HLT TOPOLOGICAL TRIGGER

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Many thanks to Matt, Gabriel, and the HLT team!!

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OVERVIEW

- Status of the topological trigger
  - Signal efficiencies
  - Minbias rates
- Ghosts in the topological trigger
- Items for discussion

IMPLEMENTATION OF THE TOPOLOGICAL TRIGGER

WHAT IS THE TOPOLOGICAL TRIGGER?

- Generic trigger for **B decays into charged hadron final states** (+ muons)
  - ➢ Can also select prompt charm
- Look for 2,3,4 track combinations in a wide mass window
  - ➢ Can trigger on signal despite reflections or missed tracks
- Use fast-track fit to improve signal efficiency and minbias rejection

IMPLEMENTATION STATUS

- **Now implemented in the standard HLT2 Combine Particles framework**
- Uses only the methods and information which will be available online with real data
- Will be released for public use and testing in due time

TOPO ARCHITECTURE

HLT1 output rate ~ 30kHz

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HLT1 output rate ~ 30kHz

Topo output rate ~ few 100 Hz

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HLT2 topological: use only "robust" cuts (no significance cuts), and aim for an output rate of ~ a few kHz

Topo output rate ~ few 100 Hz

TOPO ARCHITECTURE

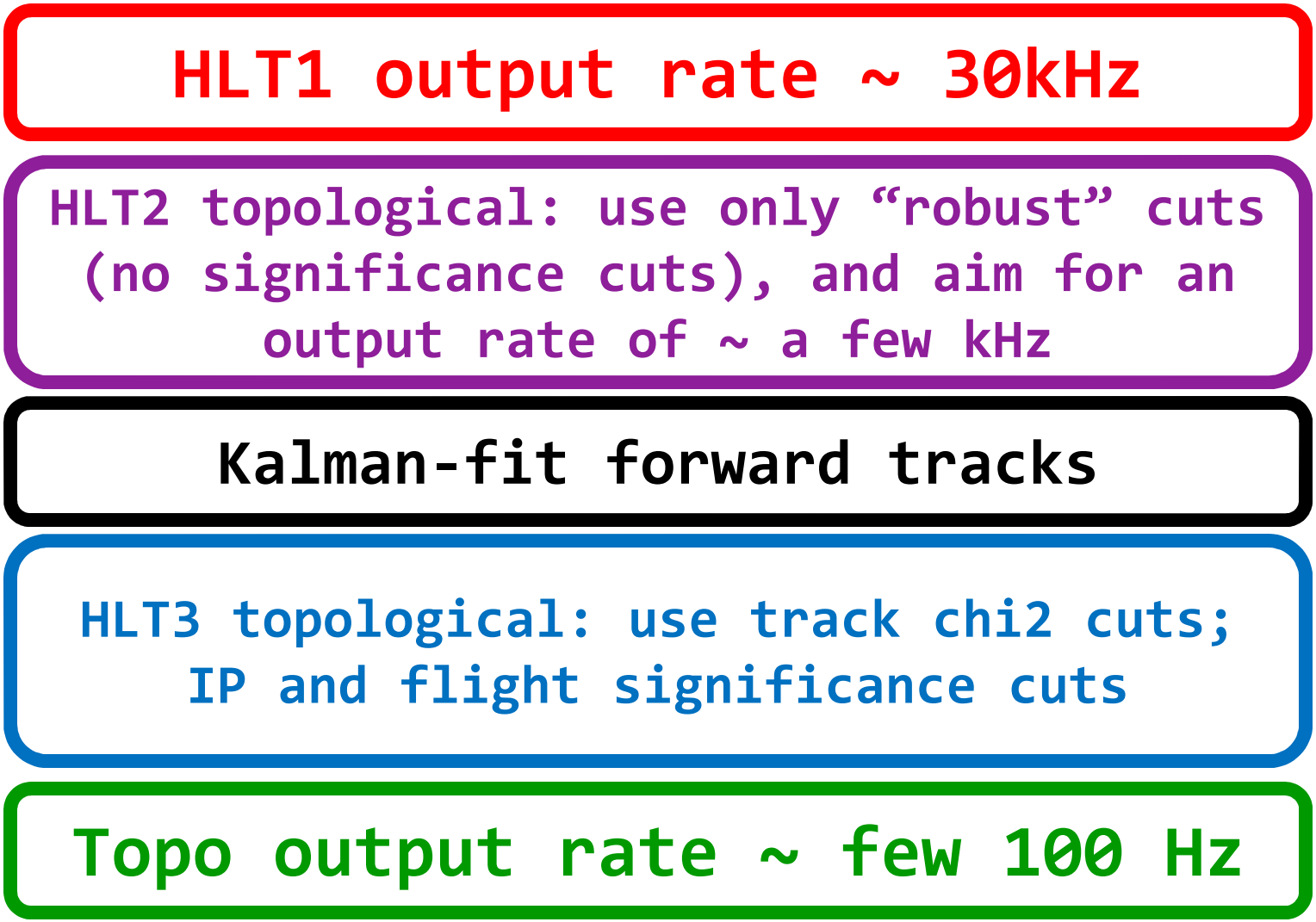
HLT1 output rate ~ 30kHz

HLT2 topological: use only "robust" cuts (no significance cuts), and aim for an output rate of ~ a few kHz

Kalman-fit forward tracks

Topo output rate ~ few 100 Hz

TOPO ARCHITECTURE

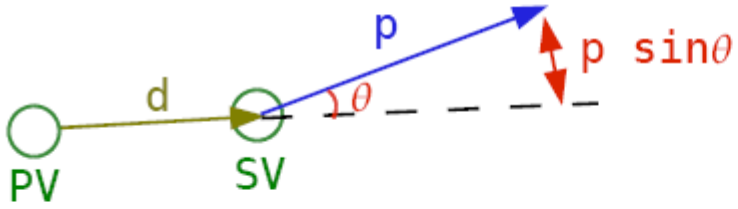


WHAT TRACK FIT DO WE USE?

- **Use the "fast" track fit**
  - 1-iteration Kalman, simplified material description
- **Use 2D primary vertices**, as in HLT1
  - Fitting 3D primary vertices is under investigation and could improve efficiencies somewhat

POINTING CUT DEFINITION

POINTING



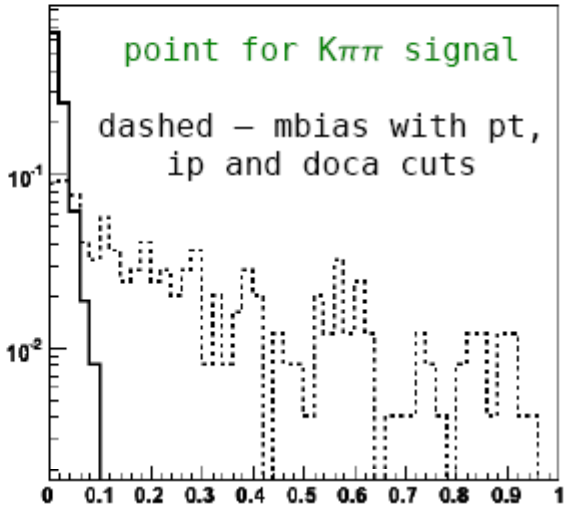
p = vector sum of daughters 3-momenta

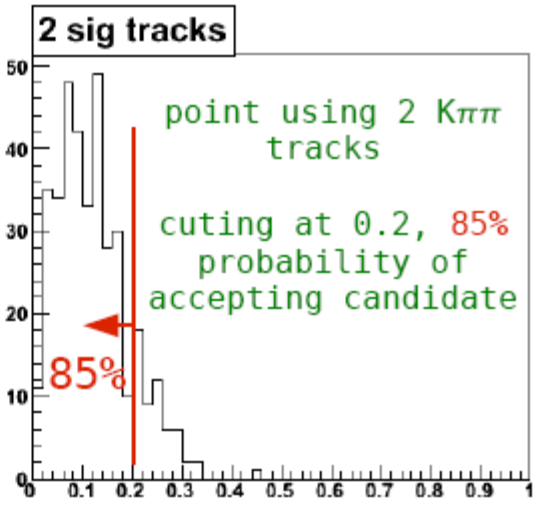
ptdaus = pt sum of B daughters

$$POINT = \left(1 + \frac{PTDAUS}{p \sin\theta}\right)^{-1}$$

- distribution range 0 – 1
  signal < 0.1
- used in HLT1 hadron alley
- cutting at 0.2 is a good strategy to select events which loose 1 track

  n-1 recovers 85% of candidates which loose one track





[7]

Thanks Gabriel!

MASS HYPOTHESES IN THE TOPO

- **Tracks are given a mixture of pion and kaon mass hypotheses**
  - **No PID used!!**
- Necessary if we eventually want to trigger on prompt charm in the topo
  - **2-body: $K^+\pi^+$, $K^+\pi^-$, $K^-\pi^-$**
  - **3-body: $K^+K^+\pi^+$, $K^+K^+\pi^-$, $K^+K^-\pi^-$, $K^-K^-\pi^-$**
  - **4-body: $K^+K^+\pi^+\pi^-$, $K^+K^+\pi^-\pi^-$, $K^+K^-\pi^-\pi^-$**

TOPOLOGICAL TRIGGER EFFICIENCIES AND RATES

TOPO CUTS – LOOSE

	HLT2 Topological Cuts		HLT3 Topological cuts	
Cuts on all tracks	MIN PT	300 MeV	MIN PT	300 MeV
	MIN IP	0.05 mm	MIN IPCHI2	9
			MIN CHI2	10
Cuts on the track combination	PTMAX	1500 MeV	PTMAX	1500 MeV
	DOCAMIN	0.1 mm	DOCAMIN	0.1 mm
	DOCAMAX	1 mm	DOCAMAX	1 mm
	MIN FD	2 mm	MIN FDCHI2	100
	POINT	0.2	POINT	0.1
	Mass window	(4,6) GeV	Mass window	(4,6) GeV

TOPO RESULTS – LOOSE CUTS

Channel	L0xHLT1 eff. (rate)	Topo eff. (rate)
L0-selected MINBIAS	31 kHz	1.1 kHz
$B \rightarrow hh$	39%	83%
$B \rightarrow hhh$	37%	87%
$B_s \rightarrow D_s K$	31%	90%
$B_d \rightarrow D^0 K^*$	28%	87%
$B_s \rightarrow \phi\phi$	18%	87%
$B_d \rightarrow K^* \mu\mu$	81%	85%
$B_s \rightarrow J/\psi\ \phi$	85%	55%
$B_s \rightarrow \mu\mu$	85%	69%

The topo efficiencies are relative to the given L0xHLT1 efficiencies

TOPO RESULTS – LOOSE CUTS (2)

Channel	L0xHLT1 eff. (rate)	HLT2 Topo eff. (rate)	HLT3 Topo eff. (rate)	Total trigger eff. (rate)
L0-selected MINBIAS	31 kHz	7 kHz	1.1 kHz	1.1 kHz
$B \rightarrow hh$	39%	94%	88%	32%
$B \rightarrow hhh$	37%	97%	90%	33%
$B_s \rightarrow D_s K$	31%	97%	93%	27%
$B_d \rightarrow D^0 K^*$	28%	97%	89%	24%
$B_s \rightarrow \phi\phi$	18%	97%	90%	15%
$B_d \rightarrow K^* \mu\mu$	81%	96%	89%	69%
$B_s \rightarrow J/\psi\ \phi$	85%	77%	71%	46%
$B_s \rightarrow \mu\mu$	85%	85%	81%	59%

The efficiency for each trigger stage is quoted relative to the preceding stages

TOPO CUTS – MEDIUM

	HLT2 Topological Cuts		HLT3 Topological cuts	
Cuts on all tracks	MIN PT	300 MeV	MIN PT	300 MeV
	MIN IP	0.1 mm	MIN IPCHI2	9
			MIN CHI2	10
Cuts on the track combination	PTMAX	2400 MeV	PTMAX	1500 MeV
	DOCAMIN	0.1 mm	DOCAMIN	0.1 mm
	DOCAMAX	1 mm	DOCAMAX	1 mm
	MIN FD	2 mm	MIN FDCHI2	100
	POINT	0.1	POINT	0.1
	Mass window	(4,6) GeV	Mass window	(4,6) GeV

The cuts listed in red are different from those in the "loose" cut configuration. No cuts have changed for the HLT3 topo.

TOPO RESULTS – MEDIUM CUTS

Channel	L0xHLT1 eff. (rate)	HLT2 Topo eff. (rate)	HLT3 Topo eff. (rate)	Total trigger eff. (rate)
L0-selected MINBIAS	31 kHz	1.7 kHz	750 Hz	750 Hz
$B \rightarrow hh$	39%	83%	96%	31%
$B \rightarrow hhh$	37%	88%	96%	32%
$B_s \rightarrow D_s K$	31%	87%	95%	25%
$B_d \rightarrow D^0 K^*$	28%	88%	94%	24%
$B_s \rightarrow \phi\phi$	18%	80%	98%	14%
$B_d \rightarrow K^* \mu\mu$	81%	71%	96%	55%
$B_s \rightarrow J/\psi\ \phi$	85%	43%	90%	32%
$B_s \rightarrow \mu\mu$	85%	65%	95%	53%

The efficiency for each trigger stage is quoted relative to the preceding stages

TOPO BBAR PURITIES

Fraction of selected events containing a B	HLT2 Topo	HLT3 Topo
Loose cuts	29%	46%
Medium Cuts	61%	62%

WHAT IS A GHOST?

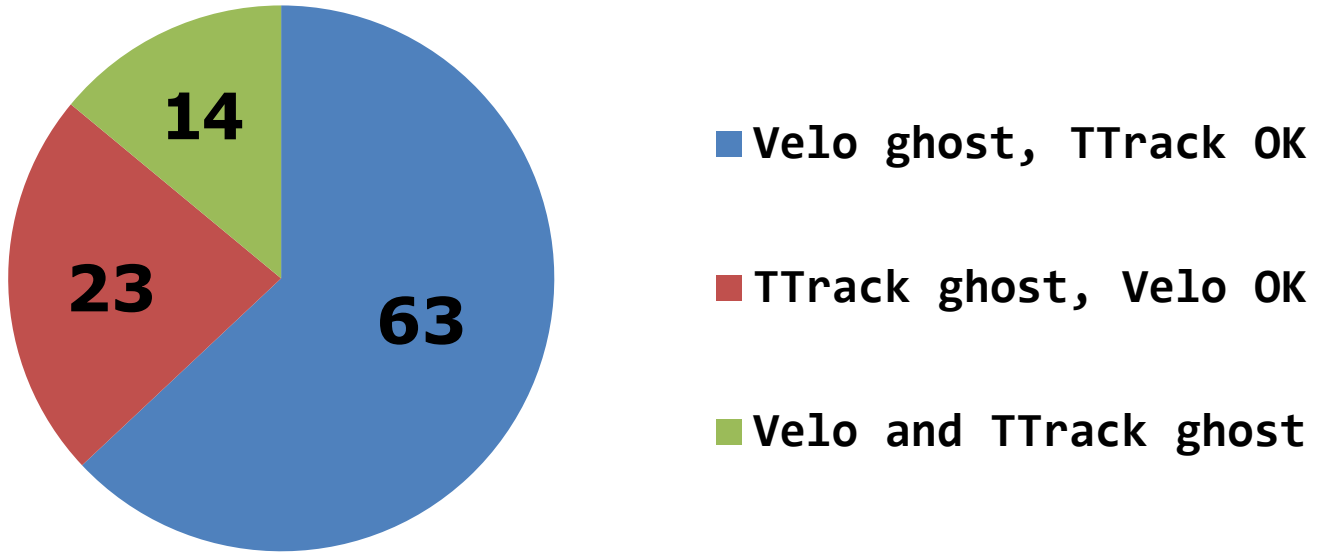
- In LHCb, a ghost is a track for which no MCParticle matches more than 70% of its hits
- The track must match in both the Velo and the T stations (minus TT) separately
- However, things are not so simple
  - Is the Velo part a ghost? The T part? Both?
  - What is the track actually made of? Noise? Hits from different real particles? EM/Hadronic showers?

HLT2 TOPO – NUMBER OF GHOSTS

31% of all long tracks firing the HLT2 topo on L0-yes minbias are ghosts

67% of candidates firing the HLT2 topo on L0-yes minbias have at least one ghost track

Ghost fractions in long tracks firing the HLT2 topological selection



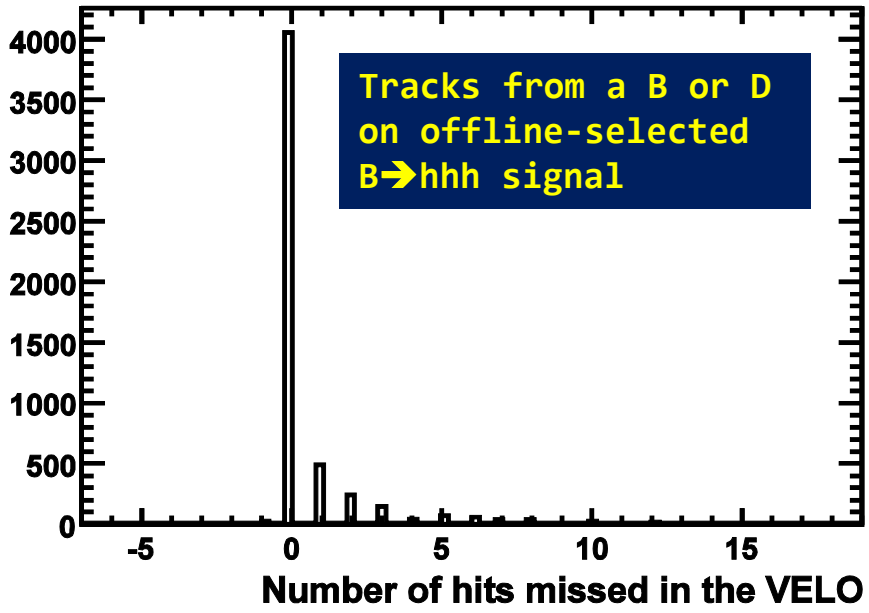
HLT2 TOPO – TYPES OF GHOSTS

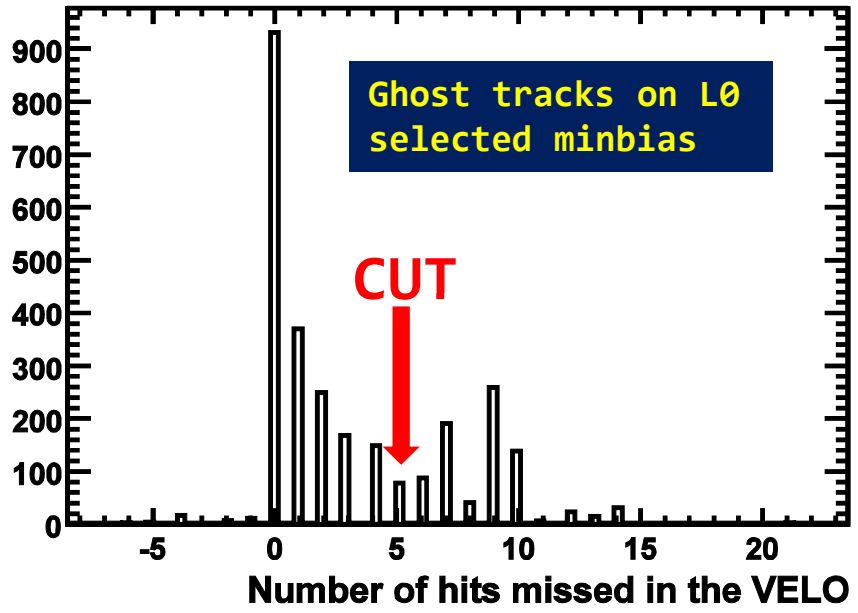
- **Velo ghosts (major sources)**
  - 65% have a Velo RZ track made with clusters from more than one MCParticle
  - 17% from Photon conversion
  - 14% from mismatched Phi and RZ parts
- **TTrack ghosts (major sources)**
  - 25% from hadronic shower

PRELIMINARY IDEAS

STOP PRESS

Number of "missed" VELO clusters between the beamline and the end of the VELO – no track fit needed!





Can kill ~30% of ghost tracks while reducing the number of signal tracks by ~5%.

Effect on event rates/efficiencies under study

SUMMARY AND PLANS FOR THE FUTURE

SUMMARY AND FUTURE WORK

- **Topological trigger implemented in Combine Particles**
- **A lot of things still left to work on**
  - Different "fast-fit" configurations
  - Fitting 3D primary vertices
  - Reoptimizing the existing cuts
  - Investigating new cuts
- **A significant ghost problem exists in the trigger**
  - Have begun work on reducing the number of ghosts **before any track fit is performed**
  - We know how to control ghosts offline – we are learning how to control them in the trigger

BACKUP

EXOTICA

Channel	L0xHLT1 eff.	Topo eff.	Total Trigger eff.
Hidden Valley	57%	70%	40%
SUSY	44%	45%	20%

CHANGES SINCE NOVEMBER

- Efficiency and rate changes are caused by
  - Using the fast track fit instead of the full offline track fit
  - Using the 2D primary vertices instead of the offline fitted primary vertices
- It is not clear how much each contributes to the loss ➔ under study!

TOPO-TRIGGER RESULTS NOVEMBER

Channel	L0xHLT1 eff. (rate)	Total loose HLT2/3 eff/rate Nov 08 LHCb week	Total medium HLT2/3 eff/rate Nov 08 LHCb week
L0-selected MINBIAS	33 kHz	700 Hz	340 Hz
$B \rightarrow hh$	40%	90%	Average 85% without $B_s \rightarrow J/\psi\ K_S$ or $B_s \rightarrow J/\psi\ \phi$
$B \rightarrow hhh$	38%	93%	
$B_s \rightarrow D_s K$	32%	94%	
$B_d \rightarrow D^0 K^*$	29%	92%	
$B_s \rightarrow \phi\phi$	18%	90%	
$B_d \rightarrow K^* \mu\mu$	82%	90%	
$B_s \rightarrow J/\psi\ \phi$	85%	64%	
$B_s \rightarrow J/\psi\ K_S$	86%	9%	

TOPO CUT DEFINITIONS

PTMAX: The highest PT track is required to have PT > PTMAX

DOCAMIN: The two track combination with the smallest DOCA is required to have DOCA > DOCAMIN

DOCAMAX: The two track combination with the largest DOCA is required to have DOCA > DOCAMAX

SOFTWARE

- All results with DaVinci v22r0p2
- No stair plots since they are not so easy to generate in the CombineParticles framework but will learn how to do it soon

BORING IMPLEMENTATION DETAILS

- At the moment we have just Hlt2Selections.py
- This needs to be split up e.g.
  - Hlt2Selections.py ➔ defines the sequencer
  - Hlt2InclusiveSelections.py,
    Hlt2ExclusiveSelections.py
  - Hlt2RefitTracks.py
  - Hlt3ExclusiveSelections.py,
    Hlt3InclusiveSelections.py
- The point is that we should probably execute all exclusive and inclusive selections that don't need a track fit, then refit, then run the rest

BREAKING TOS

- For timing reasons made the Topo sequence conditional
  - 3-body only runs if 2-body fails to find a candidate
  - 4-body only runs if 3-body fails to find a candidate
- We may not want to use this, but timing is a serious issue for the trigger because of the combinatorics involved

TESTING DETAILS

- 1000 offline-selected signal events per decay channel to evaluate the signal efficiency
- 50,000 L0-selected minimum bias events to evaluate the rate
- Will show results with a “loose” and “medium” trigger configuration

THERE IS A MONSTER IN MY CLOSET

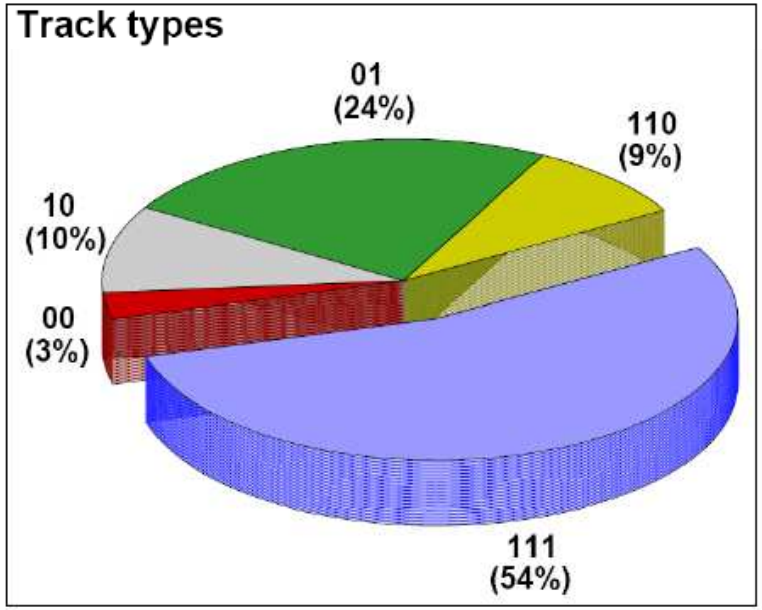
Track classification (I)

Tracks from HLT1 vertices the trigger was on, LOOSE CUTS & DEFAULT PatPV2D

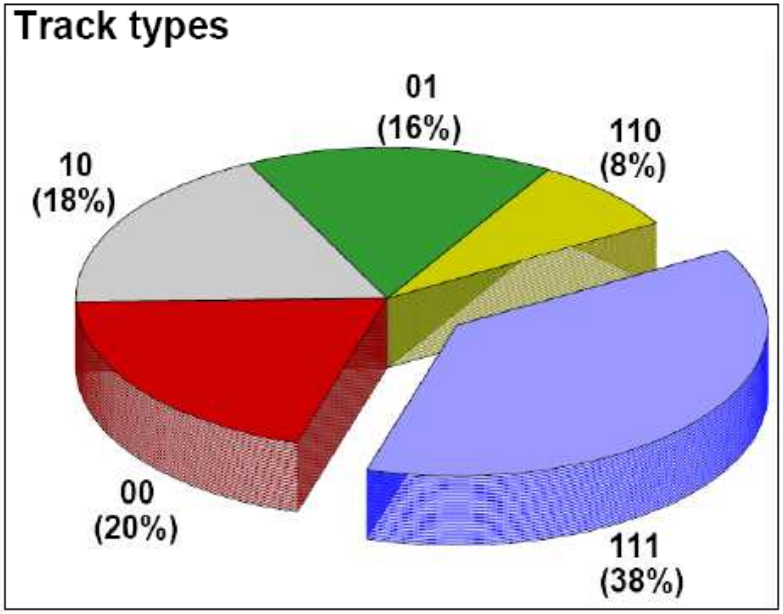
Track types (definitions by Xabier & Jose)

- **111 (good tracks)** : > 70% of hits in VELO from MCP1, > 70% of hits in T MPC1 (same)
- **110** : > 70% of hits in VELO from MCP1, > 70% of hits in T MPC2 (different)
- **01 (ghost in VELO)** : < 70% of hits in VELO from MCP1, > 70% of hits in T from MCP2
- **10 (ghost in T)** : > 70% of hits in VELO from MCP1, < 70 % of hits in T from MCP2
- **00 (ghost in VELO & T)** : < 70% of hits in VELO from MCP1, < 70 % of hits in T from MCP1 (same)

Min bias, Lumi 2, loose cuts



Min bias, Lumi 10, loose cuts



Thanks Marcin!

WHO YOU GONNA CALL?

- Try to use Matt's Ghost Categorization tool to find out what these ghosts really are
  - #include "MCInterfaces/ITrackGhostClassification.h"
- For full details of the tool see here
  - http://indico.cern.ch/getFile.py/access?contribId=44&sessionId=3&resId=1&materialId=slides&confId=10739
- This tool offers a lot more detail than a simple yes/no decision: crucial to understand not only how many ghosts, but also what they really are.

Ghost Classification

- Classification is not unique
  - For simplicity want to make unique classification
- Make a classification ordered by usefulness
  - Changing the order will change the classification

Spillover : 70 % of the linked ids for best match have null pointers to truth

Decay in flight: First + second best match are mother and daughter from chain K - > mu, pi -> mu. 70 % of ids are linked to this pair

Conversion: First and second best match e+/e- pair from conversion photon 70 % of hits are linked to this pair

Electromagnetic Shower: 70 % of the hits come from electrons

GhostClassification

Hadronic Interaction : 70 % of the linked ids came from a hadronic shower

Phi: best and second best match are K+, K- from phi, 70 % of linked ids are due to the first and second best match

Ghost Parent: Track has a parent that was a ghost ← Not for tracks stored on DST

Rest depends on the algorithm

Velo R --> Only three clusters, all from different particles Combi

Velo --> R and Phi projects don't match --> Inconsistant Parts

T seed --> x, and stereo projections don't match --> Inconsistant parts

Long --> velo and T don't match --> Inconsistant parts

All else fails --> No classification