Reconstruction and Background Discrimination

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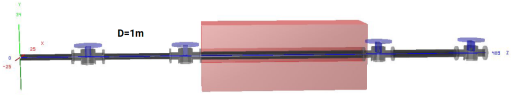
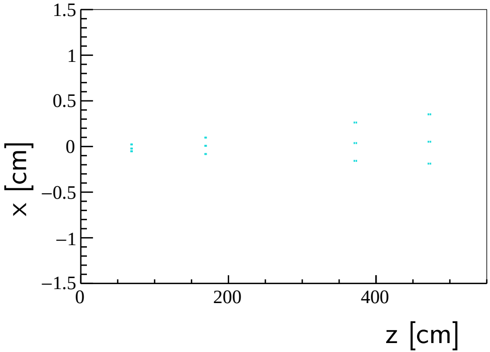
- channeled Λ_c^+ flight distance $\mathcal{O}(3\,\mathrm{cm})$

$\Rightarrow$ Highly boosted Λ_c^+ daughter tracks from the crystal within only $\mathcal{O}(10\,\mathrm{cm}^2)$ tracker area at 4.4 m distance

- 2 pixel trackers per Roman pot with 55 $\mu\mathrm{m}$ pitch
- Misidentified backgrounds from *e.g.* $D_s^+ \to K^+K^-\pi^+$ mesons $\to$ need good mass resolution

currently studied geometry

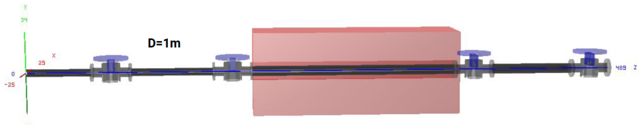




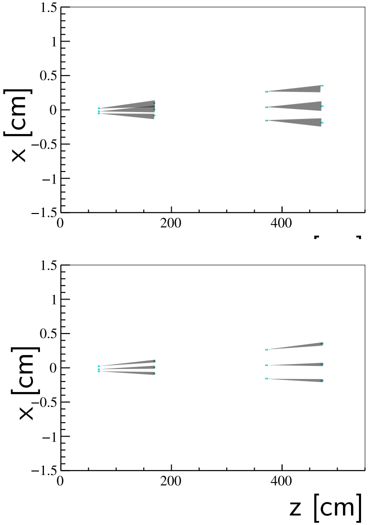
Reconstruction

- to go from **hits** in the detector to **tracks** to Λ_c^+ **candidates**, we need
  1. Pattern Recognition
  2. Track Reconstruction
  3. Particle Identification
  4. Vertexing

current setup



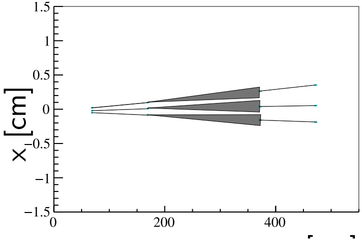
- most signal tracks originate close to z-axis $\Rightarrow$ tracks have constant azimuthal angle ϕ outside of magnetic field
- sort track hits in ϕ, create a seed from a hit in layer 1 and a hit in layer 2, if they have similar ϕ
- extrapolate seed to layer 3 and add hits, if they lie within $x - y$ window
- same for layer 4 with smaller window
- do the same in tracker behind magnet, but with looser ϕ-window (because tracks were bent in the magnetic field)

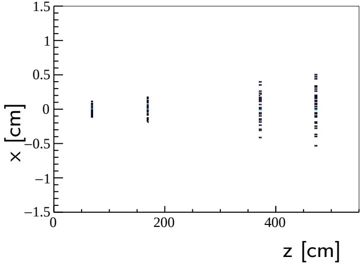


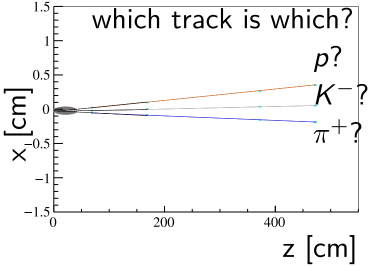
Seeding

- extrapolate downstream in (unbent) x-direction
- use Kalman Fitter to evaluate track quality and determine momenta
- test, if tracks form vertex
- additional hits from underlying event make track-finding more interesting

$\Lambda_c^+ \rightarrow pK^-\pi^+$

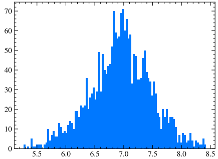




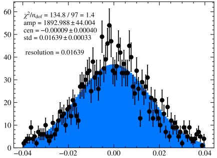


Track Angular and Momentum Resolution

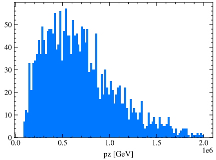
- track momenta between 100 and 2000 GeV
- track θ within 1 mrad of Λ_c^+ flight direction
- $\frac{\sigma(p_z)}{p_z} \approx 3\%$[a] for daughter tracks from channeled Λ_c^+ spectrum
- track $\Delta\theta \approx 16 \mu rad$ [b]



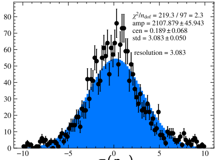
track θ [mrad]



track $\Delta\theta$ [mrad]



track p_z [GeV]



$\frac{\sigma(p_z)}{p_z}$ [%]

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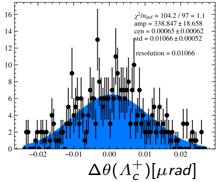
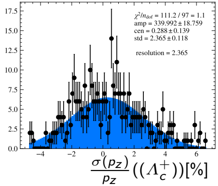
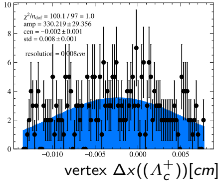
[a] 5 % for 0.4 m lever arm
[b] 29 μrad for 0.4 m lever arm

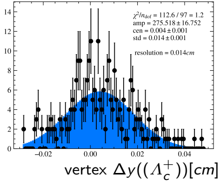
Λ_c^+ Angular and Momentum Resolution

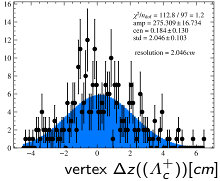
- $\Delta\theta(\Lambda_c^+) \approx 11\mu rad$
- $\frac{\sigma(p_z)}{p_z}((\Lambda_c^+)) \approx 2.4\%$ (5.8 % for 0.4 m lever arm)
- Λ_c^+ vertex resolution $80\,\mu\mathrm{m}/140\,\mu\mathrm{m}/2\,\mathrm{cm}$ in x/y/z











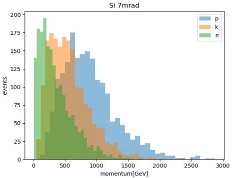
Particle Identification in $\Lambda_c^+ \to pK^-\pi^+$

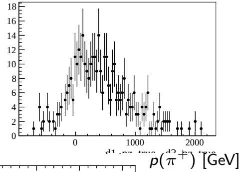
track with **negative** charge gets assigned Kaon hypothesis

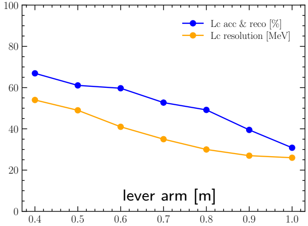
- Without RICH (see Roger's talk) need kinematics to associate track with PID: High mass daughter gets higher momentum on average''

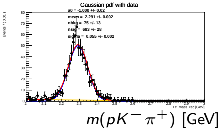
$\Rightarrow$ assign proton hypothesis to higher momentum track ($\varepsilon \approx 80\,\%$)

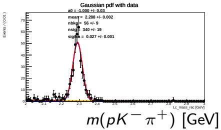
- Different detector designs: tradeoff between acceptance (constrained by beampipe) and resolution (lever arm)











Why do we need a good mass resolution?

separation from **misidientified** background:

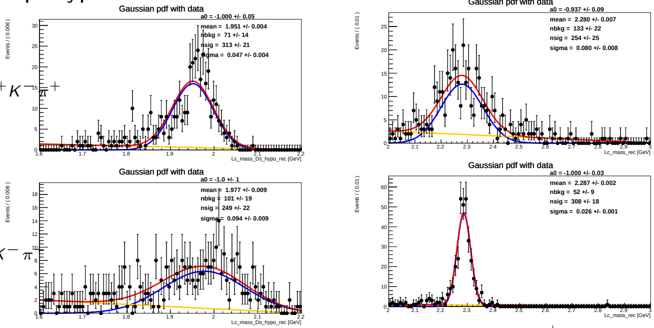
- $D^+ \to K^-\pi^+\pi^+$ one π^+ misidentified as p
- $D_s^+ \to K^+K^-\pi^+$ with $\boldsymbol{K^+}$ misidentified as p
- similar cross section, and channeling probabilities, and life times as Λ_c^+
- Use of mass veto possible, but not very efficient: $\epsilon_{sig} \approx 60\,\%$, $\epsilon_{Ds} \approx 30\,\%$[a]

[a] worse for shorter lever arms

KKpi hypo | pKpi hypo

$D_s^+ \to K^+K^-\pi^+$

$\Lambda_c^+ \to pK^-\pi^+$

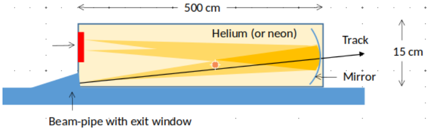


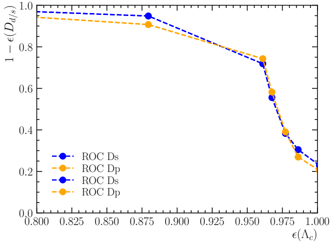
$m(pK^-\pi^+)$ [GeV] | $m(pK^-\pi^+)$ [GeV]

Particle Identification with RICH

Opposite charge track gets Kaon hypothesis

- RICH proposal by Roger Forty: 3σ separation between pion and proton from 100 to 1200 GeV
- can just take the track with higher PIDppi value to distinguish proton from pion candidates (gain 20 % efficiency wrt. kinematic association)
- can reject **80 %** of misid background with a **signal efficiency** $\boldsymbol{\epsilon_{\Lambda_c^+} = 94\,\%}$



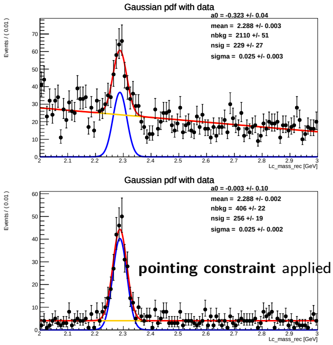


Why do we need a good angular resolution?

combinatoric background from hits from **underlying event**

- tracks including hits from several genuine particles (**clones**)
- **genuine** tracks from spray of particles out of p–W collision combined with Λ_c^+ daughters

Λ_c^+ sample with realistic underlying event



$m(pK^-\pi^+)$ [GeV]

Mitigation Options Clone Tracks

- Calculate angle between all reconstructed tracks – if below threshold, only keep the ones with best track fit quality ($\sigma(\theta_{\text{track}} \approx 16\mu$rad))

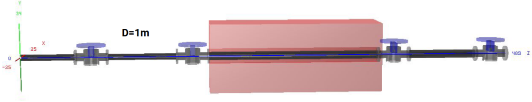
Mitigation Options Genuine extra particles

- Cut on Λ_c^+ **flight direction** (channeled Λ_c^+ have $\theta = 7.00 \pm 0.03$ mrad) ($\sigma(\theta_{\Lambda_c^+}) \approx 11\mu rad$)
- Vertexing: $\sigma_z \approx 2\,\text{cm}$ $\sigma_{xy} \approx 140\mu m$ (typical Λ_c^+ flight distance $\approx 2\,\text{cm}$)

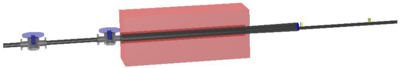
Next Steps

- study setup with beamwindow downstream of magnet: would benefit acceptance and resolution
- can additional layers inside Roman pots help with pattern recognition?
- What is performance for J/ψ adding muon stations

current setup



beamwindow setup



muon station setup

Backup

Electric dipole moments suppressed in SM. Any significant observation would be sign for NP

- strong bounds for light baryons, dominated by neutron EDM measurement ($d_n < 10^{-26} e\,\mathrm{cm}$)
- what if new physics couples stronger to heavy quarks (b-anomalies?): expect better sensitivity to NP from heavy baryon EDMs, even if sensitivity for d_B much worse than for d_n

Magnetic dipole moments of baryons can directly test different approaches for QCD calculations (sum rules, lattice, ...)

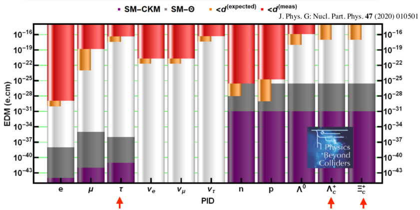
- For Λ_c^+: predictions range from $\mu = 0.15\mu_N$ to $\mu = 0.4\mu_N$ (link)

$$\vec{\delta} = \int \vec{r}\rho(\vec{r})d^3r \qquad \vec{\mu} = \frac{1}{2}\int \vec{r} \times \vec{J}(\vec{r})d^3r \tag{1}$$

$$= d\mu_N \frac{\vec{S}}{2} \qquad = g\mu_N \frac{\vec{S}}{2} \tag{2}$$

$$H = -\vec{\delta} \cdot \vec{E} + \vec{\mu} \cdot \vec{B}$$

$$\mathbf{T}(\vec{\delta}) = \mathbf{P}(\vec{\delta}) = -1\vec{\delta} \Rightarrow \not{CP}$$



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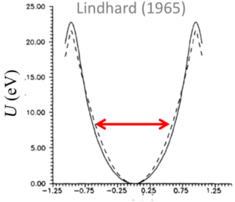
Crystal Channeling

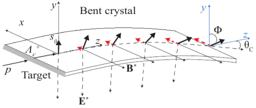
Measure dipole moments from precession of spin in magnetic field, but $c\tau_{\Lambda_c^+} \approx 5cm \Rightarrow$

- Need strong magnetic fields $\gg 1T$ for significant precession
- strong electric fields in potential well between lattice planes in a crystal $\Rightarrow$ effective B-field!

$\Rightarrow$ $\vec{E}^* \approx \gamma\vec{E}$, $\vec{B}^* \approx -\gamma\vec{\beta} \times \vec{E}$

- positively-charged particles can be **channeled**, if transverse energy is small$\Rightarrow$ Small incident angle w.r.t the crystal planes (few μrad $\Rightarrow$ low efficiency $\mathcal{O}(10^{-4})$)





Spin precession is then

$$\vec{S} \approx \left(\frac{d}{g-2}\left(\cos\Phi - 1\right), \cos\Phi, \sin\Phi\right)$$

with $\Phi \approx \frac{g-2}{2}\gamma\frac{L}{\rho_0}$ (L: crystal length, ρ_0: bending angle link and EPJ C 77 (2017) 828

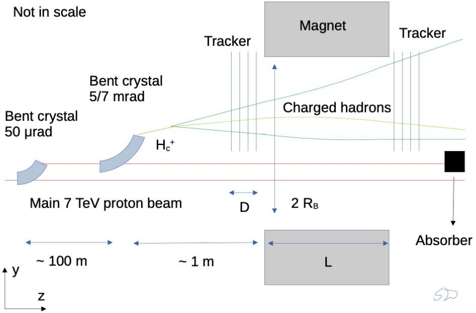
Double Crystal Channeling Setup

Need boosted source of polarized Λ_c^+
$\Rightarrow$ fixed target at LHC

- use crystal to channel 6.5 TeV protons from LHC beam halo onto W target
- produced Λ_c^+ have significant polarisation and are very collimated
- channel Λ_c^+ with second crystal

Need detector to infer **spin direction S** from decay products: $pK^-\pi^+$

- use available correction magnet at IR3 as a spectrometer
- put tracking stations in front and behind the magnet

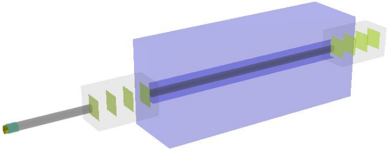


from Elisabetta's slides link

- do a full simulation of the setup with realistic description of effects from material interactions and reconstruction
- can detector concept cope with
  - misidentified decays (mostly $D \to K^+\pi^+\pi^-$ and $D_s^+ \to K^+K^-\pi^-$)
  - combinatorial background
  - decays with missing particles

simulate the full chain from particle production over detector response to event reconstruction

initial



current