
Basic information:

- Trigger, Vertex, Track, Energy Flow

What have been added for Lambda:

- Lambda, K0
- Kinematics: e-sigma
- Beam Polarization
- Jet (suggested by Stefan to re-produce jet tree to make sure Lambda is included)

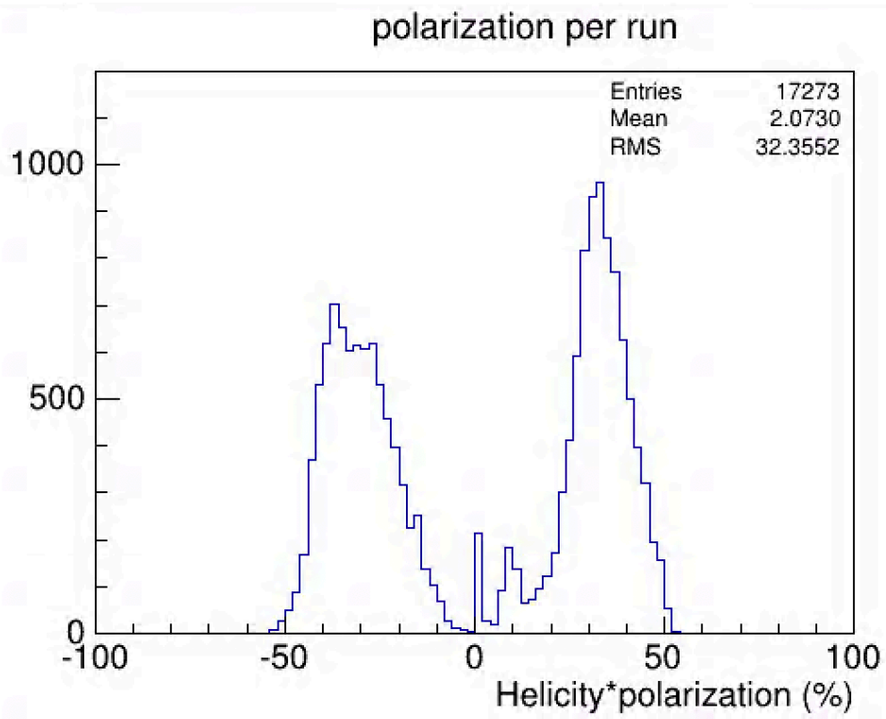
Beam Polarization



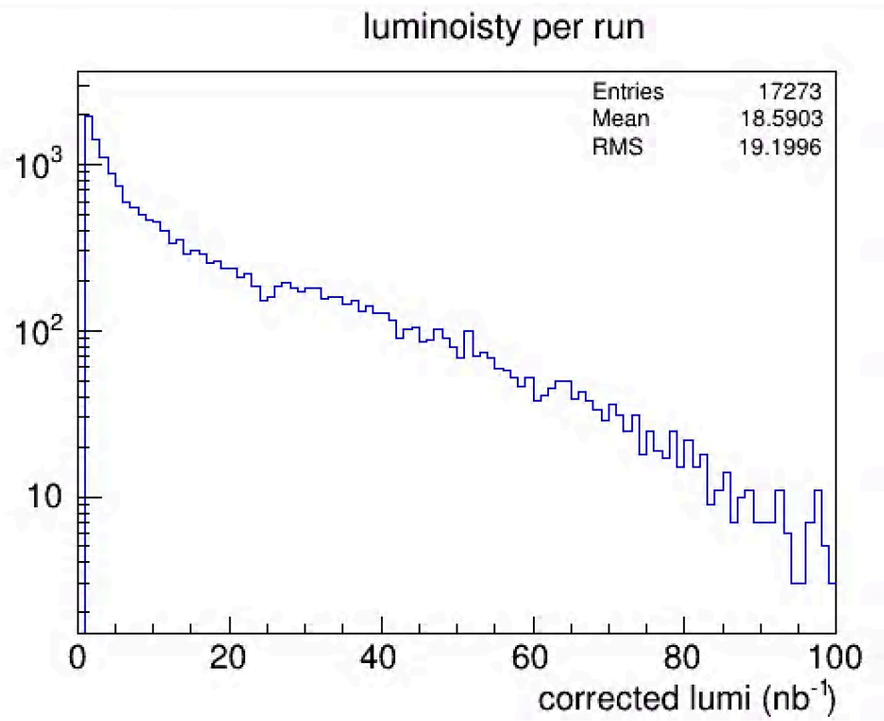
Spin direction in HERMES, H1 and ZEUS longitudinal; in arcs vertical

Two polarimeters available: TPOL near HERA-B; LPOL near HERMES

Beam Polarization

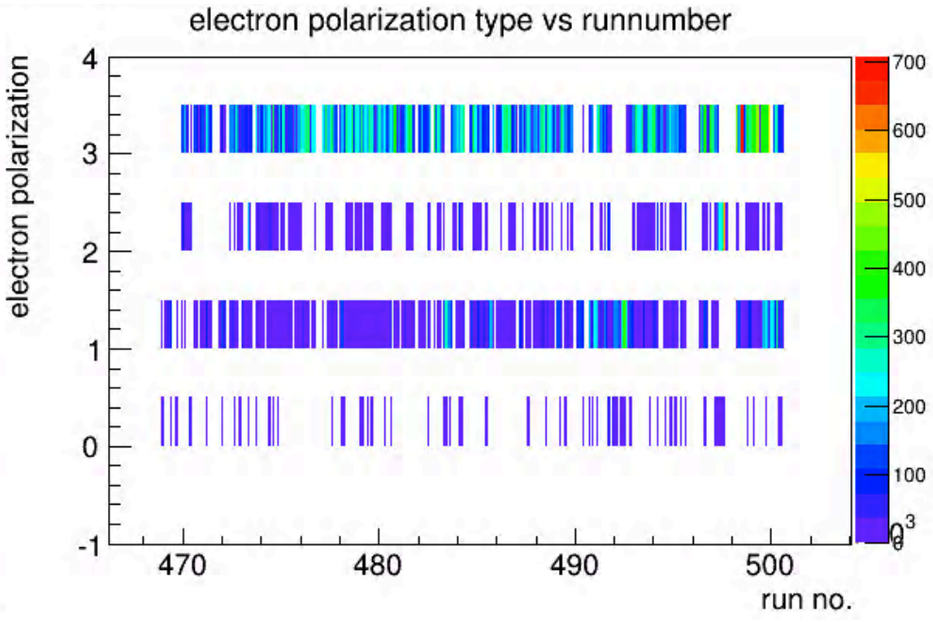


Gaus fit: -36.5 (4.8)% 30.3 (5.5)%



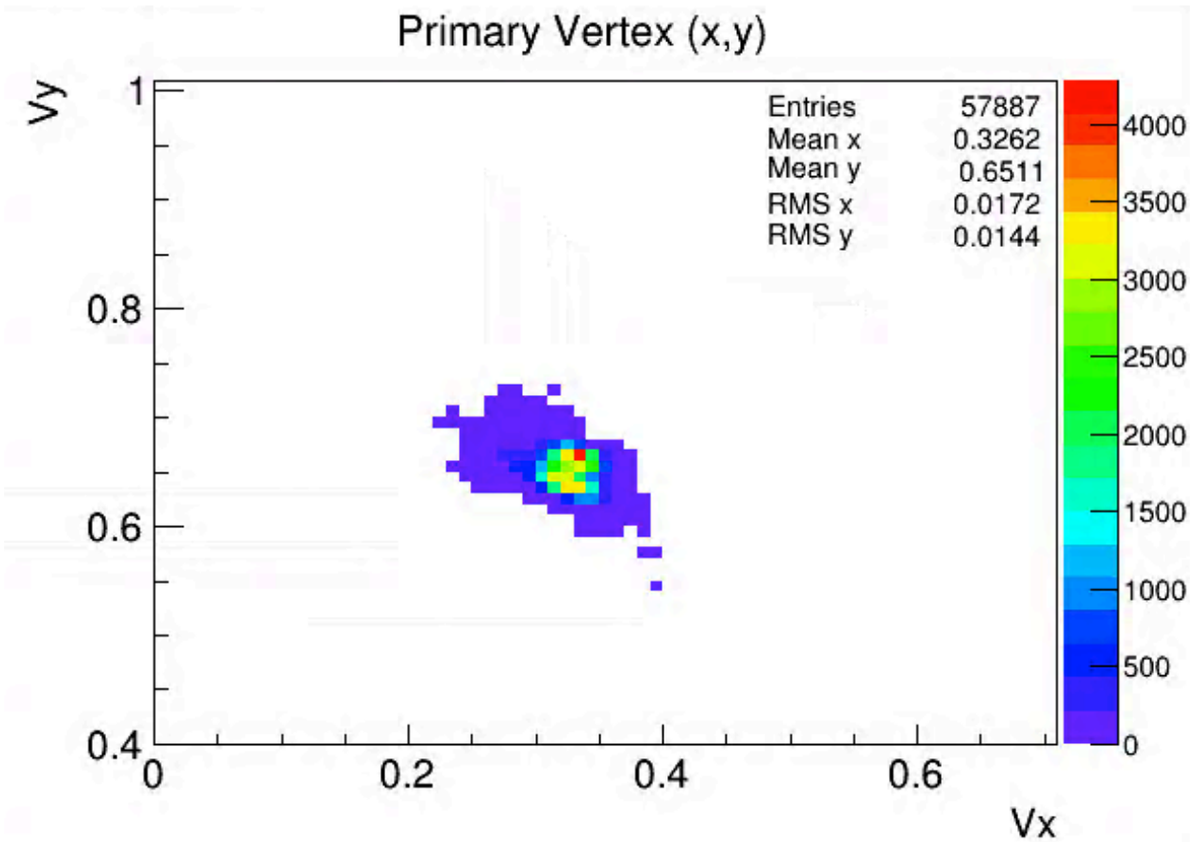
04-07: 17273 runs with lumi > 1 nb-1

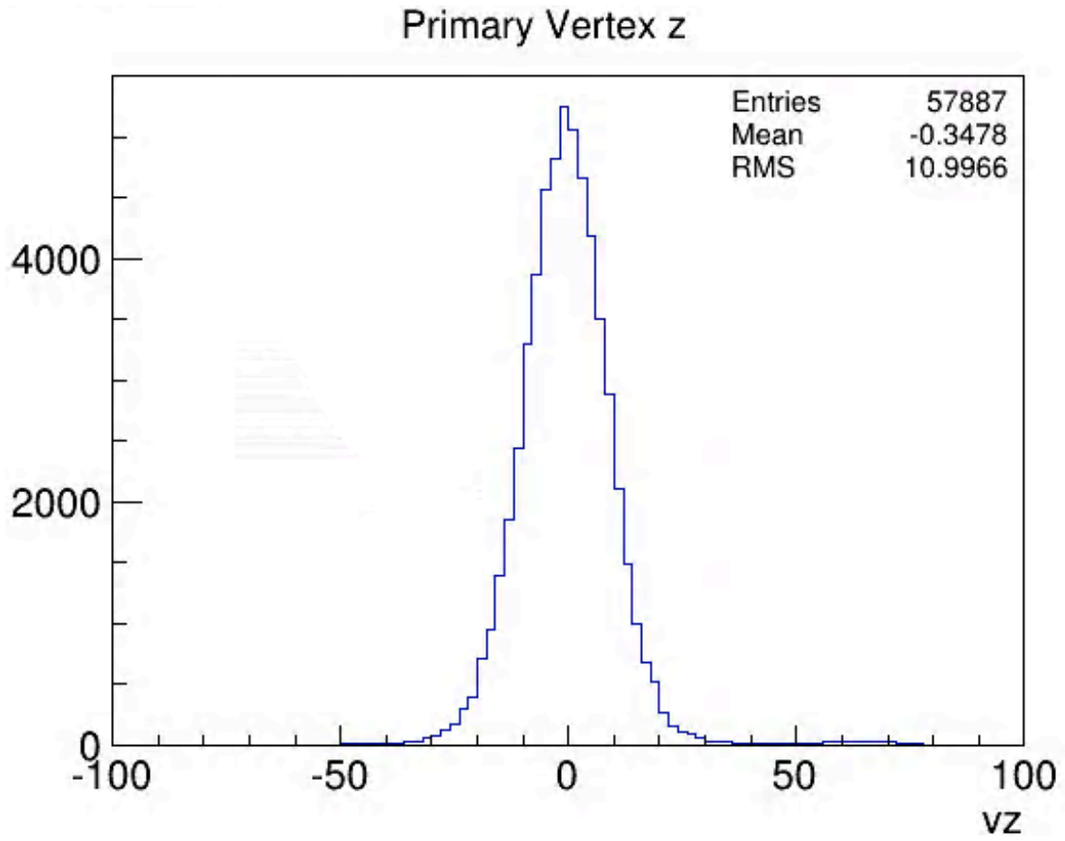
lumi weighted polarization(>15%):
33.1%, -31.2%



Polarization Type:
1 Tpol,
2 Lpol,
3 weighted mean T/Lpol,
0 measur. nok, neg.values error

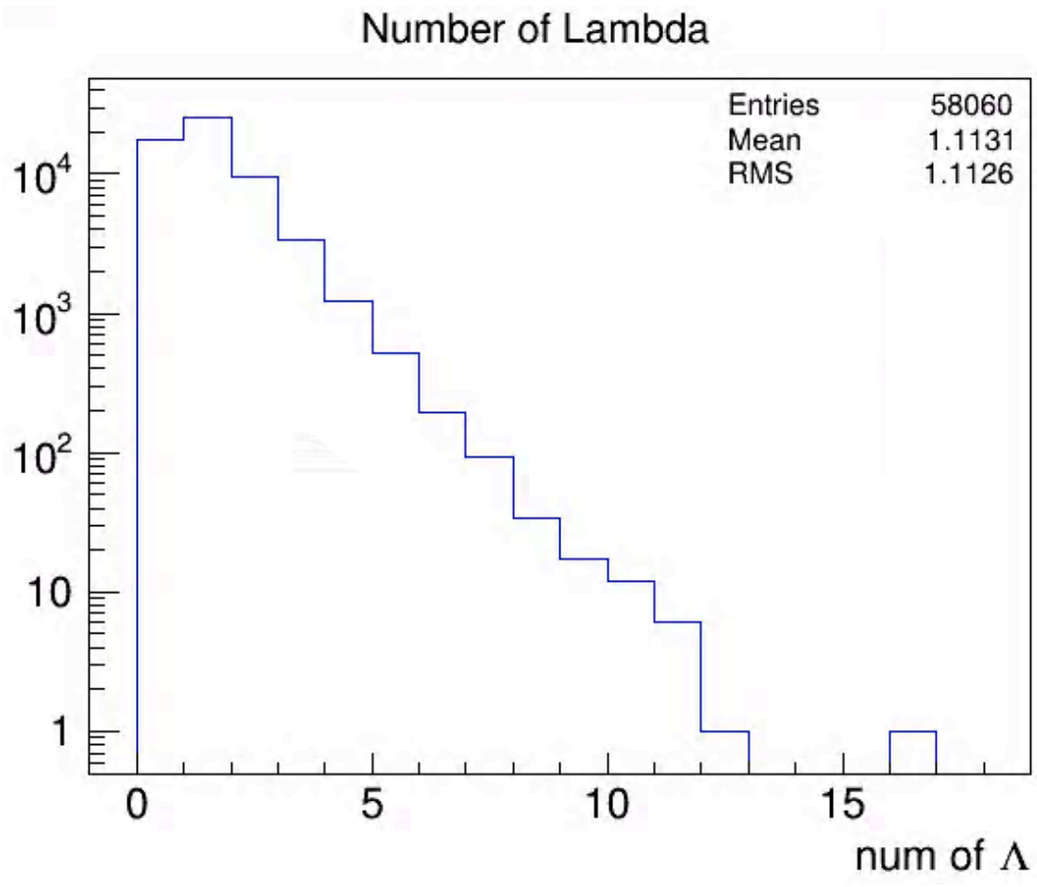
Vertex

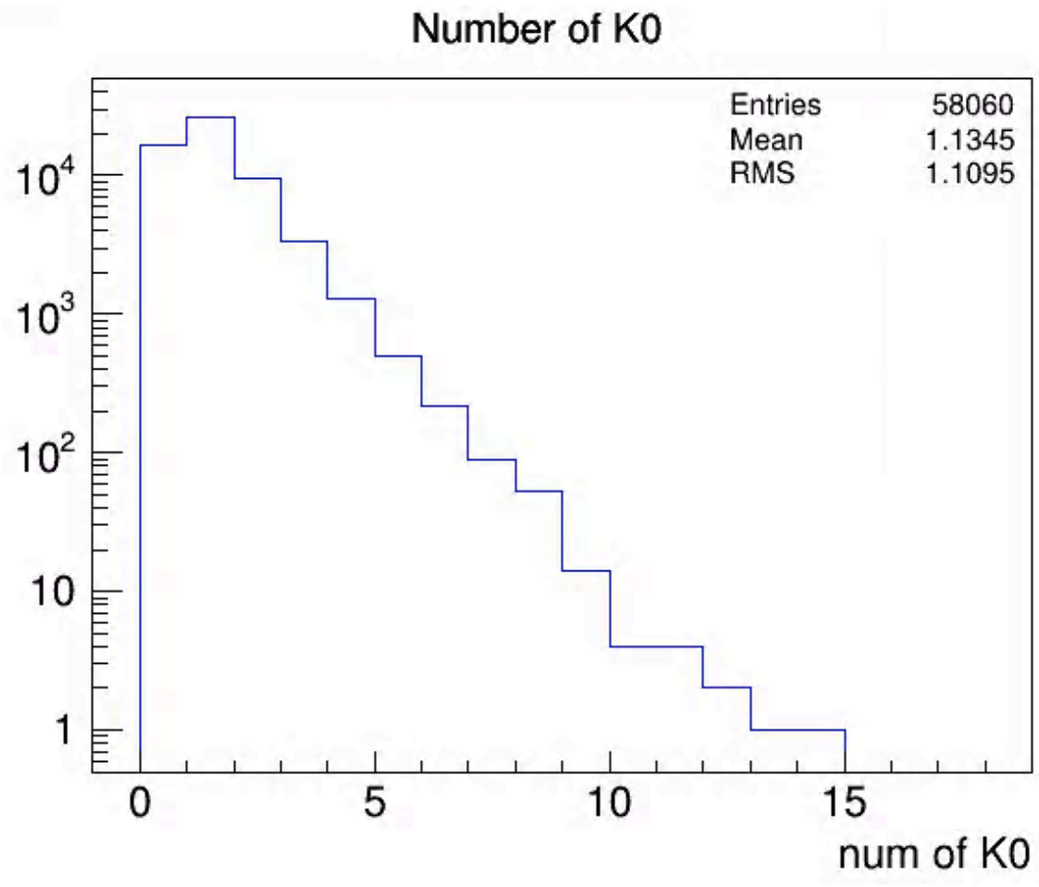




$$|V_z| < 35 \text{ cm}$$

Fitted V0 Multiplicity





- Abundant V0 candidates
- Two Lambda (current jet) spin correlation?

Lambda/K0s Reconstruction

Cut for Lambda, similar for K0s

$E_{e'} > 12$ GeV

$5 < Q^2 < 100$ GeV

$0.0375 < y < 0.6$

$35 < \Sigma(E - p_z) < 70$ GeV

$p_t(p/\pi) < 0.12$ GeV

$p_t(\Lambda) < 0.5$ GeV

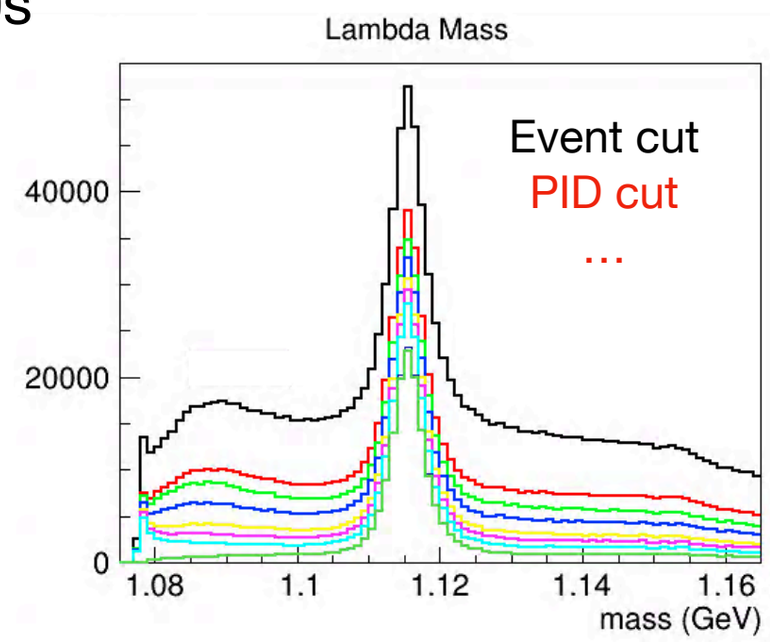
$|\eta(\Lambda)| < 1.5$ GeV

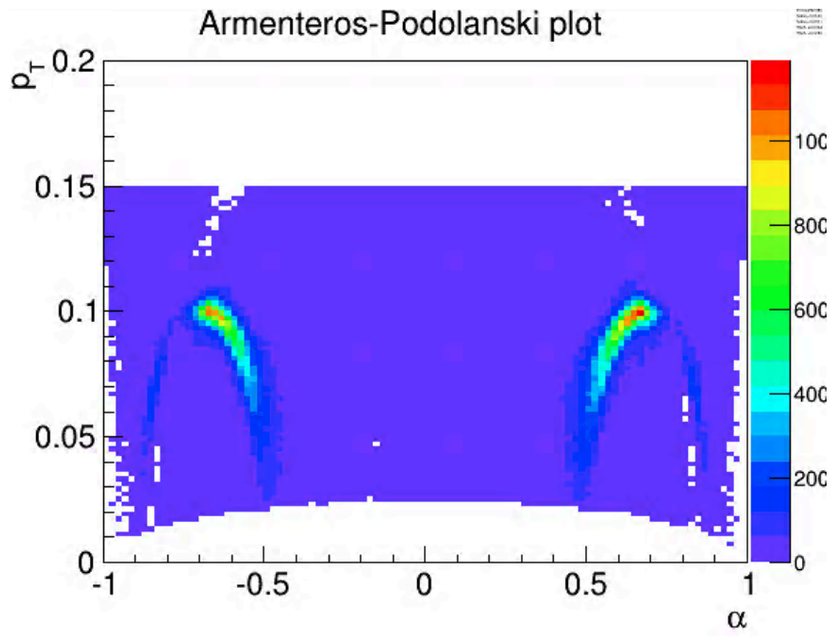
Track radial length > 15 cm

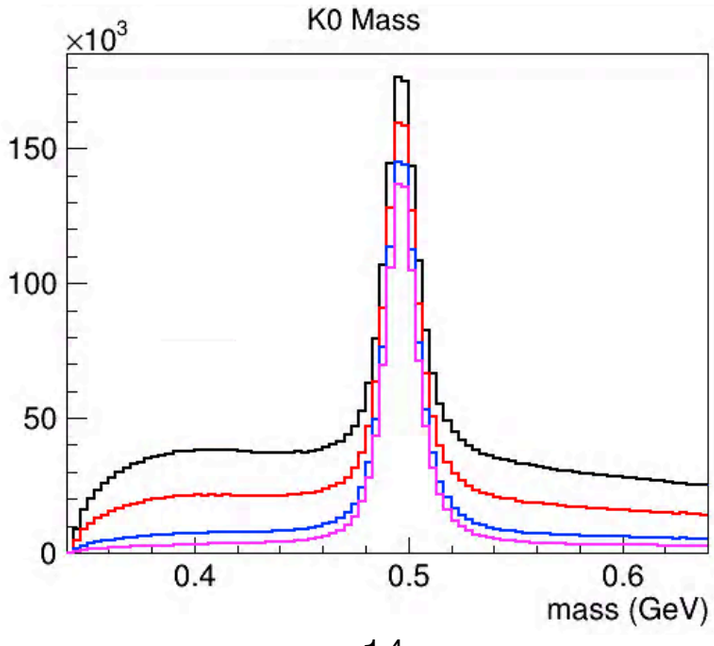
Proton $DCA/\sigma(DCA) > 2$

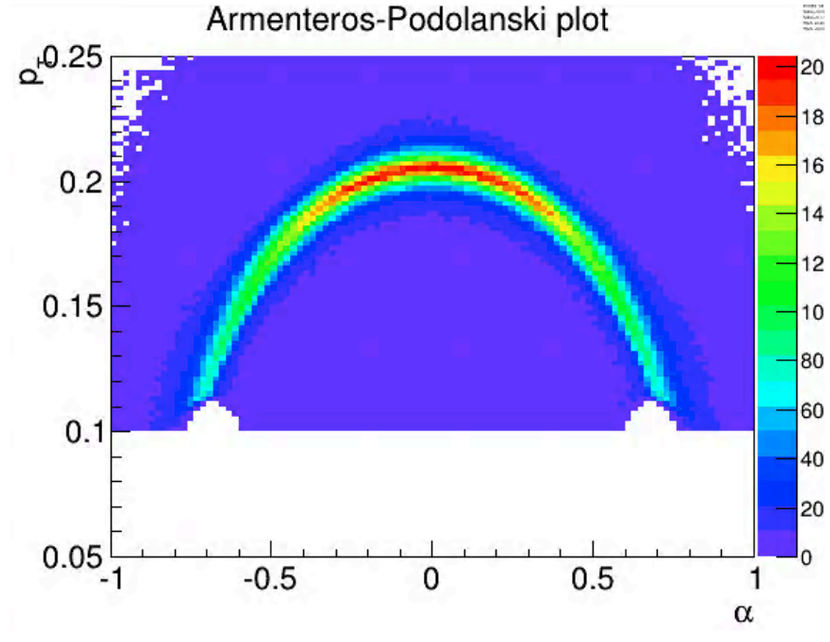
Pion $DCA/\sigma(DCA) > 1$

$L_p(\frac{dE}{dx}) > 0.003$

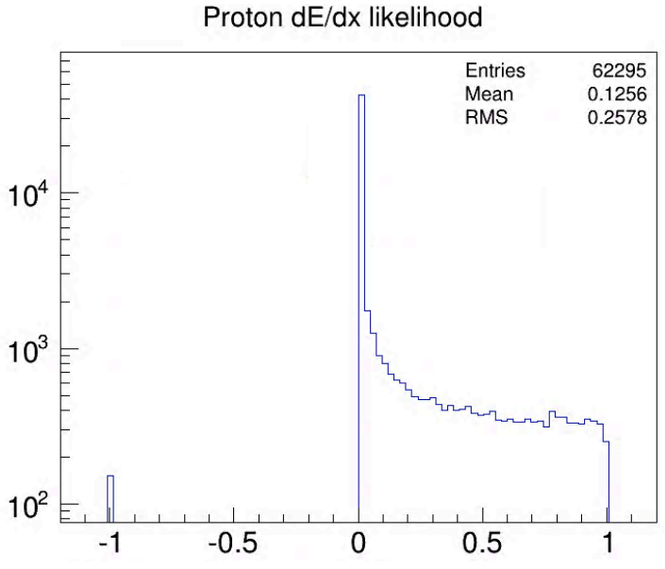


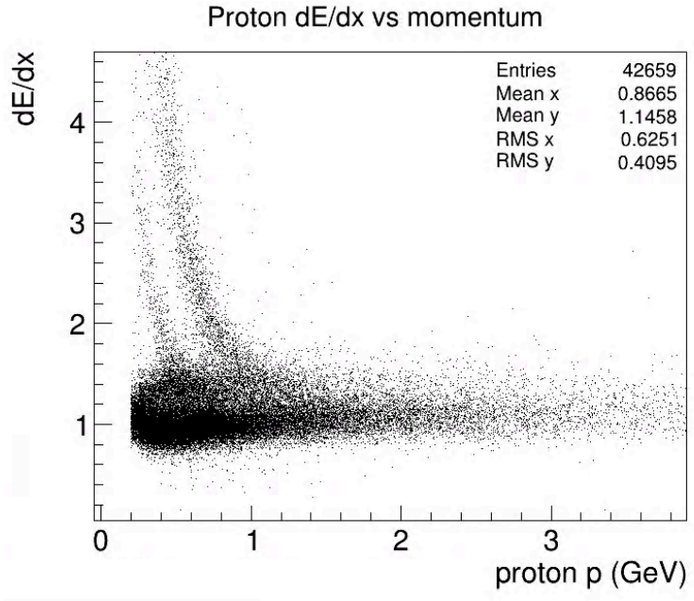


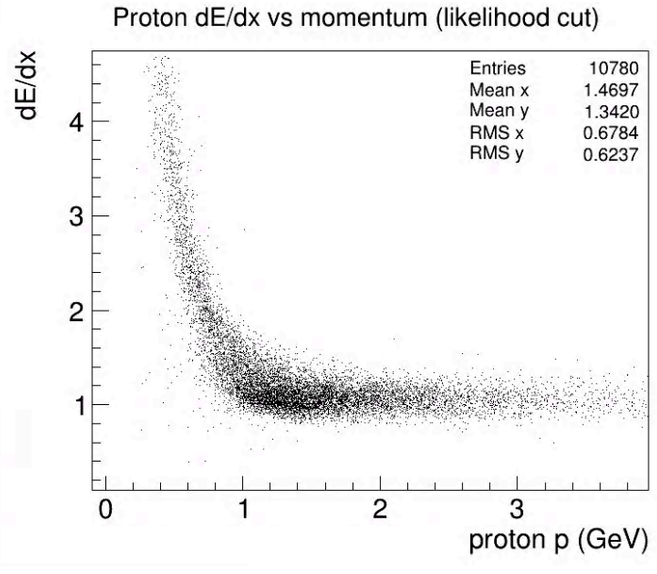




Proton PID



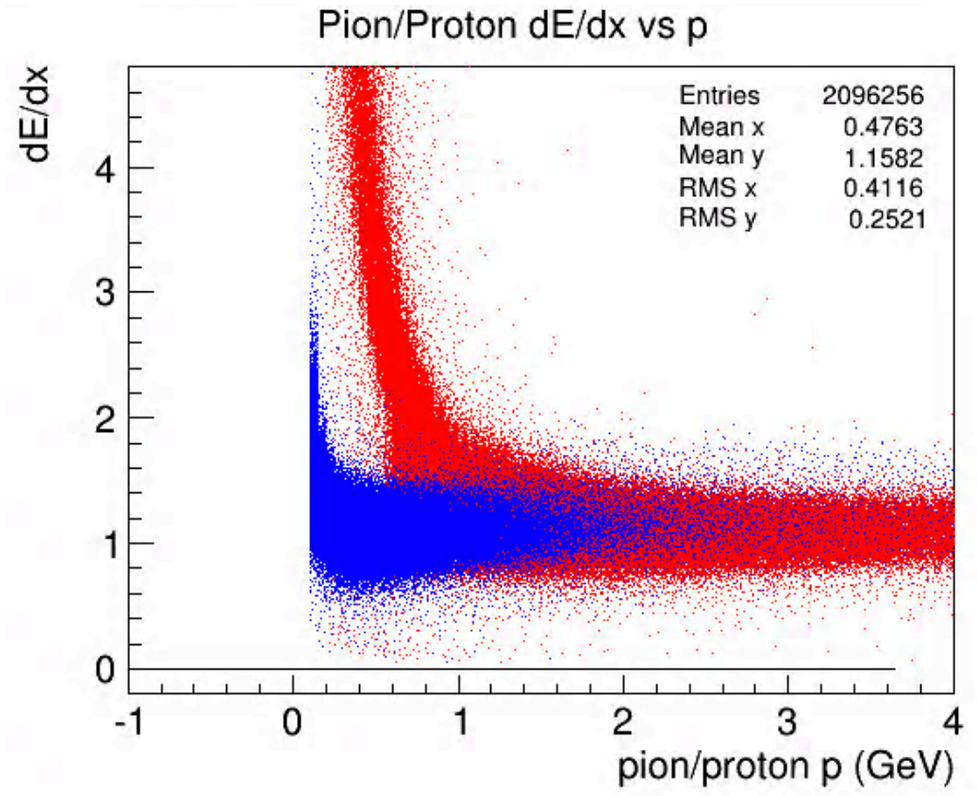




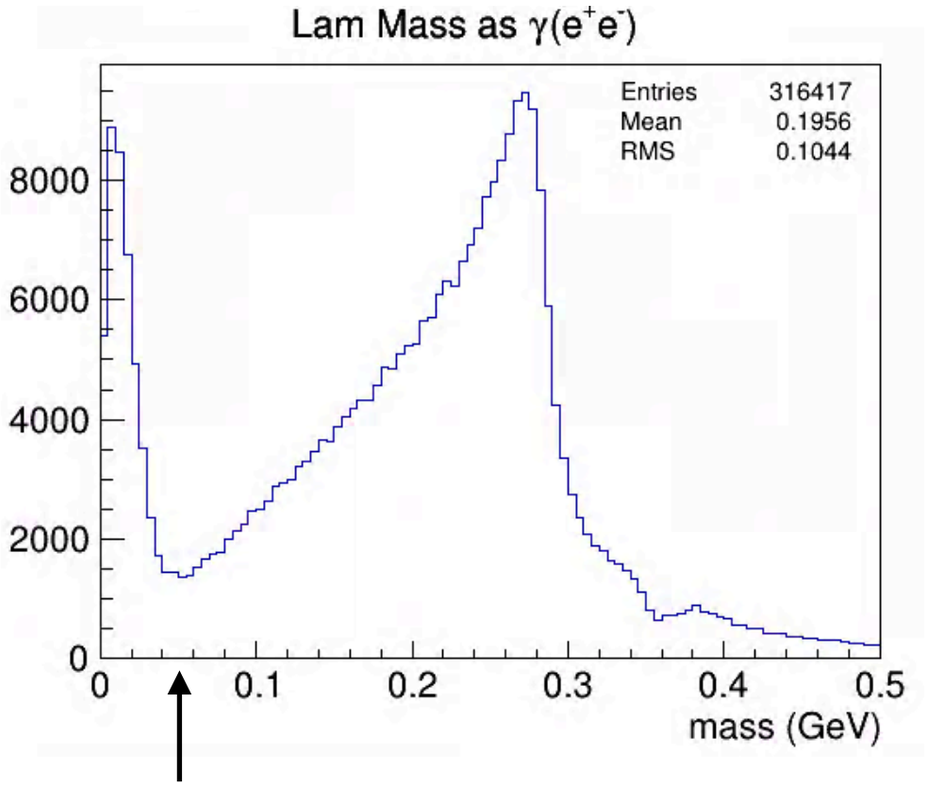
Likelihood cut:

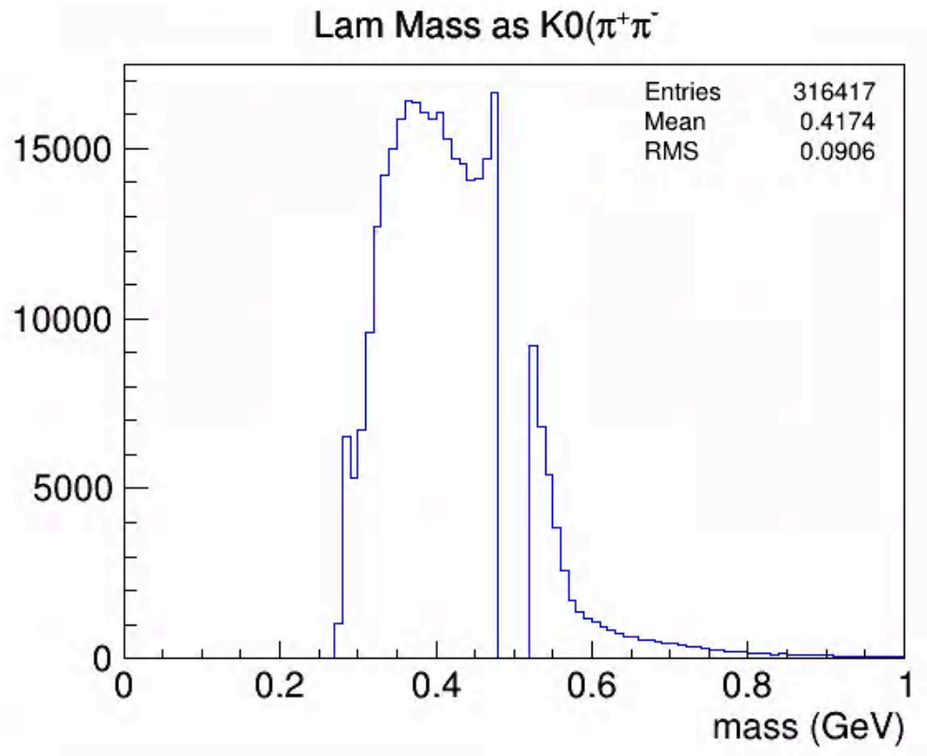
$$L_p(\frac{dE}{dx}) > 0.003$$

(H1 thesis by K. Avila, 2013)



Mis-ID from γ^* and K_s^0

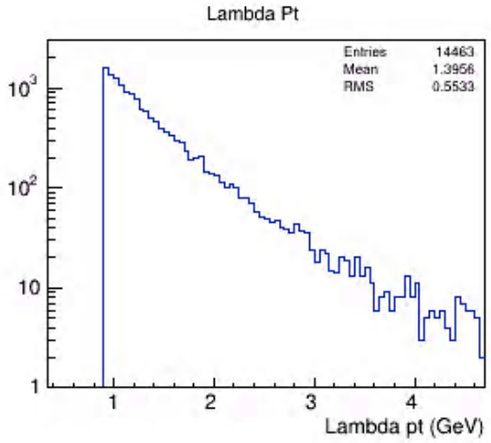


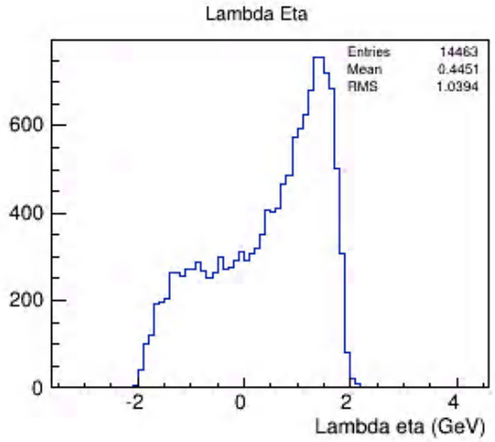


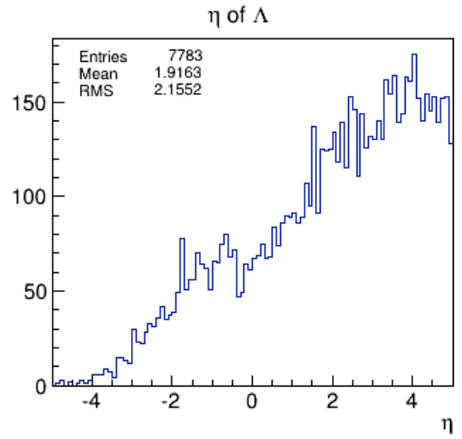
Cut range: $M_{e^+e^-} < 0.05$ GeV $\qquad$ $0.465 < M_{\pi^+\pi^-} < 0.530$ GeV

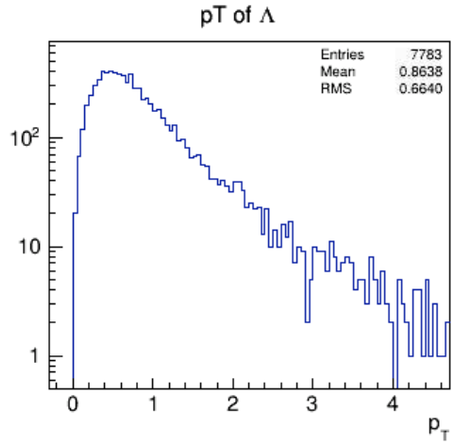
Comparison with fast simulation

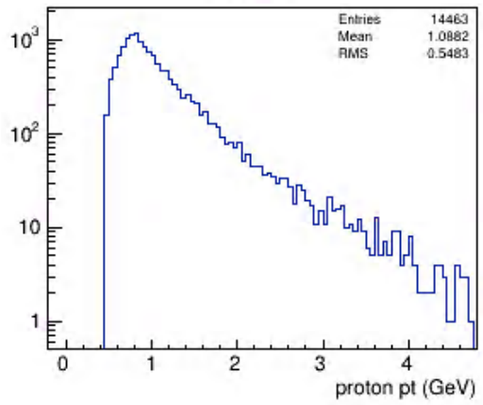
H1 **Pythia 6**

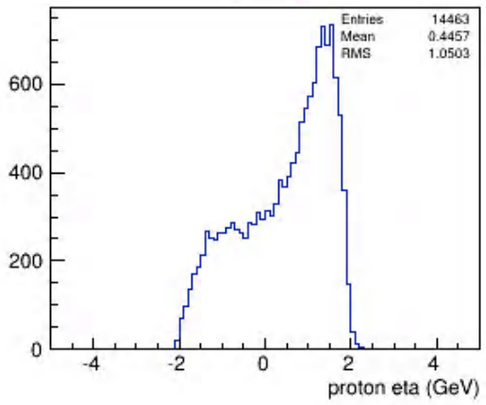


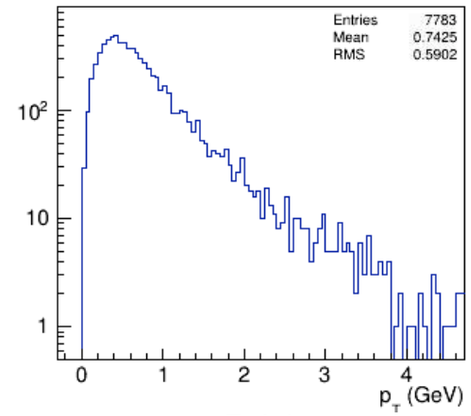


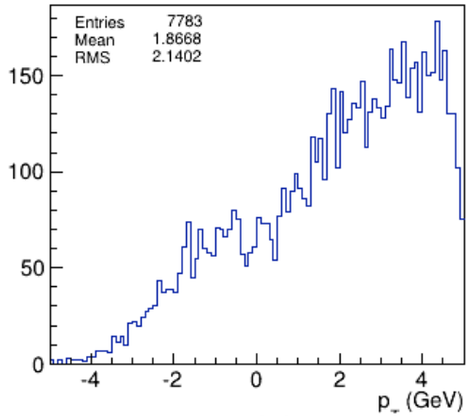


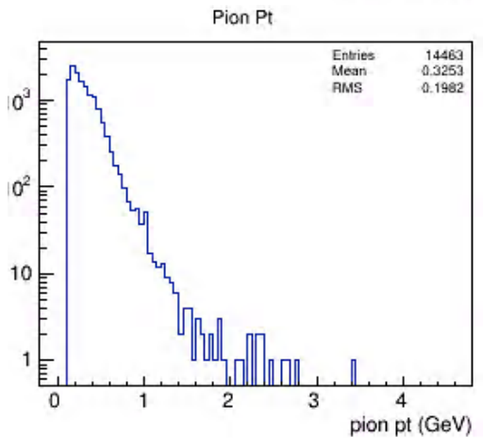


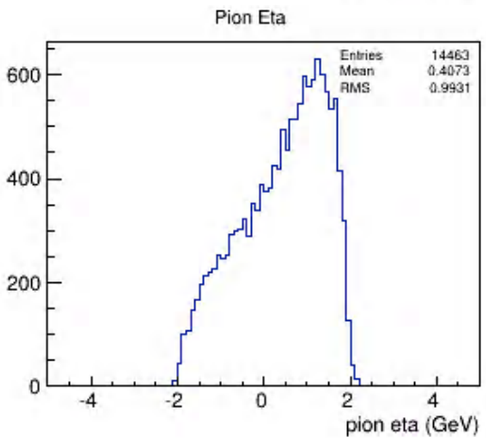


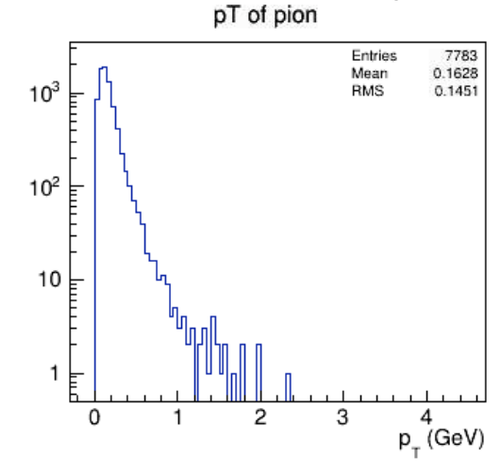


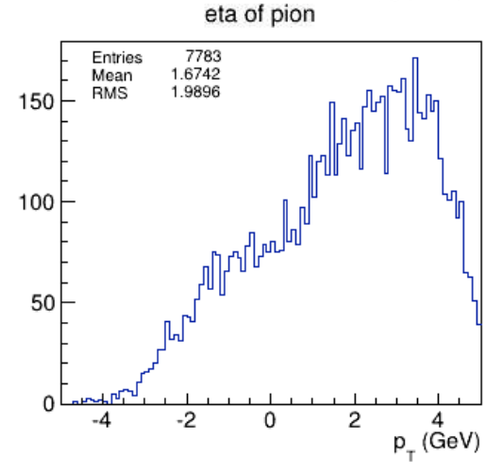




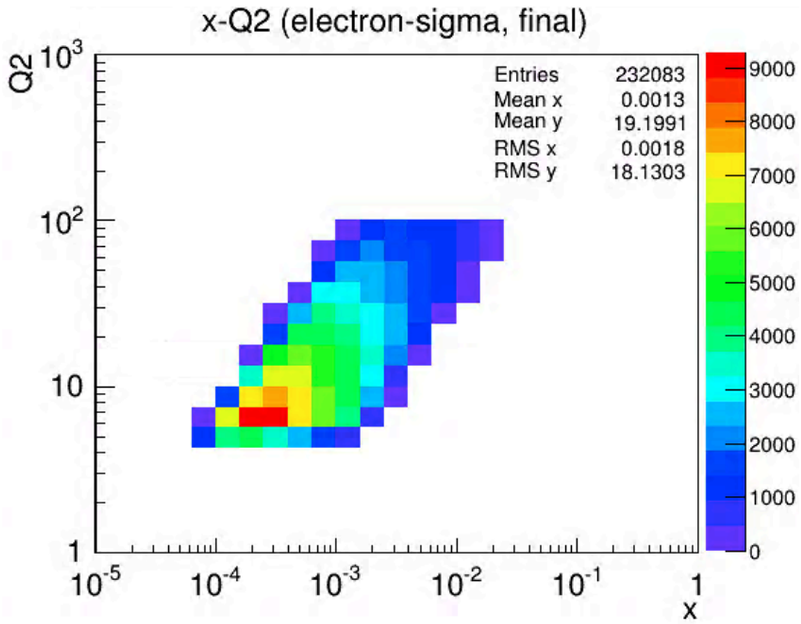


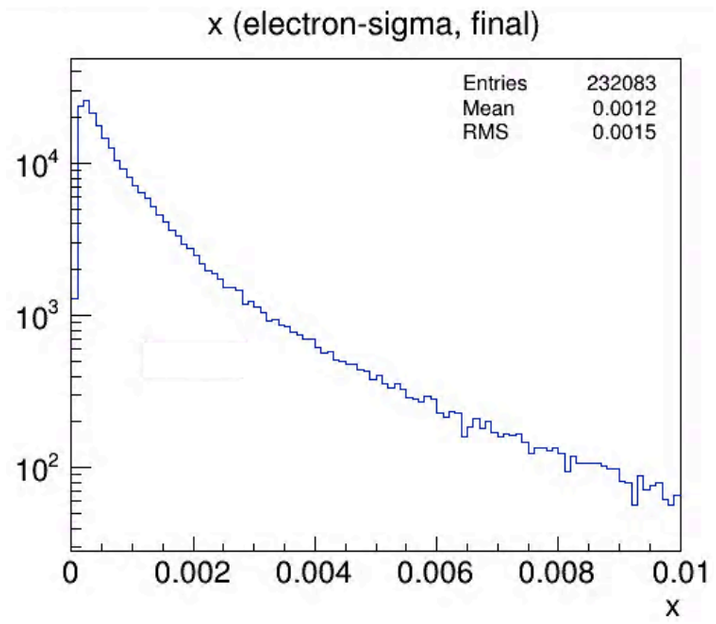


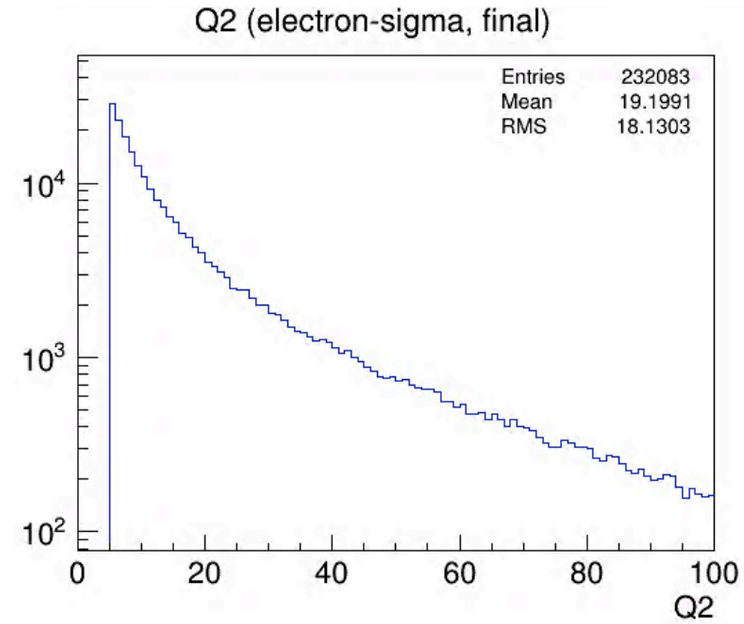


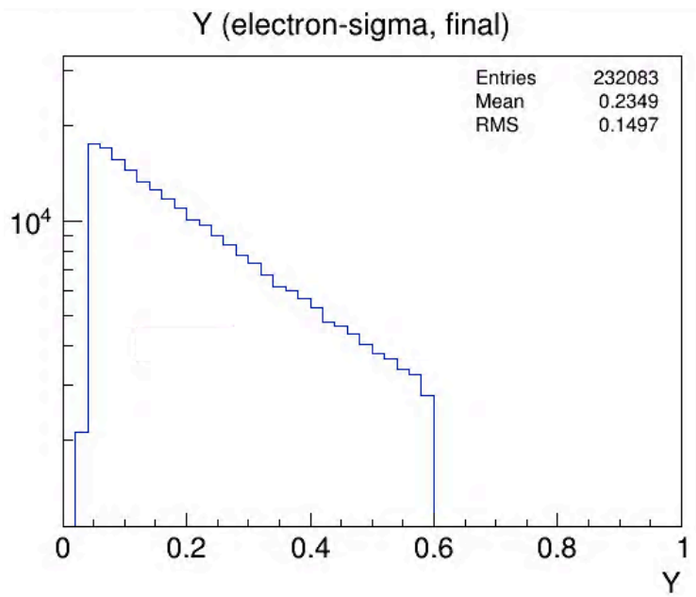


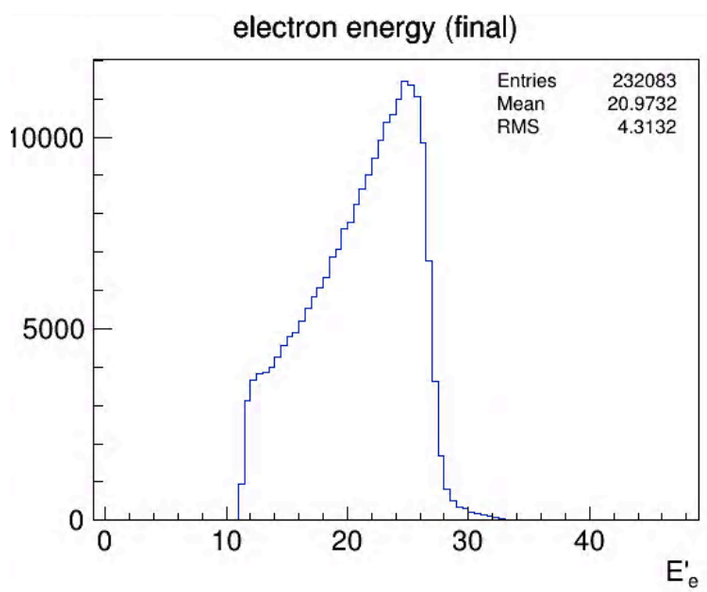
Event Variables

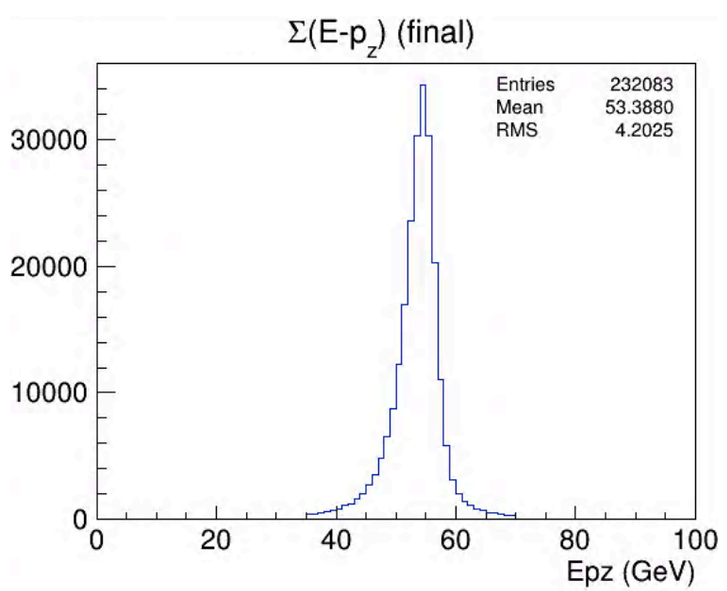




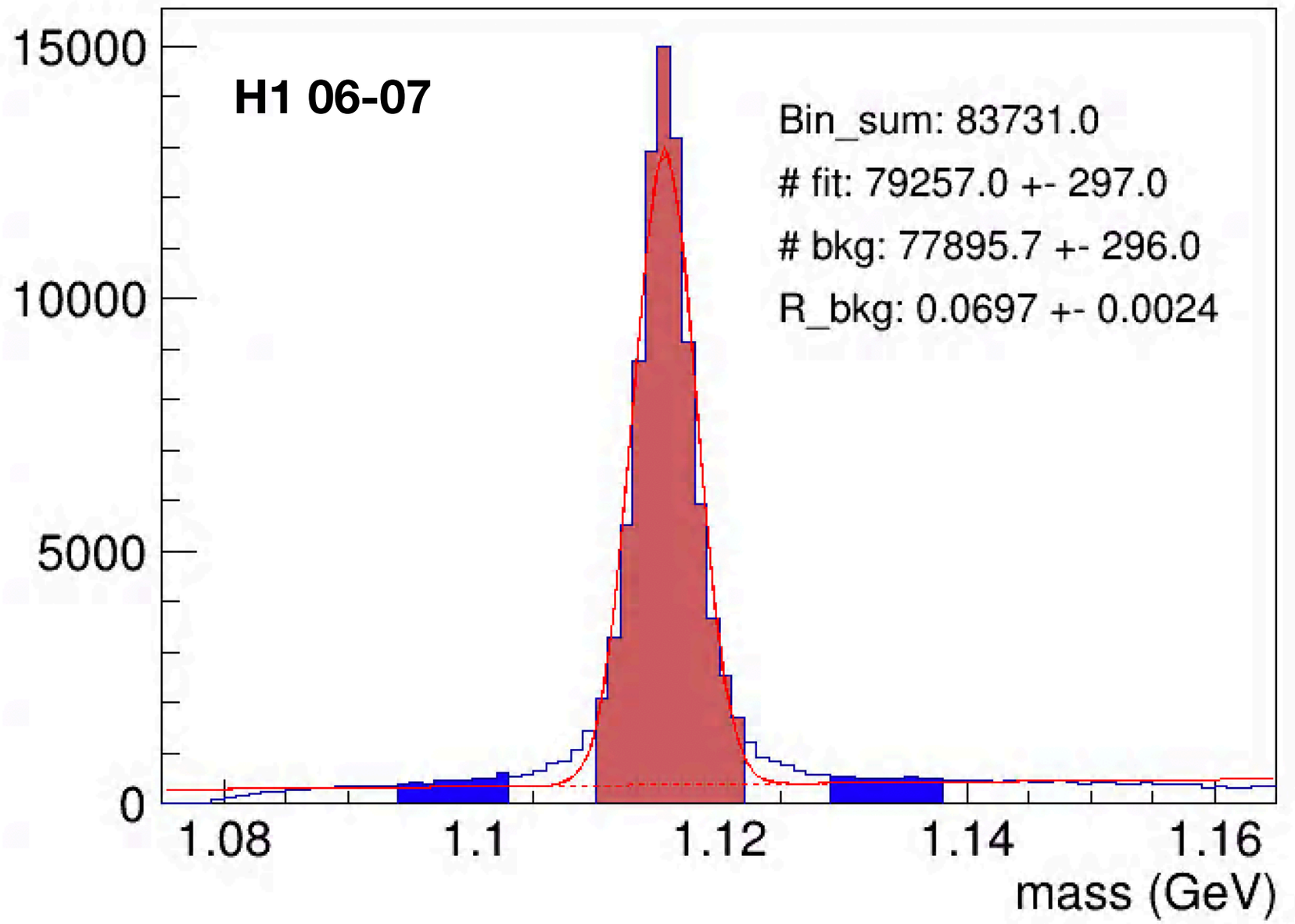








Lambda Invariant Mass



- Side band vs fitting
- 7% background

Spin transfer extraction

$$\frac{dN}{d\cos\theta*} = N_0(1 + \alpha_{\Lambda(\bar{\Lambda})} P_{\Lambda(\bar{\Lambda})} \cos\theta*$$

$$P_q = P_B D(y)$$

$$P_\Lambda = P_q \, D_{LL}$$

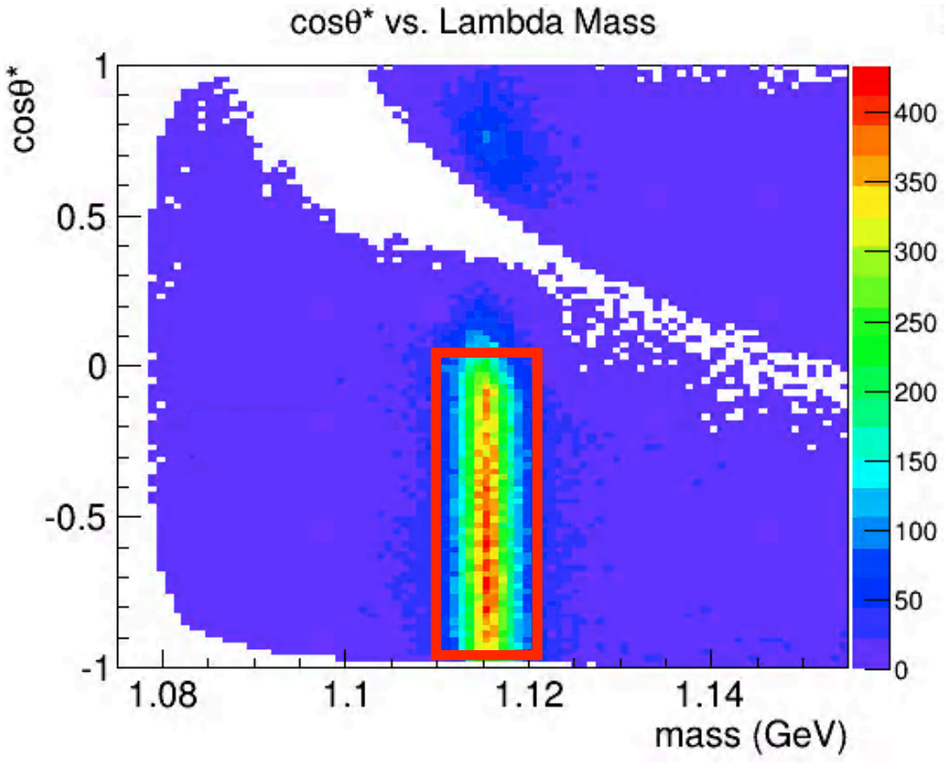
$\theta*$: proton angular with Λ p in Λ rest frame

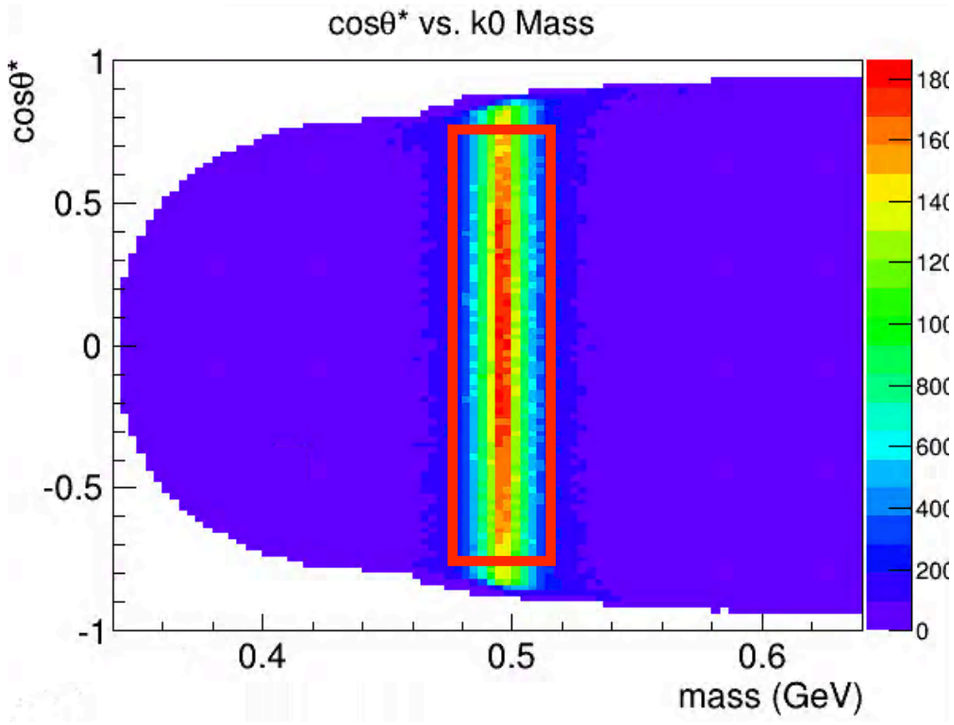
P_q : quark polarization

P_B : beam polarization

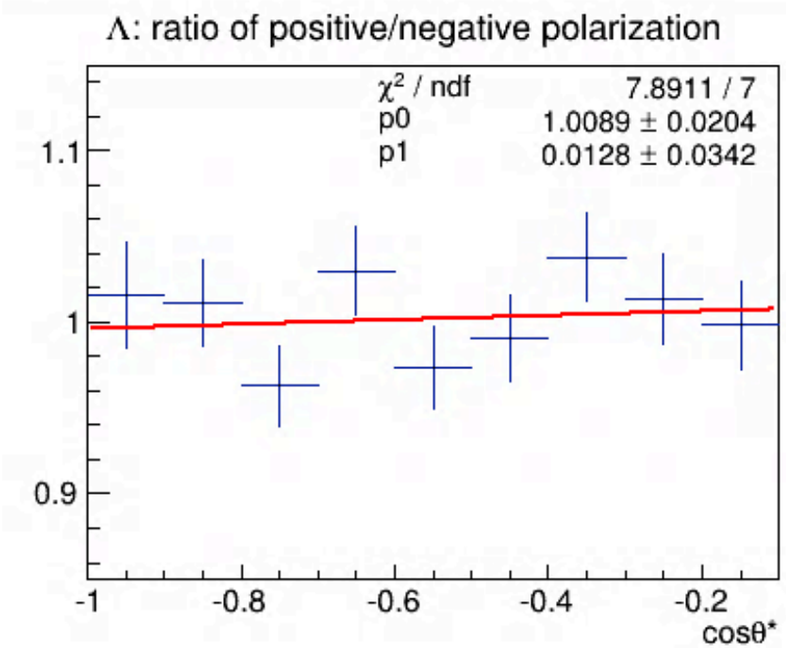
$D(y)$: depolarization factor

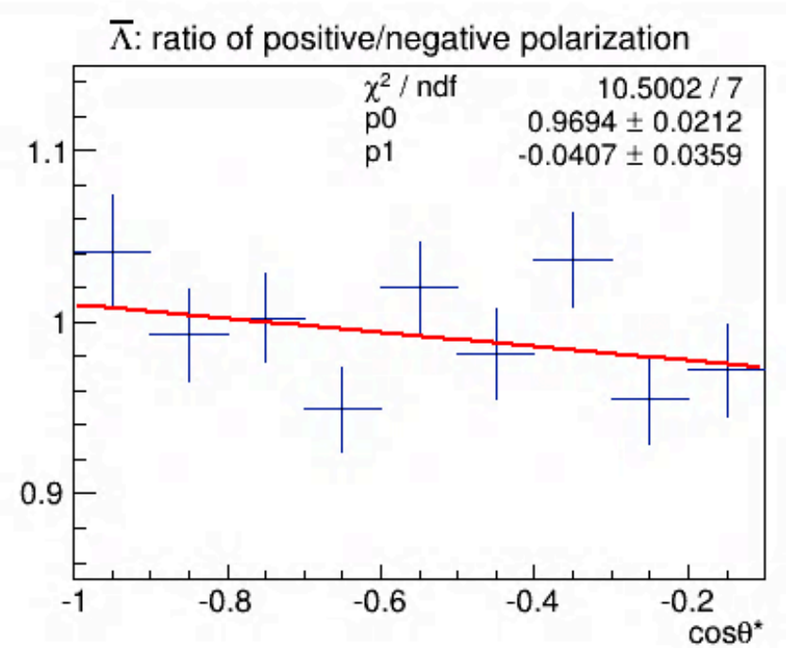
D_{LL}: spin transfer



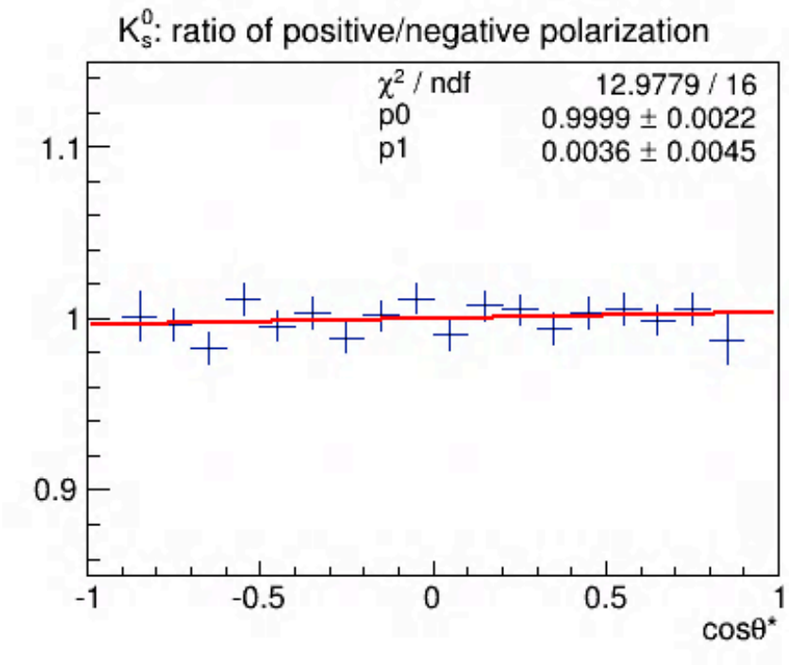


Before D_{LL} extraction





Raw ratios:
No correction
partial data



Lambda polarization extraction needs :

- acceptance correction (unfolding)
- depolarization factor

Reference measurements:

- K0s for zero-check
- Jet for kinematics (*z* in jet)

Summary and Next Step

- Longitudinal spin transfer to Lambda/Lambda-bar probes polarized FFs and hyperon structure
- Analysis frame built up and saw clear Lambda sample
- Next step:
  - Detailed MC analysis -> acceptance correction unfolding matrix
  - Lambda in Jet