Investigations of Detector Signatures from $\Lambda\bar{\Lambda}$ and $\Xi^-\Xi^+$ Events

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Outline

- **Motivation**
  - Dynamical Track and Event Reconstruction
  - SttCellTrackFinder
- $\Lambda\bar{\Lambda}$ **events**
  - STT signatures
  - MVD signatures
- $\Xi\bar{\Xi}$ **events**
  - STT signatures
  - MVD signatures
- **Comparison between simulations where the decay is handled by EvtGen and Geant4**
  - $\Lambda\bar{\Lambda}$ events and $\Xi\bar{\Xi}$ events
- Outlook and Summary

Motivation

- Hyperons might be difficult to reconstruct due to their decay topology with *e.g.* displaced vertices

Hyperon	$c\tau$[cm]
Λ	8.0
Ξ^-	4.9

- DyTER-Dynamical Track and Event Reconstruction
- STTCellTrackFinder
  - Cellular Automaton to form tracklets from STT hits
  - Riemann fit to combine tracklets

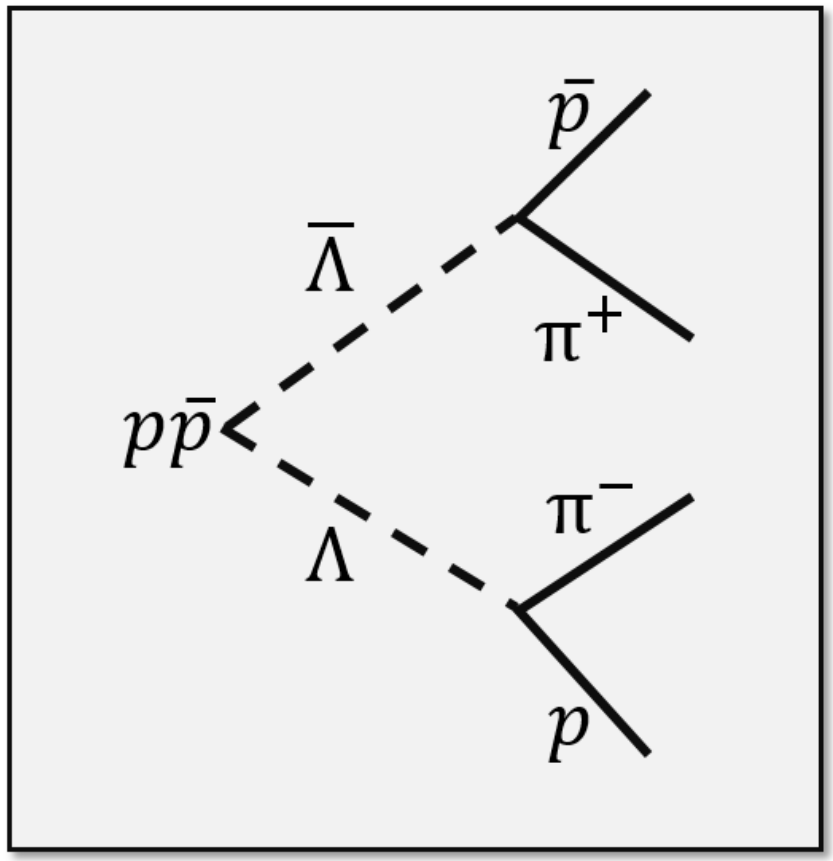
Goal: Dynamic track finder which is as general as possible but works for hyperon tracking

Motivation

Focus:

- $\Lambda\bar{\Lambda}$ and $\Xi^{-}\Xi^{+}$ events due to their complex decay topology
- MVD and STT for tracking
- MVD and SciTil for possibility of providing a t_0

$p\bar{p} \to \Lambda\bar{\Lambda} \to p\pi^-\bar{p}\pi^+$



$p\bar{p} \to \Lambda\bar{\Lambda} \to p\pi^-\bar{p}\pi^+$

- 10,000 events
- Beam momenta: 1.642 GeV, 7 GeV and 15 GeV
- Forward peaking distribution, $\bar{\Lambda}$ forward boosted
- EvtGen, entire decay chain specified
- In analysis: only consider particles actually part of the interesting reaction
- Ideal track finder, standard track functor
- Target spectrometer
  - Before bug fix
  - Standard track functor ($\geq$ 4 hits in MVD or $\geq$ 6 hits in MVD+STT+GEM)
  - Bug: if this track functor was used, all tracks which do not hit forward spectrometer were classified as reconstructible
  - Bug fixed in trunk

$p\bar{p} \rightarrow \Lambda\bar{\Lambda} \rightarrow p\pi^{-}\bar{p}\pi^{+}$

- For events, only hits from final state particles
- Only tracks with ≥ 4 STT hits from final state particles (from now, only tracks with ≥ 4 STT hits will be considered)

	1.642 GeV	7 GeV	15 GeV
Number of events	10,000	10,000	10,000
Events with a MVD hit	99.94 %	99.47 %	99.14 %
Events with a SciTil hit	34.64 %	3.00 %	1.36 %
Number of tracks	26,013	7,253	6,614
Tracks with a MVD hit	95.5 %	98.3 %	98.0 %
Tracks with a SciTil hit	38.7 %	5.8 %	2.9 %
Tracks with a MVD and a SciTil hit	36.9 %	5.6 %	2.7 %
Tracks with a MVD or a SciTil hit	97.3 %	98.5 %	98.2 %

- MVD itself useful for most events and tracks
- At higher beam momenta, most tracks do not reach SciTil
- MVD and SciTil together are useful at all beam momenta

$p\bar{p} \to \Lambda\bar{\Lambda} \to p\pi^-\bar{p}\pi^+$

	1.642 GeV	7 GeV	15 GeV
p tracks	74.4 %	18.4 %	11.2 %
π^- tracks	65.8 %	54.0 %	54.9 %
Reconstructible Λ	47.9 %	7.3 %	4.3 %
$\bar{p}$ tracks	50.4 %	0 %	0 %
π^+ tracks	69.5 %	0 %	0 %
Reconstructible $\bar{\Lambda}$	33.7 %	0 %	0 %
Exclusive Λ and $\bar{\Lambda}$	17.8 %	0 %	0 %

Normalization: number of events (all simulated tracks of the certain kind)

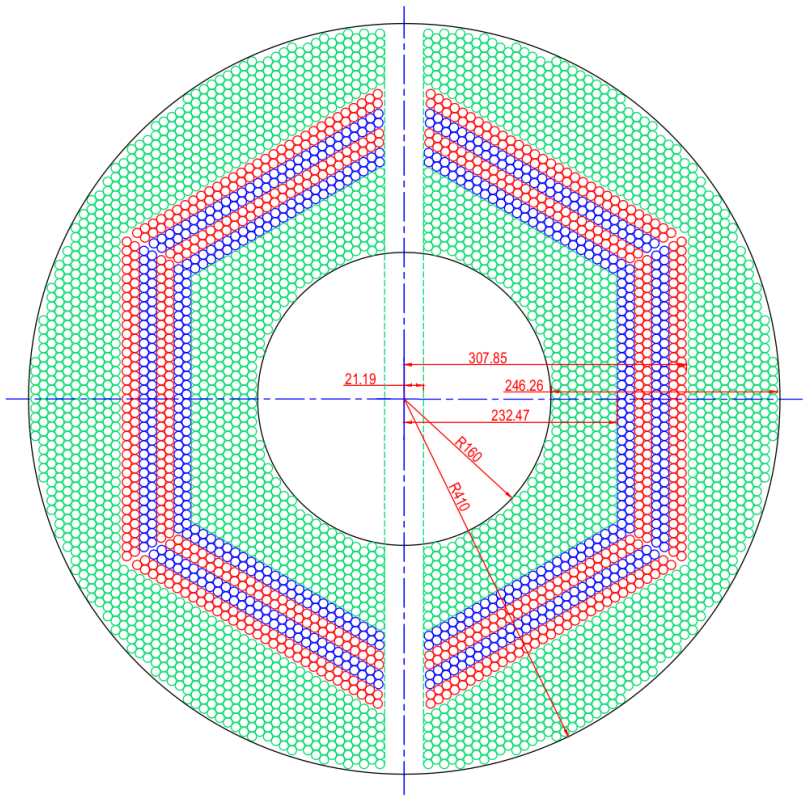
STT

At PANDA: 20 MHz interaction rate

$\Rightarrow$ On average one event every 50 ns

STT

- 4,636 straws
- 27 layers
- When straw tube is hit, gas is ionized and free electrons created
- Electrons travel towards wire at center of tube - signal for readout
- Maximum drift time of electrons: 200 ns
- During drift time no more signals can be registered



$\Rightarrow$ one straw might be occupied for the next 3 or 4 events and might not fire if hit by a particle!

STT

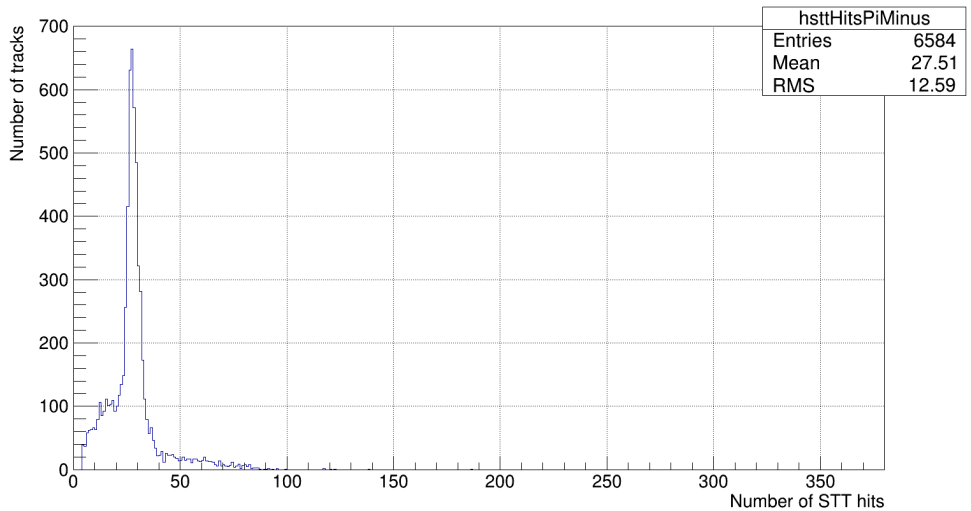
Forward/backward asymmetry of distribution might cause spiralling in magnetic field since Λ decays almost at rest and its decay products are not given much energy

Challenges concerning spiralling tracks with many STT hits:

- Might be difficult to reconstruct
- Particles trapped in magnetic field - might not reach outer detectors
- Might block tubes for tracks from later events - makes later tracks harder to reconstruct

$p\bar{p} \to \Lambda\bar{\Lambda} \to p\pi^-\bar{p}\pi^+$

STT hits, π^-, 1.642 GeV

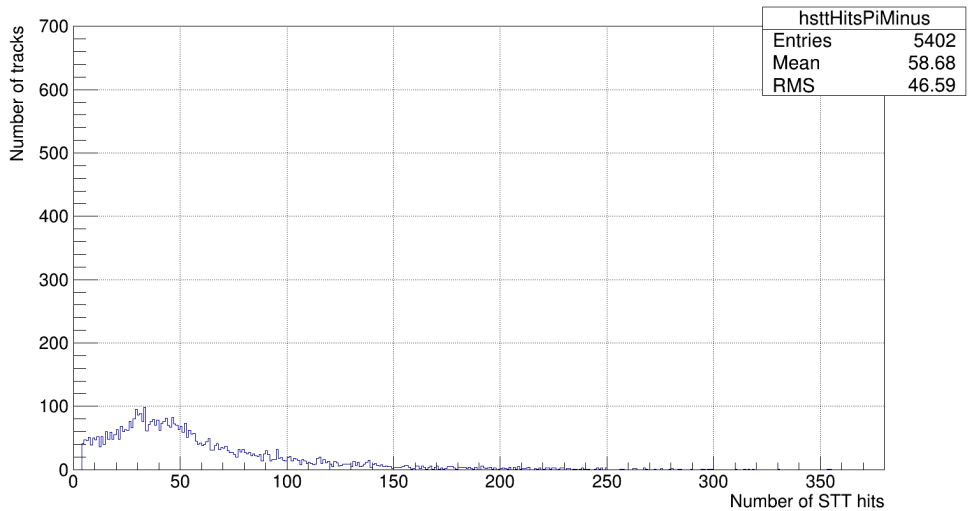


- Peak around 27 hits
  - $\Rightarrow$ most tracks go fairly straight through the STT
- 0.4% of all events contain π^- tracks with $\geq$ 50 STT hits
  - $\Rightarrow$ not many tracks tend to spiral

$\Rightarrow$ **no cause for concern!**

$p\bar{p} \rightarrow \Lambda\bar{\Lambda} \rightarrow p\pi^{-}\bar{p}\pi^{+}$

STT hits, π^{-}, 7 GeV



- Peak around 27 hits
  - $\Rightarrow$ most tracks go fairly straight through the STT
- 24.5% of all events contain π^{-} tracks with $\geq$ 50 STT hits
  - $\Rightarrow$ many tracks tend to spiral
- Exist tracks with $\geq$ 300 STT hits

$\Rightarrow$ **might cause trouble!**

$p\bar{p} \to \Lambda\bar{\Lambda} \to p\pi^-\bar{p}\pi^+$, STT hits

Events with final state particle tracks with ≥ 50 STT hits

Kind of track	1.642 GeV	7 GeV	15 GeV
π^-	0.4 %	24.5 %	24.1 %
π^+	0.4 %	0 %	0 %
p	0 %	0 %	0 %
$\bar{p}$	0 %	0 %	0 %

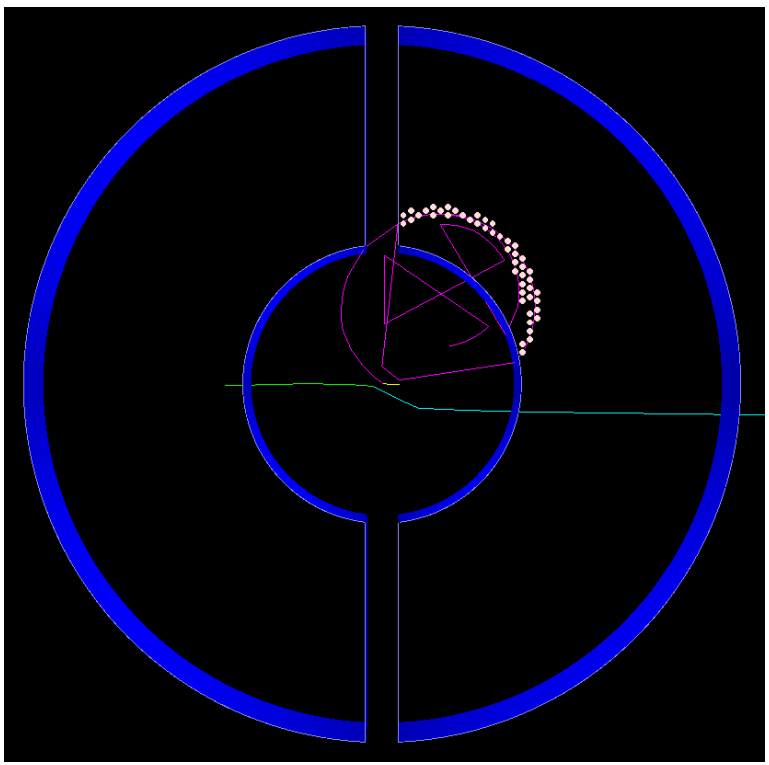
Normalization: total number of events

- At higher beam momenta, $\sim$ **1/4 of all events** contain a spiralling π^-

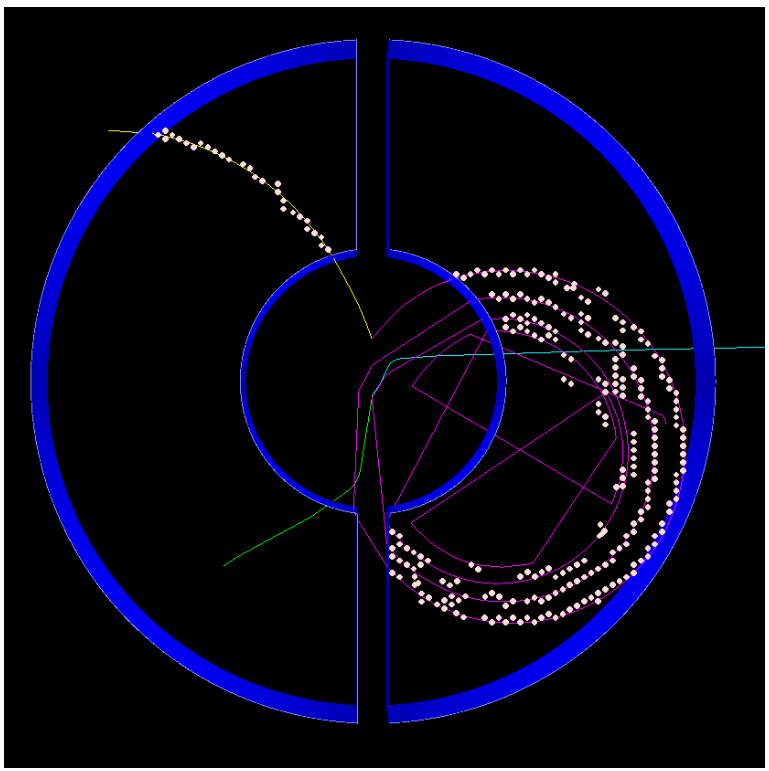
$\Rightarrow$ might cause trouble!

$p\bar{p} \to \Lambda\bar{\Lambda} \to p\pi^-\bar{p}\pi^+$, STT hits, 15 GeV

- 60 STT hits from π^-
- Spiralling is confined to one quarter of the STT

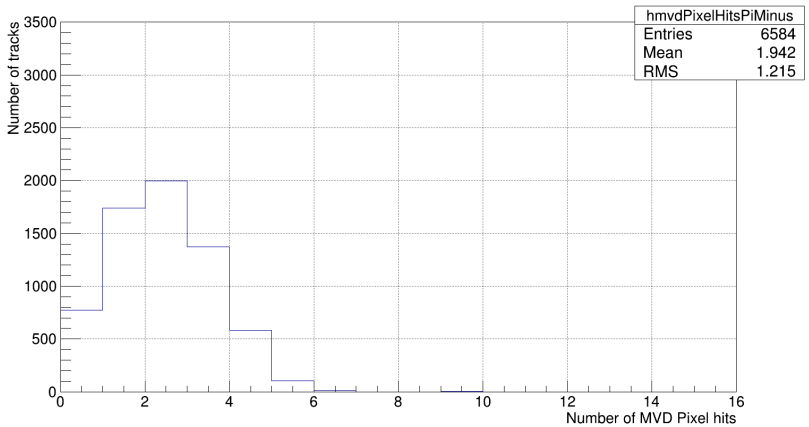


- 256 STT hits from π^-
- Spiralling is confined to half of the STT

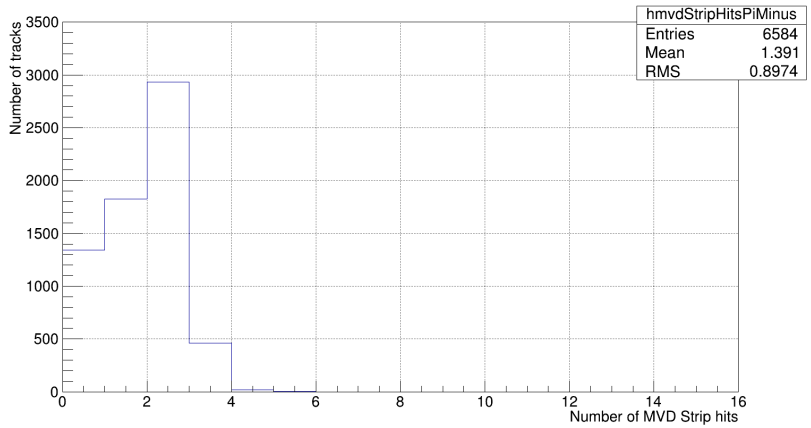


$p\bar{p} \to \Lambda\bar{\Lambda} \to p\pi^-\bar{p}\pi^+$, MVD hits

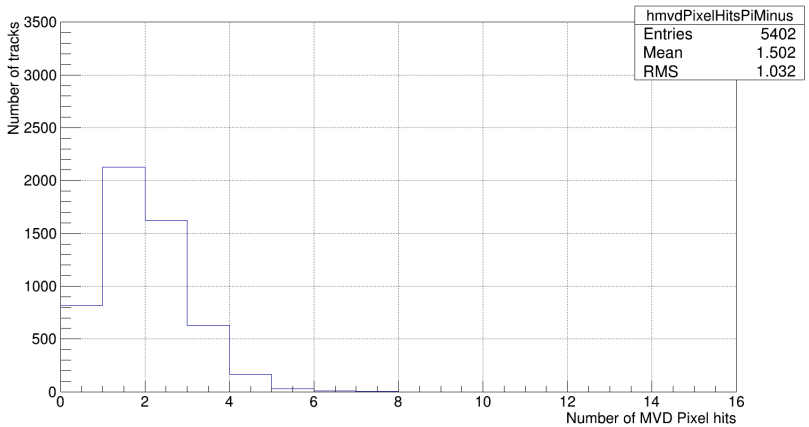
Pixel Hits, 1.642 GeV



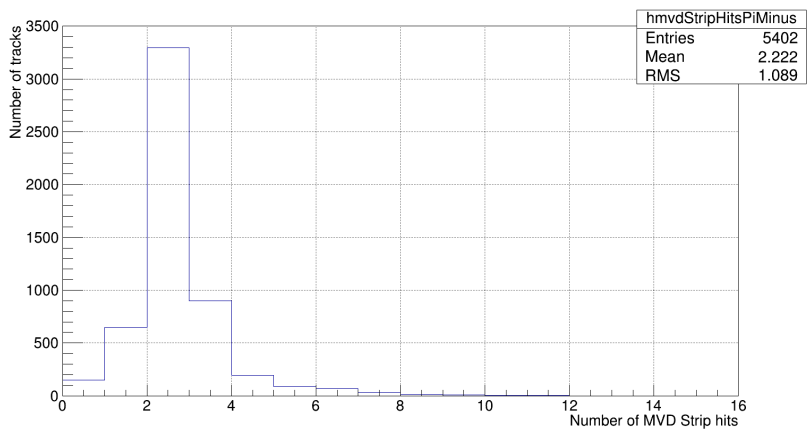
Strip Hits, 1.642 GeV



Pixel Hits, 7 GeV



Strip Hits, 7 GeV



$p\bar{p} \to \Lambda\bar{\Lambda} \to p\pi^-\bar{p}\pi^+$, MVD hits

Tracks with 0 MVD hits

	1.642 GeV	7 GeV	15 GeV
p	2 %	1 %	1 %
$\bar{p}$	5 %	–	–
π^-	3 %	2 %	2 %
π^+	7 %	–	–

Tracks with 0 Pixel hits

	1.642 GeV	7 GeV	15 GeV
p	4 %	19 %	21 %
$\bar{p}$	6 %	–	–
π^-	12 %	15 %	15 %
π^+	12 %	–	–

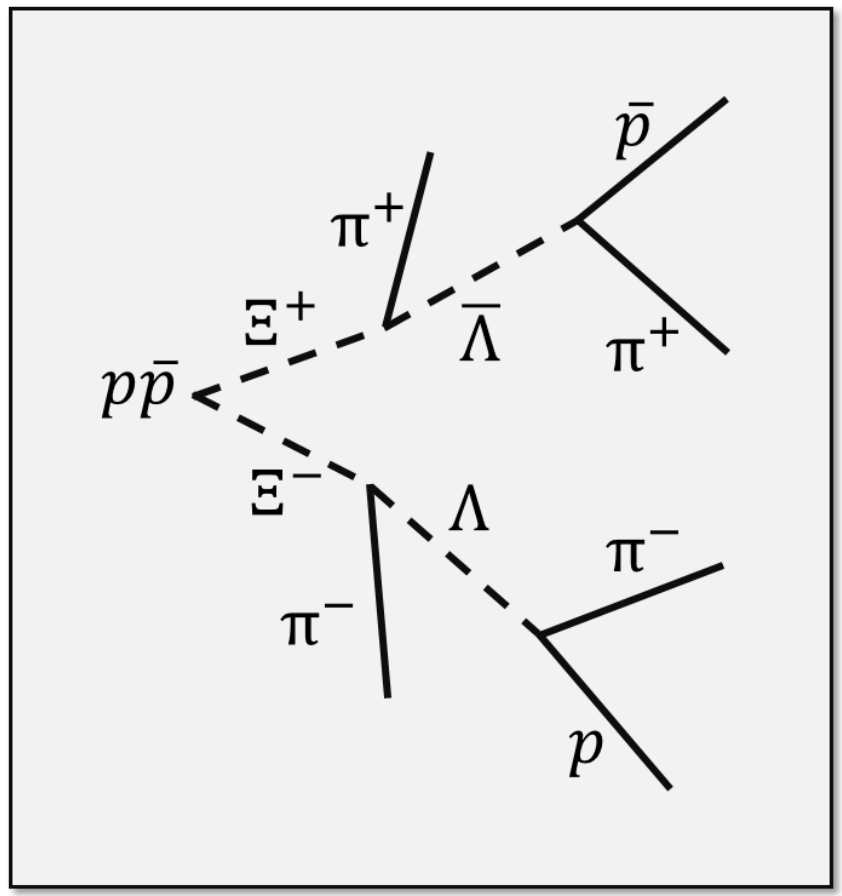
Tracks with 0 Strip hits

	1.642 GeV	7 GeV	15 GeV
p	54 %	1 %	1 %
$\bar{p}$	73 %	–	–
π^-	20 %	3 %	3 %
π^+	39 %	–	–

Normalization: total number of tracks of the given type

- MVD useful for these tracks
- Strip part more useful at higher momenta
- Pixel part more useful at lower momenta

$$p\bar{p} \to \Xi^-\Xi^+ \to \Lambda\pi^-\bar{\Lambda}\pi^+ \to p\pi^-\pi^-\bar{p}\pi^+\pi^+$$



$p\bar{p} \to \Xi^-\Xi^+ \to \Lambda\pi^-\bar{\Lambda}\pi^+ \to p\pi^-\pi^-\bar{p}\pi^+\pi^+$

- 10,000 events
- Beam momentum: 4.6 GeV
- Flat phase space distribution, isotropic
- EvtGen, entire decay chain specified
- Ideal track finder, standard track functor
- Target spectrometer
  - Before bug fix
  - Standard track functor ($\geq$ 4 hits in MVD or $\geq$ 6 hits in MVD+STT+GEM)
  - Bug: if this track functor was used, all tracks which do not hit forward spectrometer were classified as reconstructible
  - Bug fixed in trunk

$$p\bar{p} \rightarrow \Xi^{-}\Xi^{+} \rightarrow \Lambda\pi^{-}\bar{\Lambda}\pi^{+} \rightarrow p\pi^{-}\pi^{-}\bar{p}\pi^{+}\pi^{+}$$

- For events, only hits from final state particles
- Only tracks with $\geq$ 4 STT hits from final state particles

	4.6 GeV
Number of events	10,000
Events with a MVD hit	99.3 %
Events with a SciTil hit	77.6 %
Number of of tracks	41,750
Tracks with a MVD hit	69.0 %
Tracks with a SciTil hit	81.3 %
Tracks with a MVD and a SciTil hit	55.0 %
Tracks with a MVD or a SciTil hit	95.3 %

- More tracks leave SciTil hit than MVD hit
  - Might be due to Λ and $\bar{\Lambda}$ decaying outside of MVD

$p\bar{p} \to \Xi^-\Xi^+ \to \Lambda\pi^-\bar{\Lambda}\pi^+ \to p\pi^-\pi^-\bar{p}\pi^+\pi^+$, STT hits

Kind of track (final state particle)	Events with tracks with $\geq$ 4 STT hits	Events with tracks with $\geq$ 50 STT hits
p	80.4 %	0 %
$\bar{p}$	78.8 %	0 %
First π^-	66.7 %	6.3 %
Second π^-	62.2 %	6.2 %
First π^+	67.5 %	6.2 %
Second π^+	62.0 %	6.3 %

Normalization: total number of events

- 6-25 % of all events contain spiralling pions

$\Rightarrow$ Might be a cause of concern

$p\bar{p} \to \Xi^-\Xi^+ \to \Lambda\pi^-\bar{\Lambda}\pi^+ \to p\pi^-\pi^-\bar{p}\pi^+\pi^+$, MVD hits

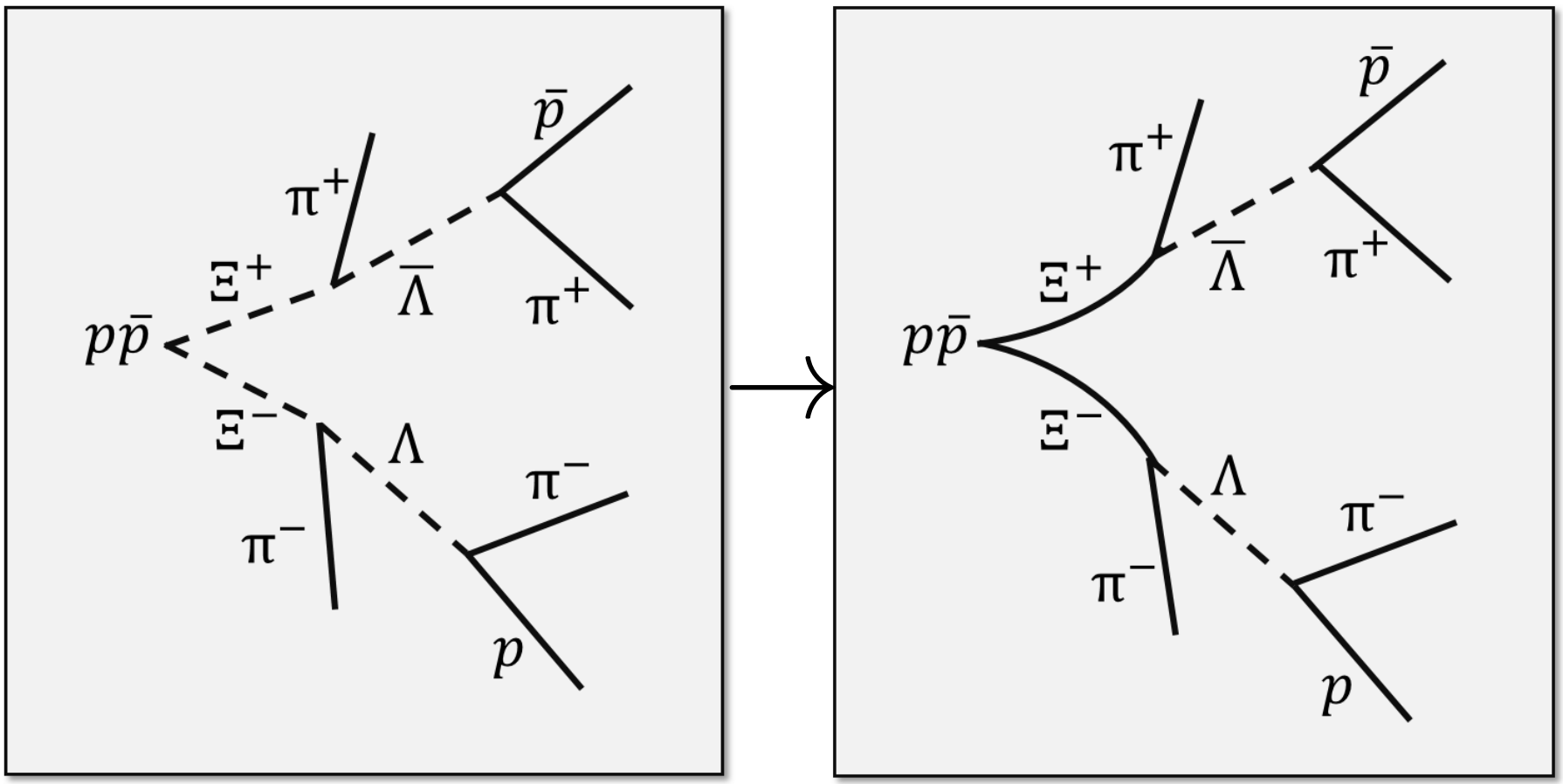
Kind of track (final state particle)	0 MVD hits	0 Pixel hits	0 Strip hits
p	38 %	56 %	52 %
$\bar{p}$	39 %	58 %	53 %
First π^-	10 %	21 %	34 %
Second π^-	43 %	62 %	55 %
First π^+	10 %	20 %	34 %
Second π^+	43 %	63 %	55 %

Normalization: total number of tracks of the given type

- A significant fraction of these tracks leave no hit in MVD
- More of the particles created later in the decay chain misses the MVD than the particles created earlier

Comparison between simulations where the decay is handled by EvtGen and Geant4

$$p\bar{p} \to \Xi^-\Xi^+ \to \Lambda\pi^-\bar{\Lambda}\pi^+ \to p\pi^-\pi^-\bar{p}\pi^+\pi^+$$



Comparison between simulations where the decay is handled by EvtGen and Geant4

EvtGen

- Entire decay chain defined in decay file

Geant4

- Production of primary particles defined in a decay file
- Primary particles defined as stable for EvtGen
- Interesting decay modes set in UserDecayConfig.C

For more details:

https : *//panda − wiki.gsi.de/foswiki/pub/Computing/Minutes*02*May*2017/2.5.2017_*teammeeting.pdf*

Comparison between simulations where the decay is handled by EvtGen and Geant4

$p\bar{p} \to \Lambda\bar{\Lambda} \to p\pi^-\bar{p}\pi^+$

	Decay by Geant4	Decay by EvtGen
Number of final state particle tracks	25,897	26,013
Number of tracks with at least one MVD hit	24,766	24,851

- No significant difference, as expected

$p\bar{p} \to \Xi^-\Xi^+ \to \Lambda\pi^-\bar{\Lambda}\pi^+ \to p\pi^-\pi^-\bar{p}\pi^+\pi^+$

	Decay by Geant4	Decay by EvtGen
Number of Ξ^- tracks with at least one MVD hit	173	0
Number of Ξ^+ tracks with at least one MVD hit	175	0

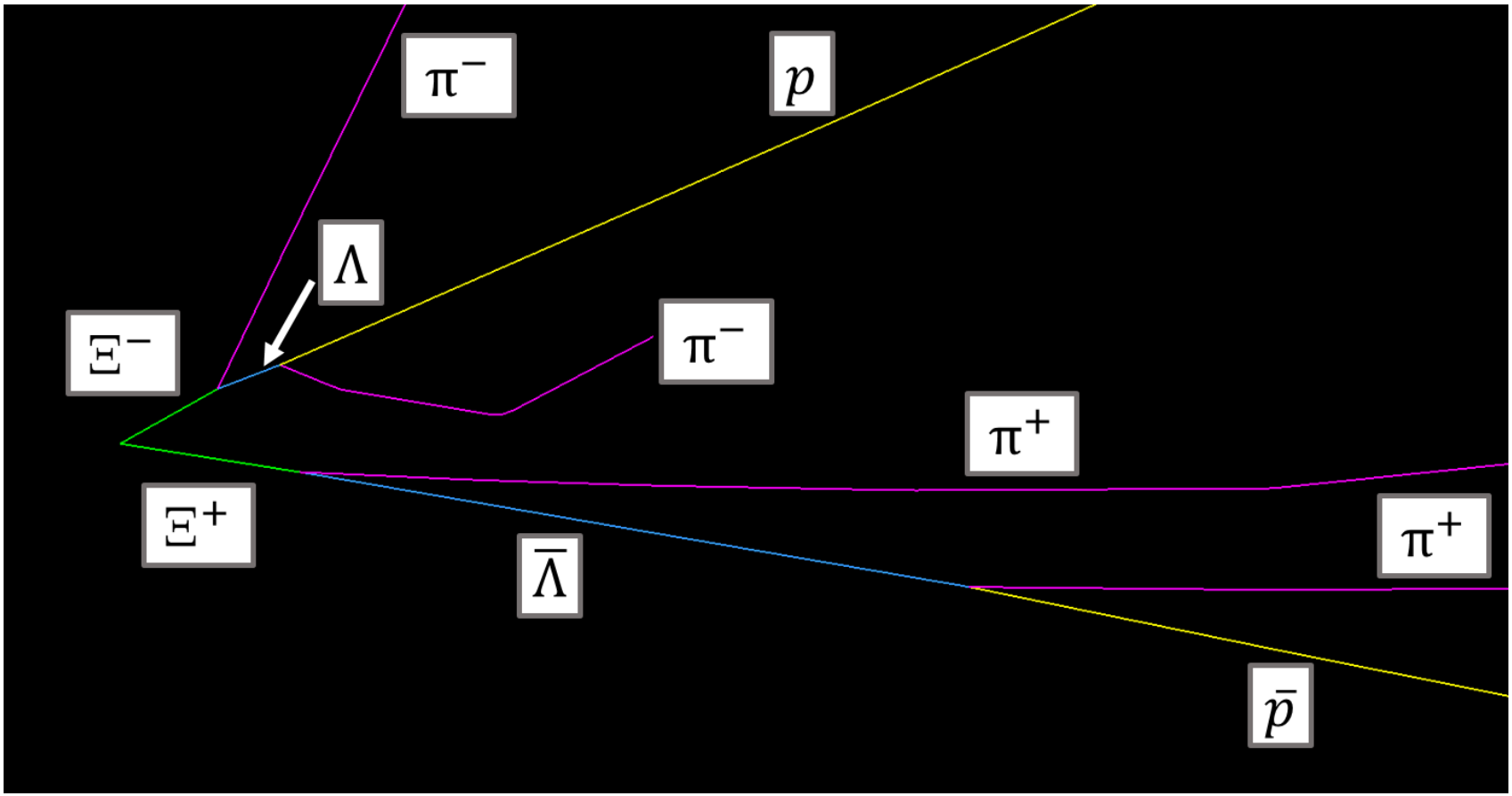
For numbers in this table: no restriction on number of STT hits

- A MC track is obtained if secondaries are decayed by Geant4 but not if they are decayed by EvtGen

Decay handeled by Geant4

$p\bar{p} \rightarrow \Xi^{-}\Xi^{+} \rightarrow \Lambda\pi^{-}\bar{\Lambda}\pi^{+} \rightarrow p\pi^{-}\pi^{-}\bar{p}\pi^{+}\pi^{+}$

Event Display, 3D view



Outlook

- Analyse Ξ^- events further decaying the particles in Geant4
- Investigate Ω^- events
- Thorough investigation of decay vertex positions
- Investigate usefulness of GEM plates
- Investigate performance of STTCellTrackFinder for Λ ,Ξ^- and Ω^- events

Summary

$\Lambda\bar{\Lambda}$ events:

- MVD useful for most events and final state particle tracks
- More final state particle tracks hit MVD pixels at lower beam momenta and MVD strips at higher beam momenta
- SciTil useful for $\sim 1/3$ of events and final state particle tracks at lowest beam momentum but not at higher beam momenta
- π^- tend to spiral in magnetic field at higher beam momenta
  - Spiralling usually confined to less than 1/2 of STT

$\Xi^-\Xi^+$ events:

- MVD useful for $\simeq$99 % of events and $\simeq$69 % of final state particle tracks
- SciTil useful for $\simeq$77 % of events and $\simeq$81 % of final state particle tracks (more than MVD)

Thank you!