Studies for the Super VELO

The task of coping with 40x current luminosity

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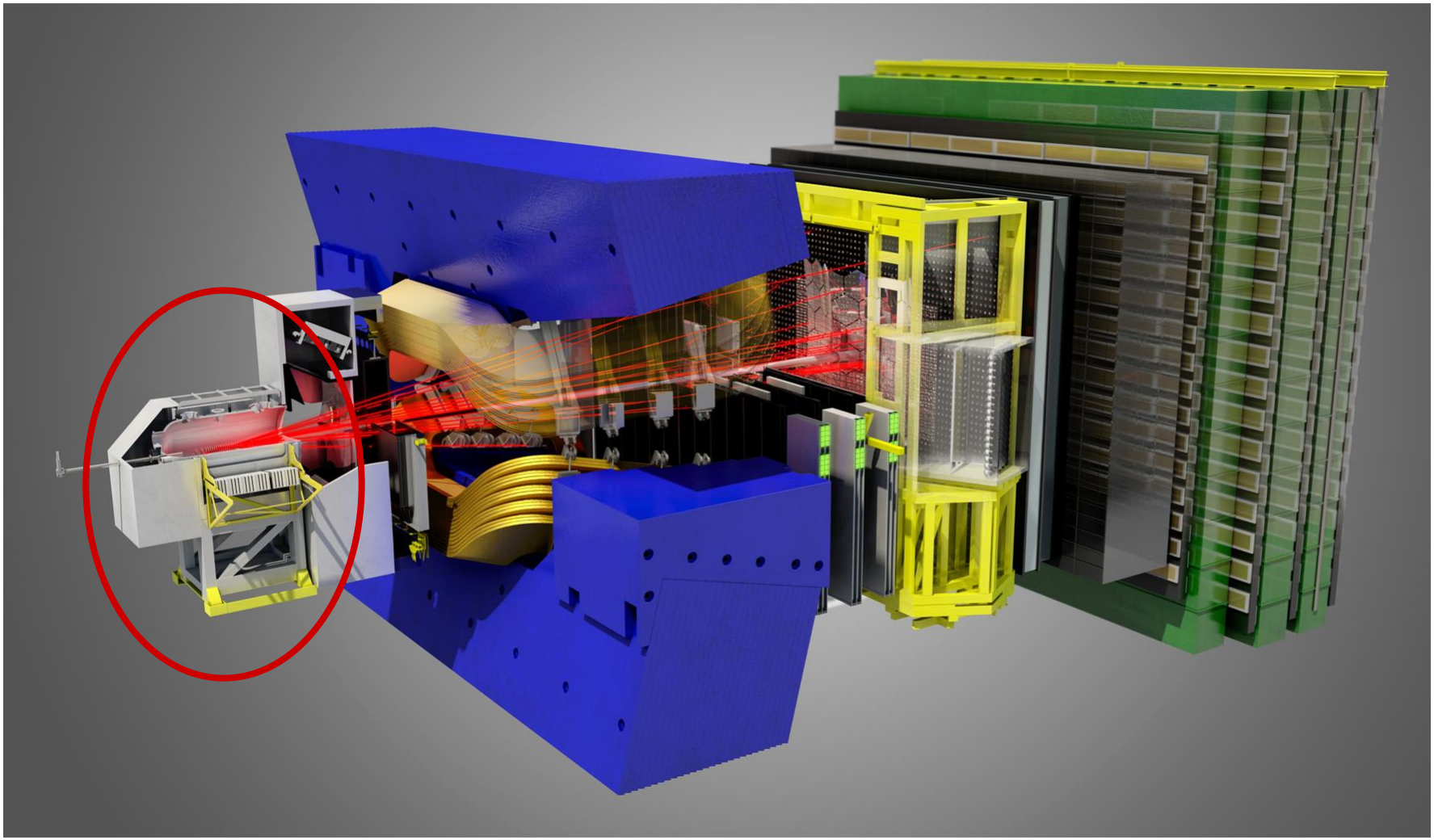
About me

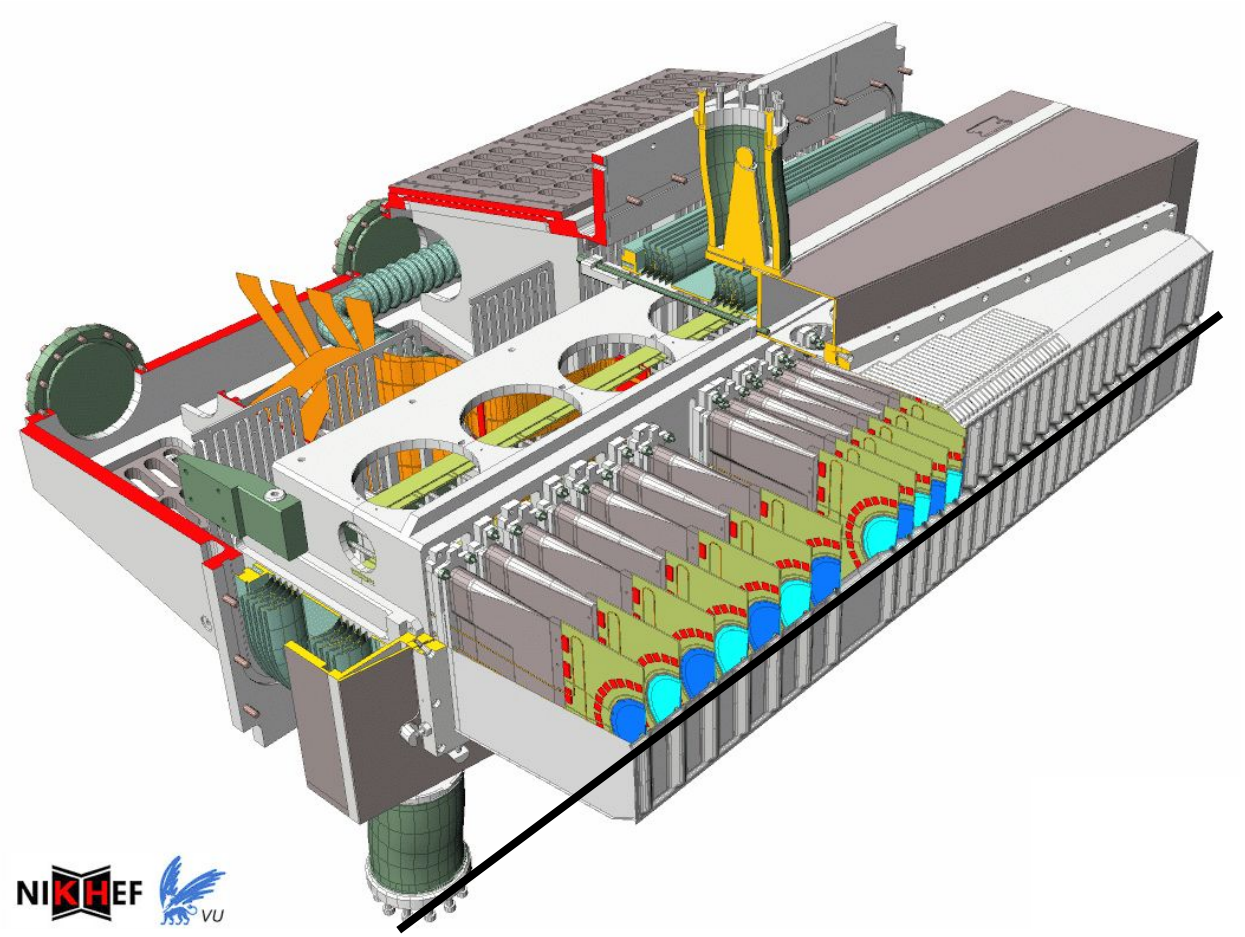
- Undergraduate student at University of Heidelberg
- Main interests: particle physics and computer sciences
- When I am not in the office...

LHCb and the VELO



http://lhcb-public.web.cern.ch/lhcb-public/en/LHCb-outreach/multimedia/LHCbDetector.png

The current VELO



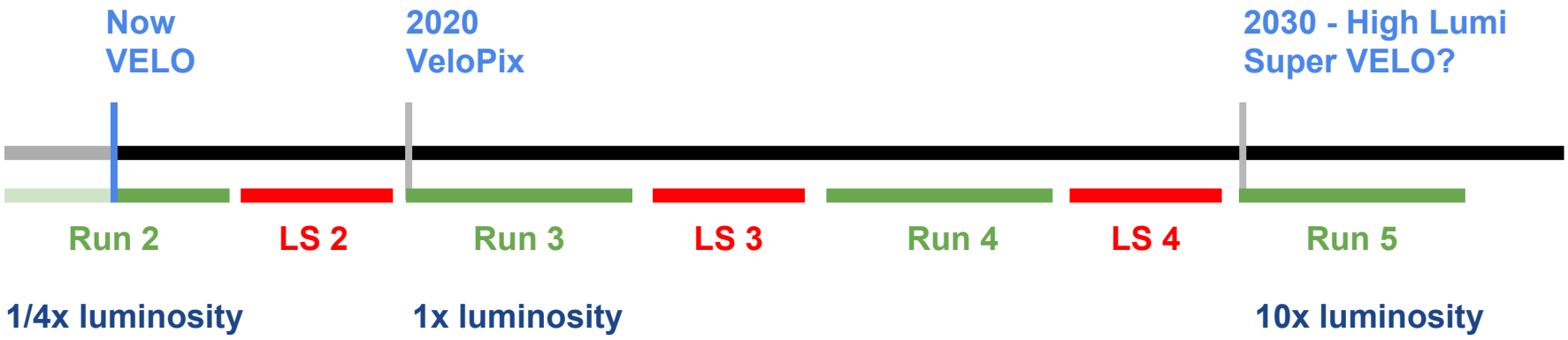
https://lbtwiki.cern.ch/pub/VELO/VELOConferencePlots/HalfVelo.gif

Silicon strip detector

Task: High accuracy **VE**rtex **LO**calization

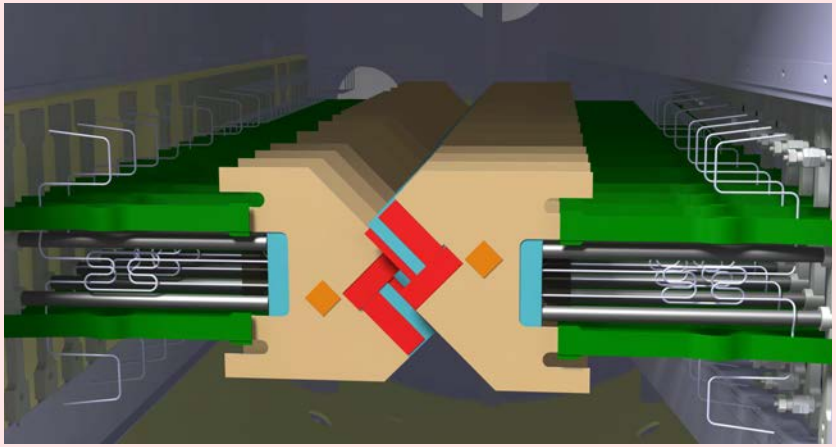
Exceptional: Only 8.4 mm distance to primary beam

Future upgrades of the VELO



VeloPix – Scheduled for Run 3 (starting 2020)

- Only 5.1 mm distance to beam line
- 41 million **pixels** - 55 x 55 µm
- High occupancy at 2×10^{33} $cm^{-2}s^{-1}$
- But increase in resolution and reco speed



Project goal:

Study the potential physics performance of the Super VELO

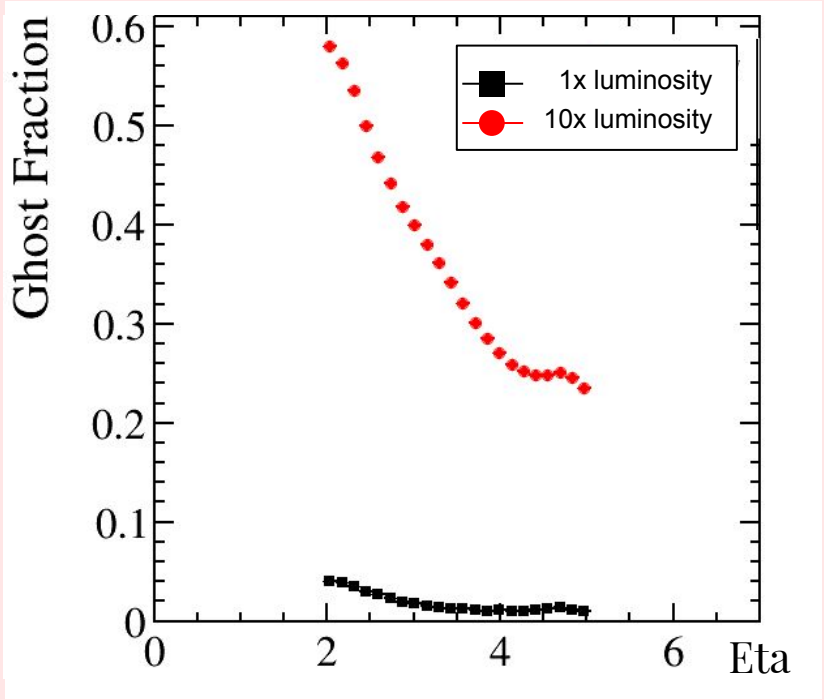
Conducting a Monte-Carlo simulation

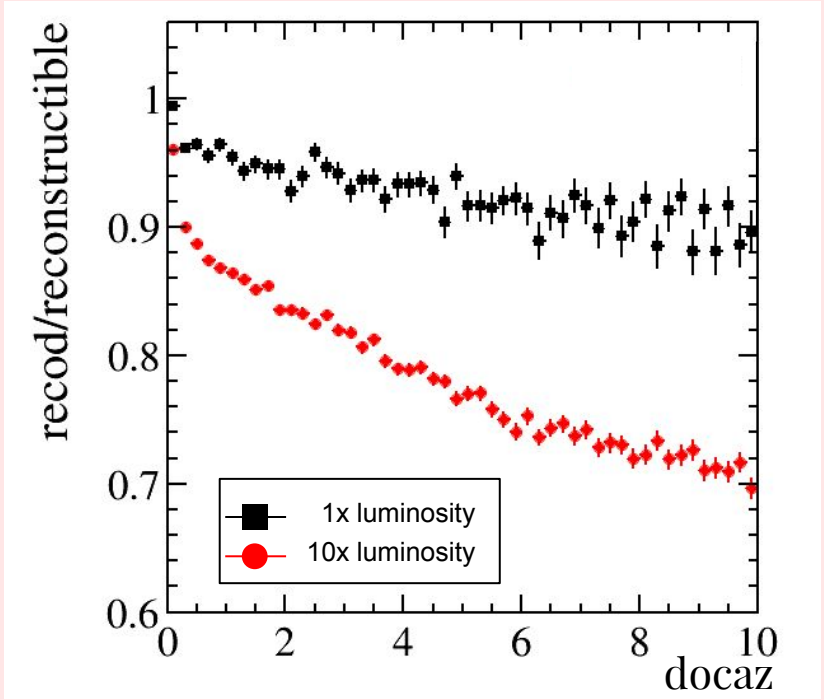
- Using a VeloPix-like detector
- With 10x design luminosity

Improving performance

- Changing material/geometry
- Modifying track reconstruction

Spooky results: Ghost rates at 10x luminosity





$$\text{ghost rate} = \frac{N_{\text{tracks without real particles}}}{N_{\text{all reconstructed tracks}}}$$

$$\text{efficiency} = \frac{N_{\text{correctly reconstructed tracks}}}{N_{\text{charged particles passing detector}}}$$

Unmodified VeloPix shows very high ghost rates at 10x luminosity

Detector improvements: Technological progress

Assumption 1: Thinner silicon sensors

Current thickness: 200 µm

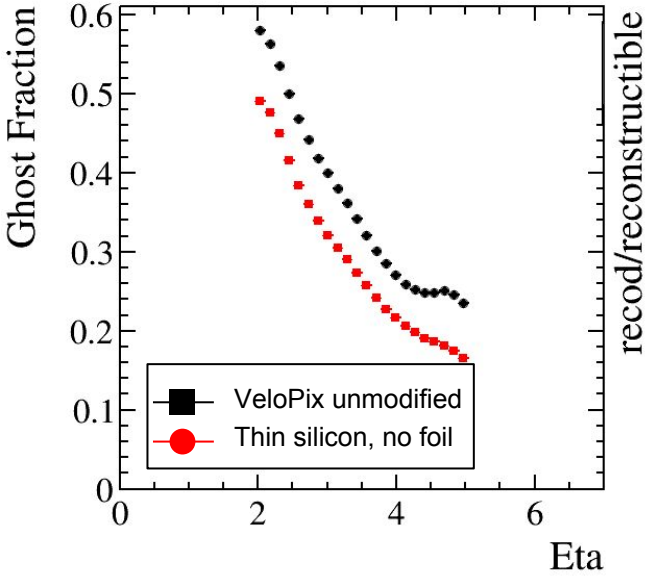
Study thickness: 100 µm

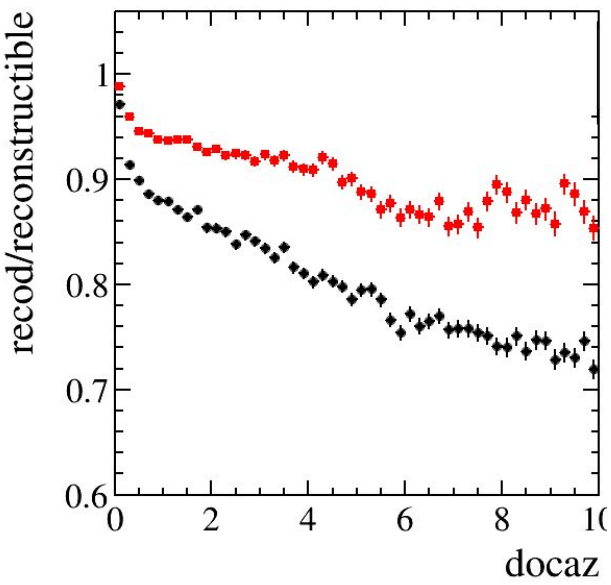
Aside assumption: Removing RF foil

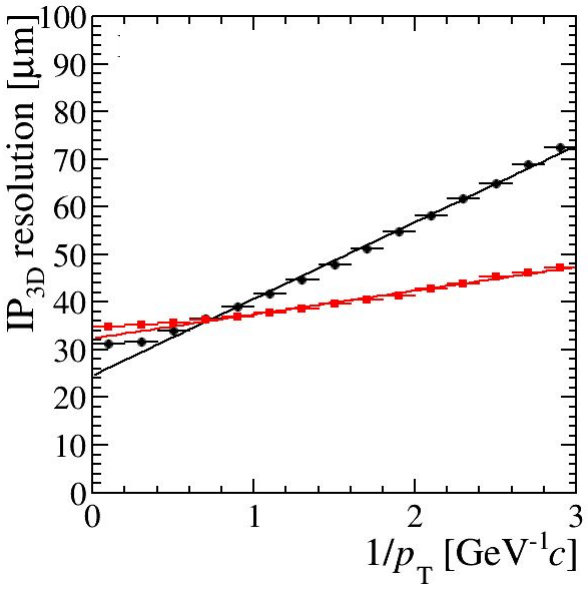
How to get there:

- (Use Gauss, Boole, Brunel, Panoramix, …)
- Simulate *VELO detector only* and change Gauss conditions to 10x upgrade luminosity
- Work with a local detector description database (DDDB)
- Apply changes to DDDB
- Optimize track reconstruction

Results for thin silicon & RF foil removal







\+ Increase in efficiency and resolution

\+ 20% decrease in ghosts

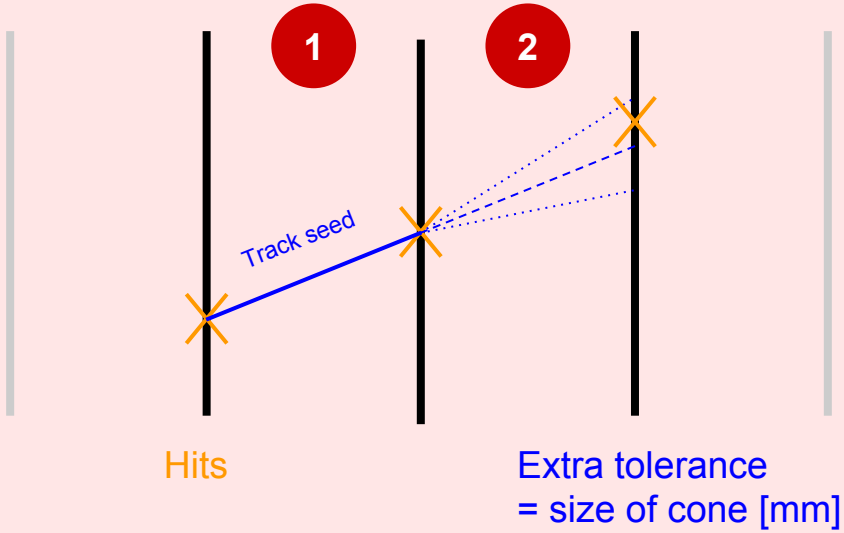
Effects dominated by foil removal

	Default VeloPix	Thin silicon foil removal
Track efficiency	95.7 %	98.3 %
Ghost rate	40.5 %	32.4 %

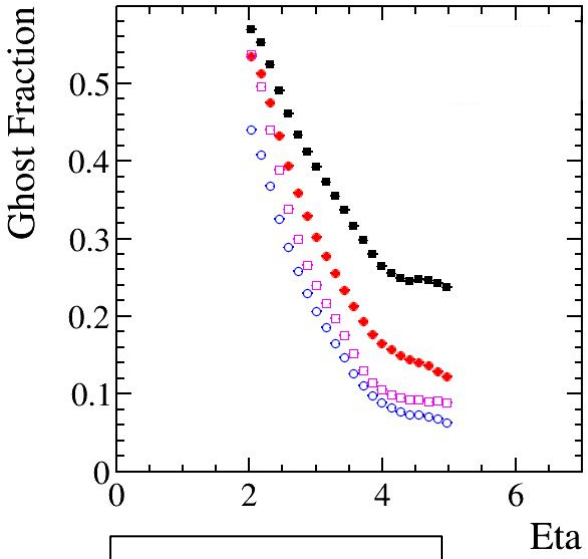
Thinner silicon and RF foil removal decreases ghost rate significantly

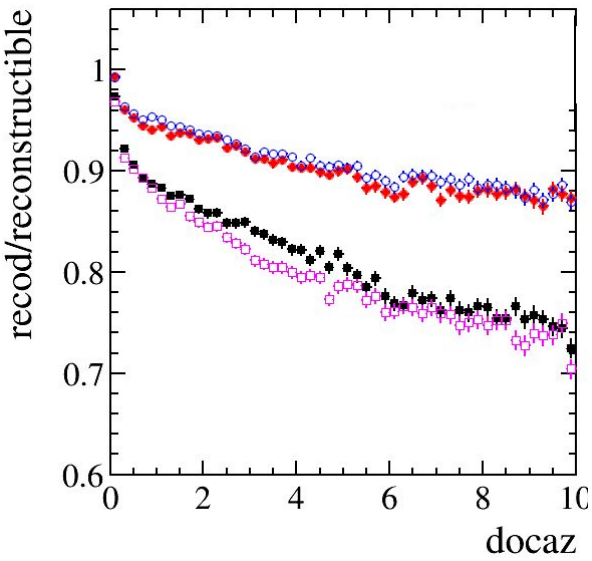
Optimizing track reconstruction parameters

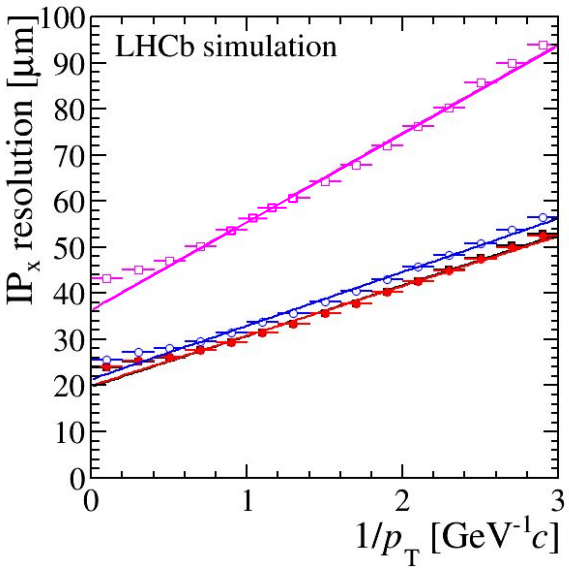
- Current track reconstruction optimized for upgrade luminosity
- Retuning needed for optimal track reconstruction
- Change of track finding parameters such as *ExtraTolerance*:

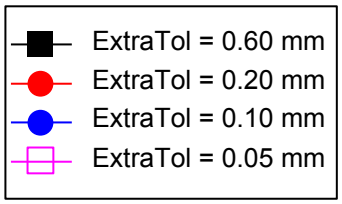


Optimizing parameters for thin silicon







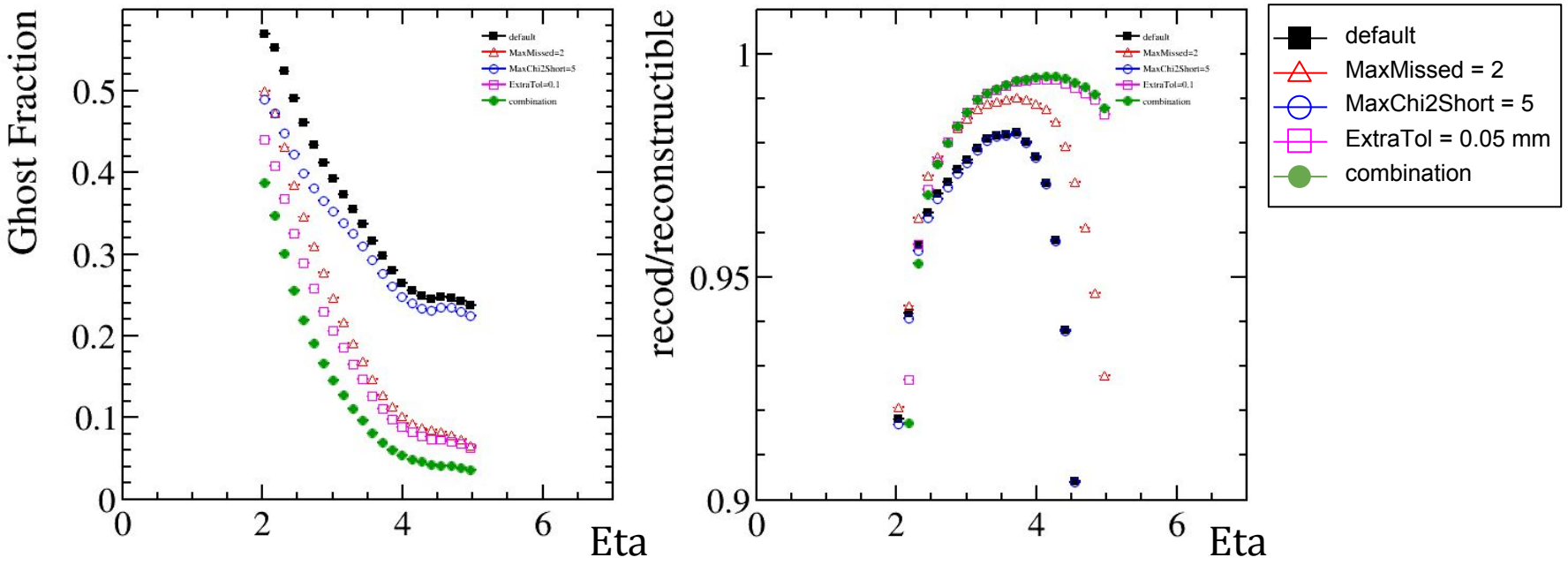


Parameter scan for ExtraTolerance:

+ Strong effect on ghosts (-50%) and efficiency even without RF foil removal

	VeloPix Thin silicon	Thin silicon ExtraTol 0.1
Track efficiency	95.7 %	98.5 %
Ghost rate	40.5 %	20.8 %

Optimizing parameters for thin silicon



Identified 3 beneficial tracking parameters and combined the optimal values:

+ Highly improved efficiency and ghost rate

	VeloPix Thin silicon	Thin silicon param.combi
Track efficiency	95.7 %	98.4 %
Ghost rate	40.5 %	15.3 %

Retuning of track finding parameters can shrink the ghost rate by 65 %

Detector improvements: Technological progress

Assumption 1: Thinner silicon sensors

Current thickness: 200 µm

Study thickness: 100 µm

Aside assumption: Removing RF foil

How to get there:

- (Use Gauss, Boole, Brunel, Panoramix, …)
- Simulate *VELO detector only* and change Gauss conditions to 10x upgrade luminosity
- Work with a local detector description database (DDDB)
- Apply changes to DDDB
- Optimize track reconstruction

Assumption 2: Smaller pixels

Current size: 55µm, 256x256 pixels per chip

Study size: 27.5µm, 512x512 pixels per chip

How to get there:

- Change DDDB (detector geometry)
- Use spare bits in the detector addressing in order to double rows and columns
- Replace magic numbers in C++ code by constants (backward compatible)
- Concerns mainly the way the data is read out and stored (in raw banks)

Status and plans for small pixels assumption

- Creation of new git branch “VPFutureUpgrades”
- Committed and pushed code changes necessary for 512x512 pixels
- New nightly build slot, code compiled fine
- Final modifications still to be made – aim for first results in the next week
- Will test default and *modified track-finding* scenarios

LHCb Nightly Builds

lhcb-VPFutureUpgrades:

Project	Version	x86_64-slc6-gcc49-opt completed at 2:18:48	
Gaudi	master	build (1)	tests (1)
Lbcom	upgradeTracking	build	tests (1)
Brunel	upgradeTracking	build	tests (4)
LHCb	VPFutureUpgrades	build	tests (2)
Rec	VPFutureUpgrades	build	tests (1)
Boole	master	build	tests (20)

GitLab commits

22 Aug, 2016 2 commits

Merge branch 'majahn-prpixelhitmanager-bitmasks-by-bitshift' into 'VPFutureUpgrades' ...
Mark Richard James Williams authored 7 days ago

Edited PrPixelHitManager.cpp to create bitmasks by bitshifting
Manuel Christoph Jahn authored 7 days ago

21 Aug, 2016 1 commit

Merge branch 'majahn-prpixelhitmanagercpp-fix-typecasting' into 'VPFutureUpgrades' ...
Mark Richard James Williams authored 8 days ago

19 Aug, 2016 1 commit

Edited PrPixelHitManager.cpp to fix missing ; and wrong type casting
Manuel Christoph Jahn authored 10 days ago

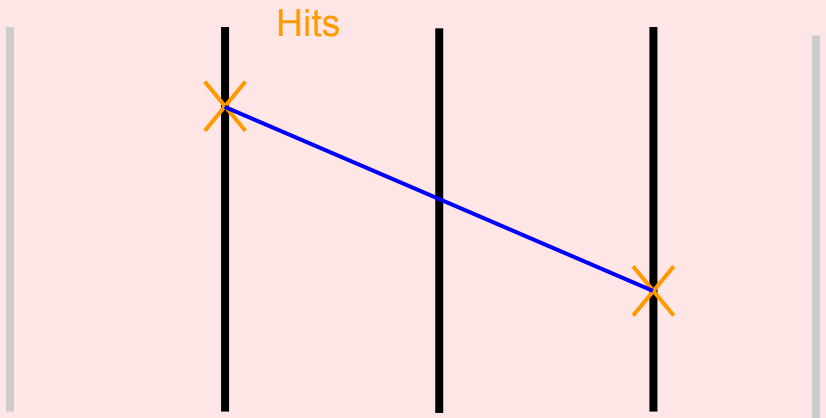
Summary

- The study examined the performance of a VeloPix-like detector for high luminosity LHC in Run 5
- An unmodified VeloPix shows high ghost rates at high luminosity
- Thinner silicon and the removal of the RF foil decreases the ghost rate by 20%
- Retuning the track reconstruction parameters shows an decrease of 65% even without removal of the RF foil
- Smaller pixels are promising, results will be available soon

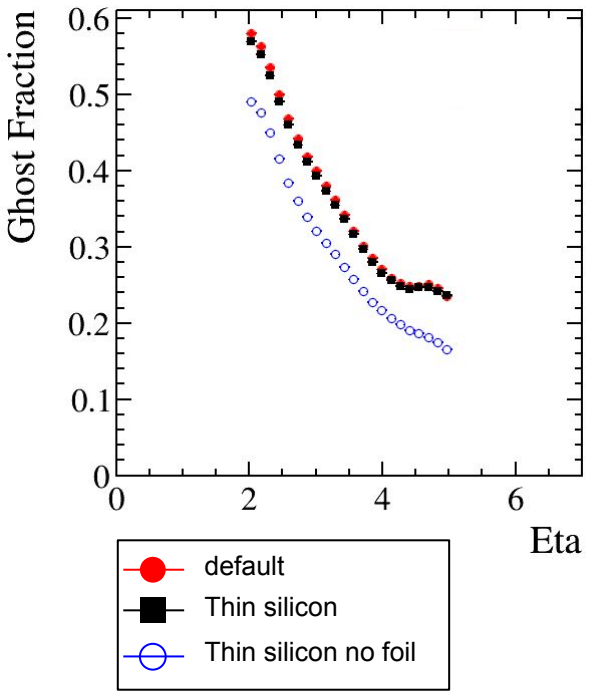
Acknowledgements:
Thanks to Marco Cattaneo, Ben Courtier, Kurt Rinnert and Heinrich Schindler.
Special thanks to my supervisor Mark Williams!

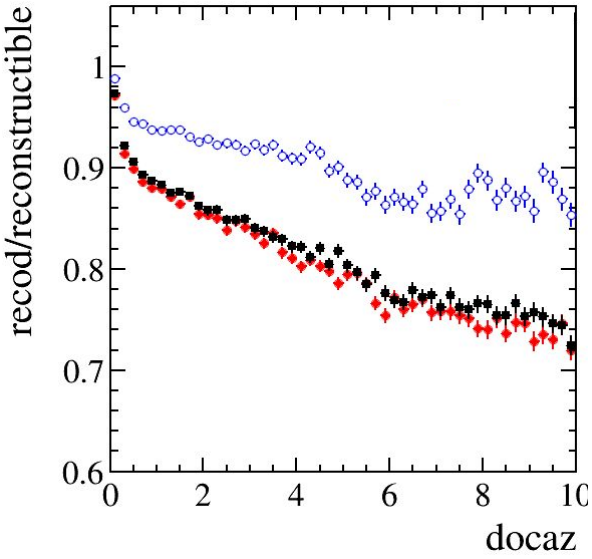
Backup

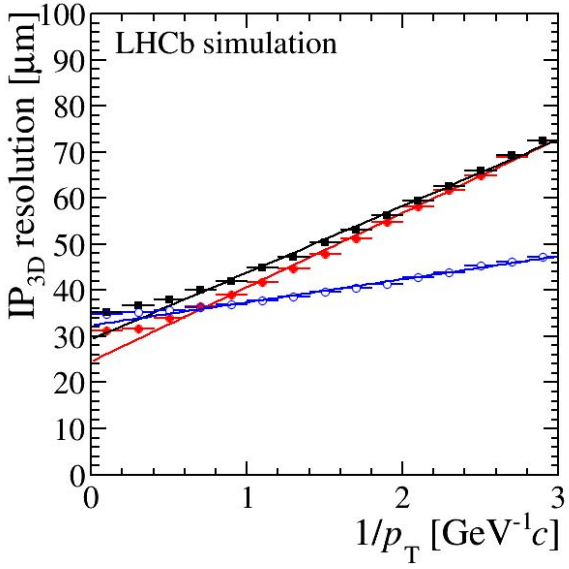
Tracking parameter: MaxMissed



Comparison of default, thin silicon and foil removal







	Default VeloPix	VeloPix ThinSi	ThinSi NoFoil
Track efficiency	95.7 %	96.5 %	98.3 %
Ghost rate	40.5 %	38.1 %	32.4 %