The Vertex Detector of LHCb - VeLo

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On behalf of the
VeLo group

University of Glasgow

Outline:

- The VeLo group.
- Introduction to LHCb .
- Design goals of the VeLo.
- The VeLo Module
- Readout Chain
- VeLo Peformance
- VeLo Commissioning
- Conclusion.

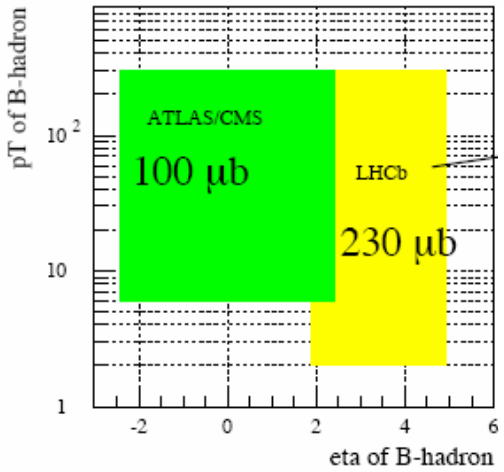
The VeLo group

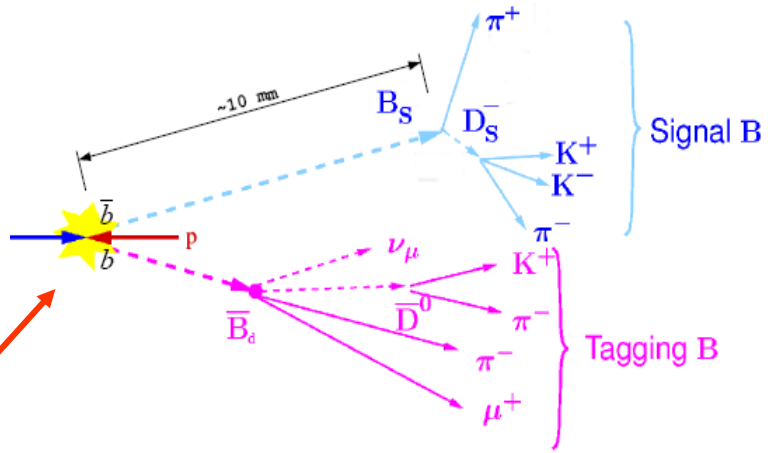
- Heidelberg University, Germany
- MPI Heidelberg, Germany.
- NIKHEF/Free University, The Netherlands.
- CERN, Switzerland.
- EPFL, Switzerland.
- Glasgow University, UK.
- Liverpool University, UK
- Syracuse University, USA.

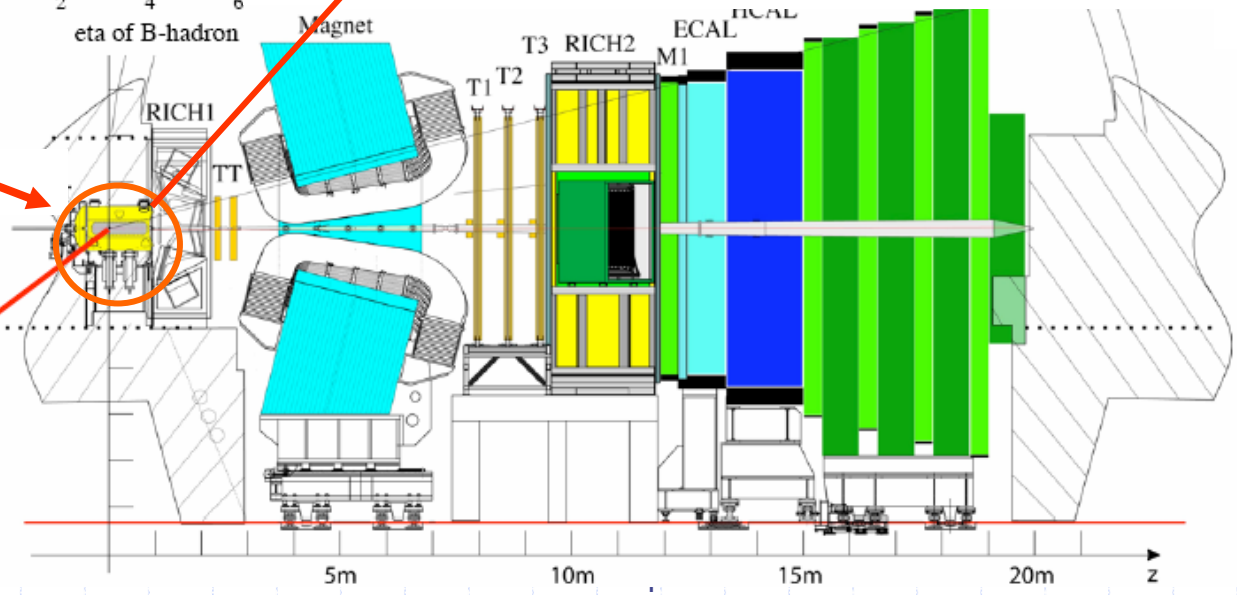
LHCb

Dedicated b-physics experiment at LHC

- 10^{12} bb-pairs per year
- CP violation and rare b-decays
- Correlated boost of the bb-pairs
- Single forward spectrometer



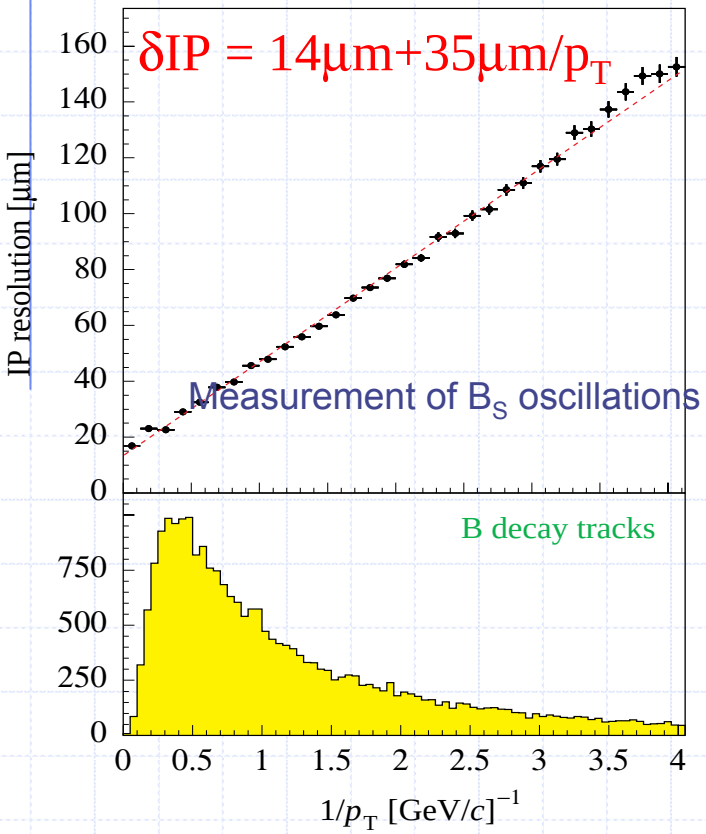




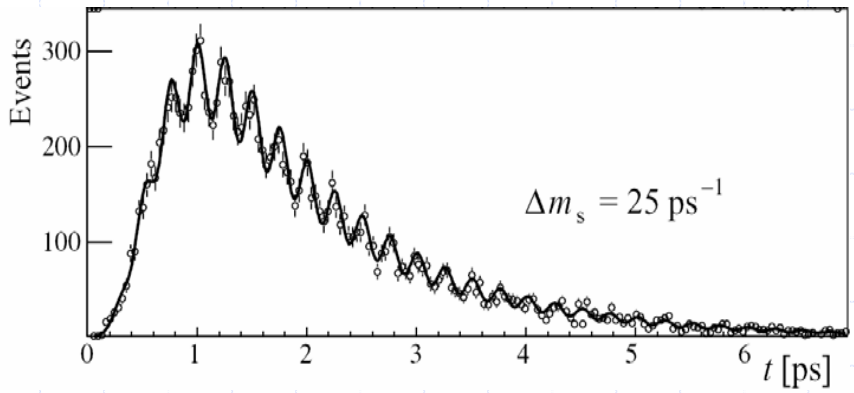
VeLo design goals

- Primary vertex resolution of 8μm for the x and y direction and 44μm for z.

Impact parameter resolution



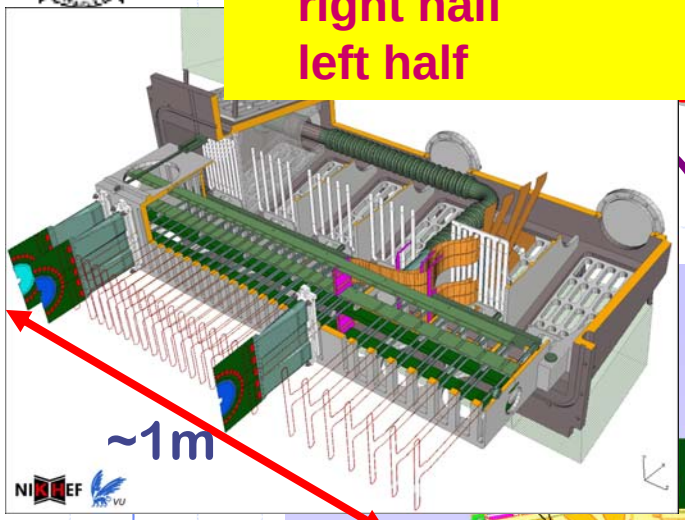
- Provide tracking – On average each track will have 13 VeLo hits. One event expected to have 72 tracks.
- 40fs proper time resolution.

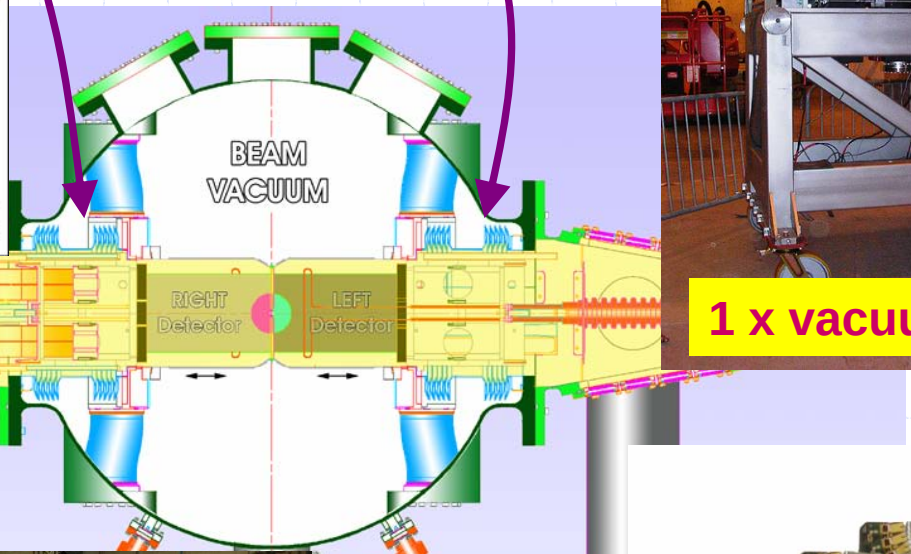


- Part of the 2nd level trigger. A fast offline algorithm using the R z information finds displaced tracks.

VeLo Detect

2 x "module halves"
right half
left half

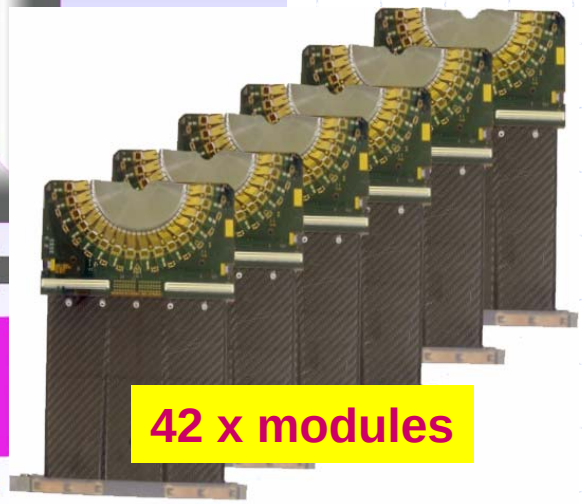




1 x vacuum vessel

42 x sets of
kapton cables

2 x "rf boxes"



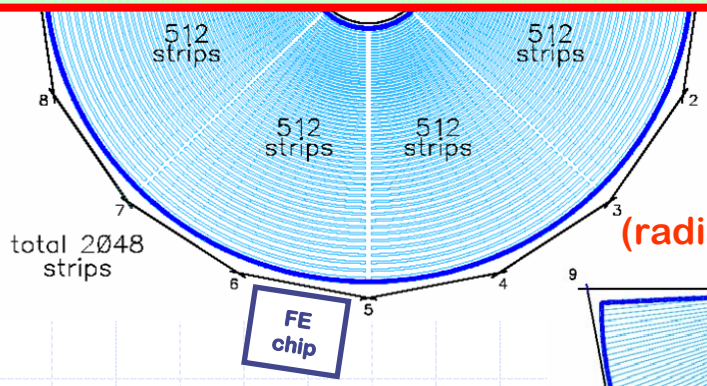
42 x modules

The VeLo Module

- Each module consists of two hybrids back to back.
- The sensor is a 300μm silicon thick n^+ in n-bulk.
- Each hybrids posses either a R or Phi measuring sensor.
- Pitch changes as a function of radius (40 – 100 μm).

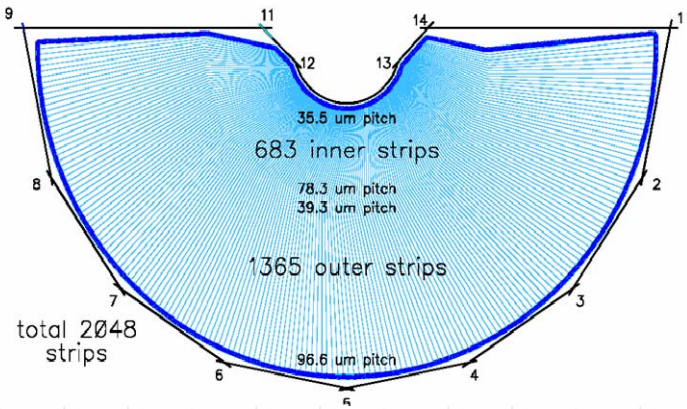
Production sensors are tested under vacuum:

Individual sensors require a breakdown voltage greater than 350V and a current of a few μA.



Phi–measuring sensor

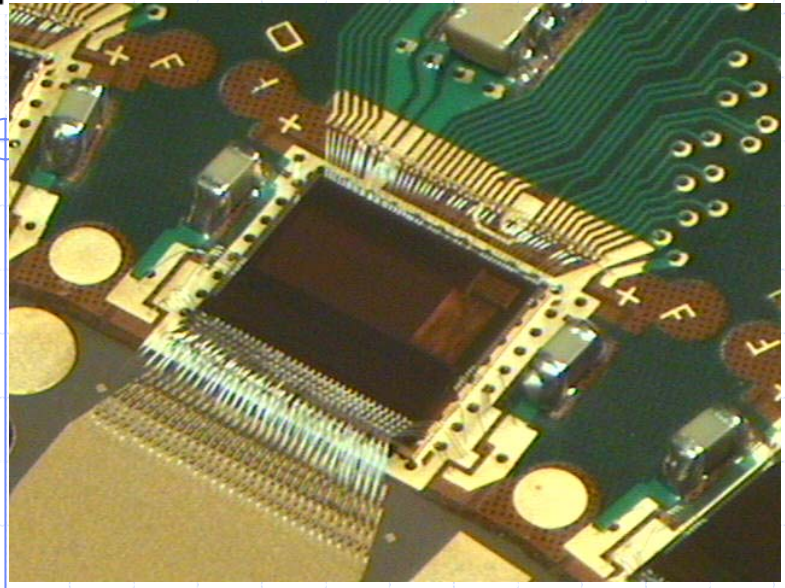
(radial strips with an stereo angle)



The geometry and position of the VeLo results in non-uniform irradiation:

- $1.3 * 10^{14}$ $n_{eq}/cm^2/year$ at R = 8 mm
- $5 * 10^{12}$ $n_{eq}/cm^2/year$ at R = 42 mm

The VeLo Module



- The VeLo the chips is operated in analogue mode:
  The output of each channel is proportional to the charge deposited on the sensor.
- This maximises the resolution of the position of clusters.

- Each hybrid has 16 Beetle v1.5 front end chip. A total of 1344 chips are required for the complete VeLo.

- The Beetle chip has 128 channels. Each consists of a low noise charge sensitive pre-amplifiers, an active CR-RC pulse shaper and a buffer.

- Fabricated on deep submicron (0.25μm) technology, thin gate oxide (~0.62Å) and enclosed NMO gates

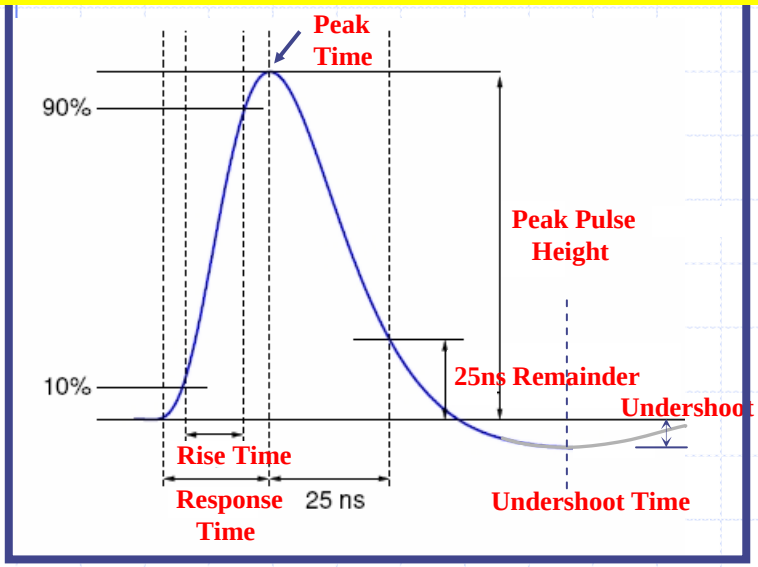
→ Total dose radiation hardness > 130MRads

- Triple-redundant logic ensures a robustness against Single Event Upsets (SEU)

The VeLo Module

The chip selection for VeLo production was based on the data gathered during the wafer probing performed at Heidelberg.

The different analogue parameters measured



The probing measured:

- Currents and register integrity.
- Digital performance
- Analogue performance of pre-amplifier and pipeline.

- Cuts were applied to 69 variables in a bid to select a uniform batch of chips.

- Variables were seperated in two groups.

1st group of 18, most important, included: currents, gain of pipeline cells, pulse variables such as Remainder/PH, Pulse

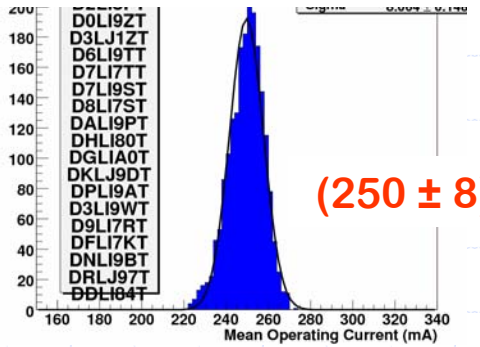
Group 1 cut set at 2.2 sigma

Yields 2092 chips out of 5000

d:
eader amplitudes

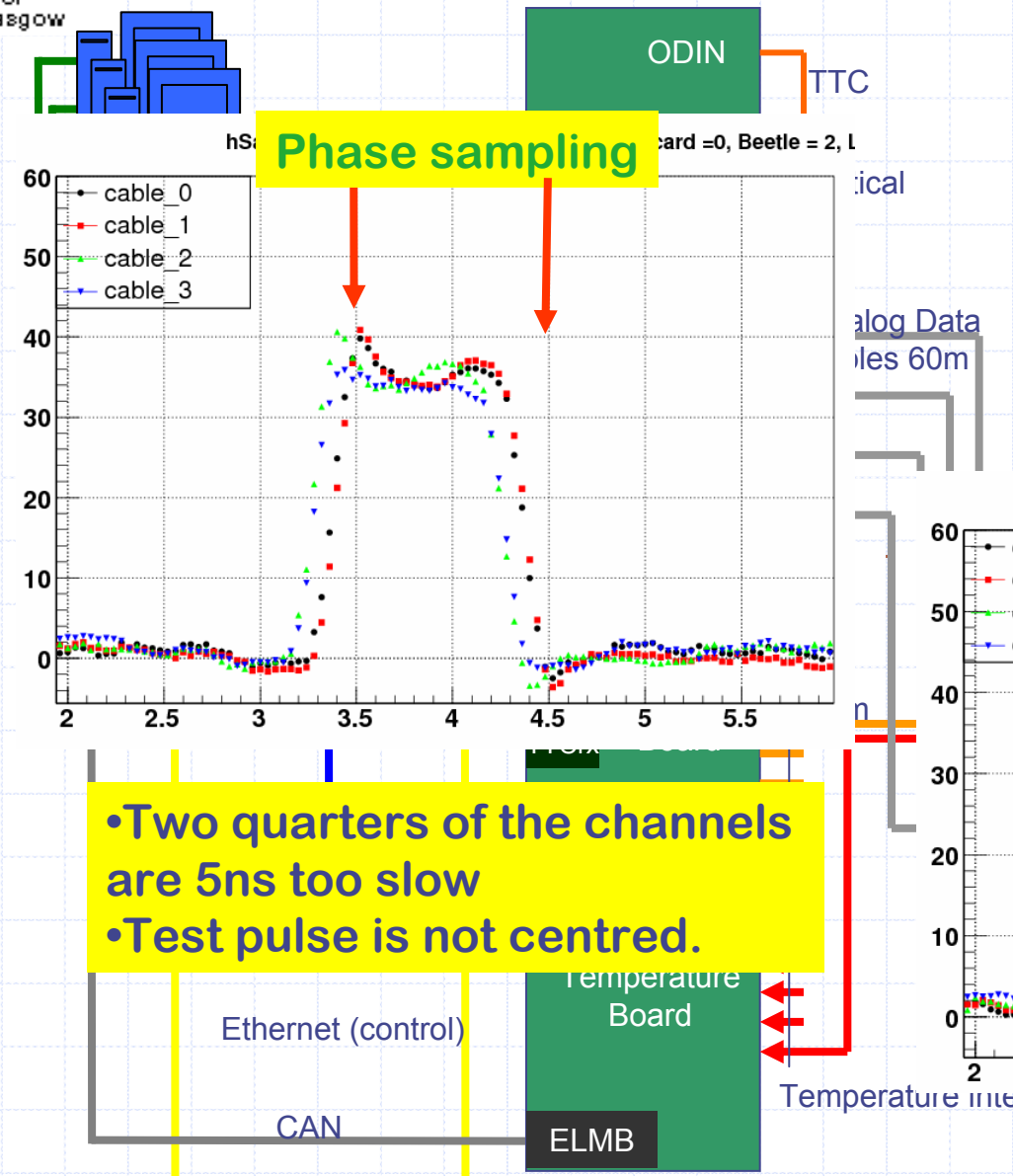
Group 2 cut set at 3.5 sigma

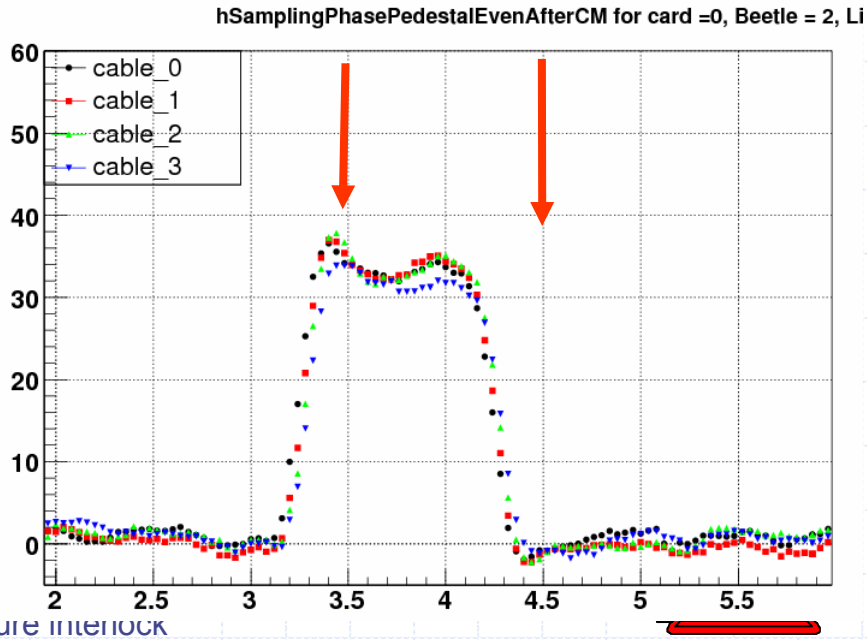
Mean Operating Current



(250 ± 8)mA

The Readout Chain





Performance of the VeLo Module

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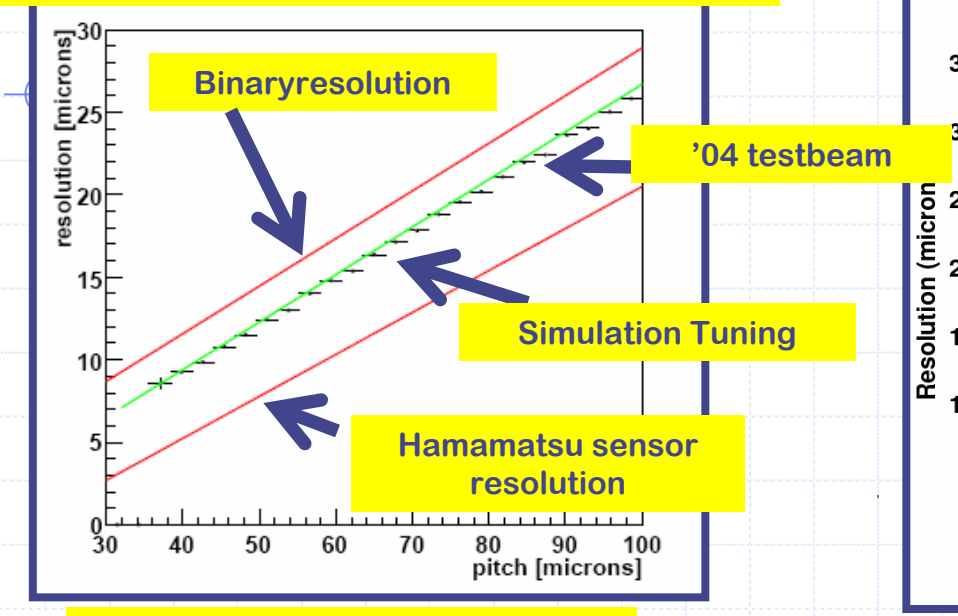
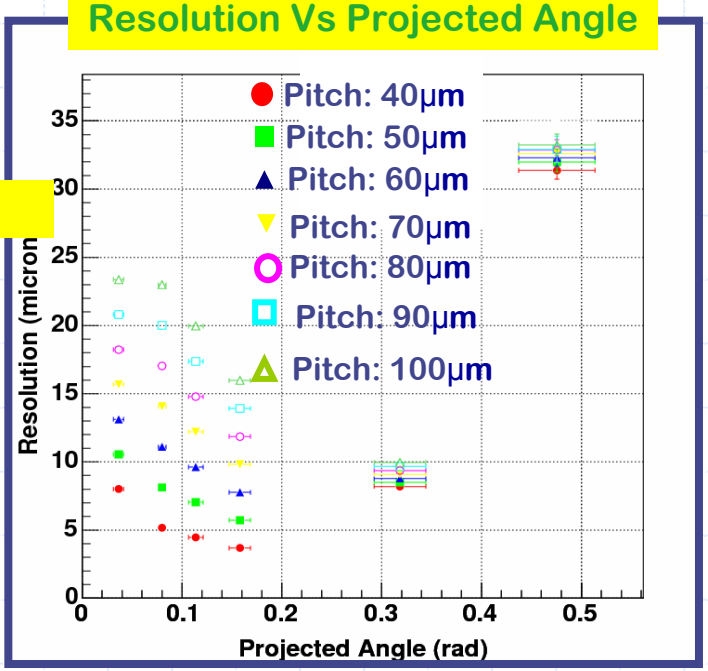
Results test beam November 2004 – 300 μm thick Φ measuring sensor

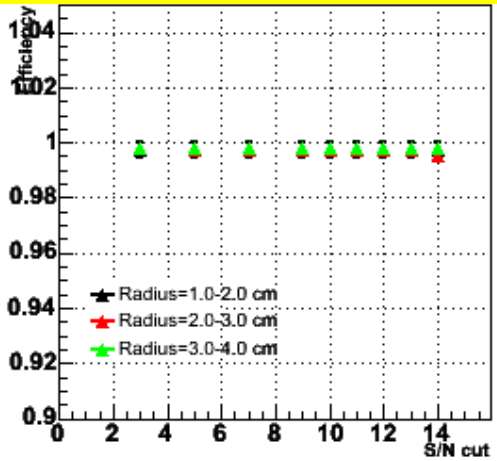
Resolution vs Pitch All Clusters (RMS)



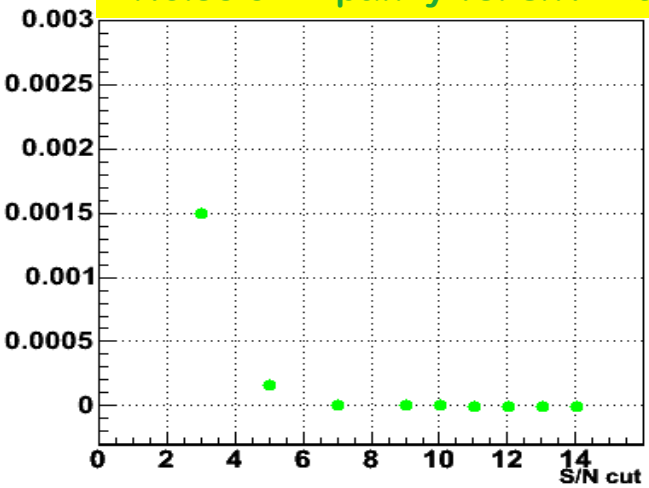
Resolution Vs Projected Angle



Cluster efficiency vs. S/N cut



Noise occupancy vs. S/N cut



VeLo Commissioning

- The commissioning of the VeLo detector is a three step program before the final commissioning which will take place at the pit. They are fondly referred to as ACDCs. (Alignment Challenge / Detector Commissioning)

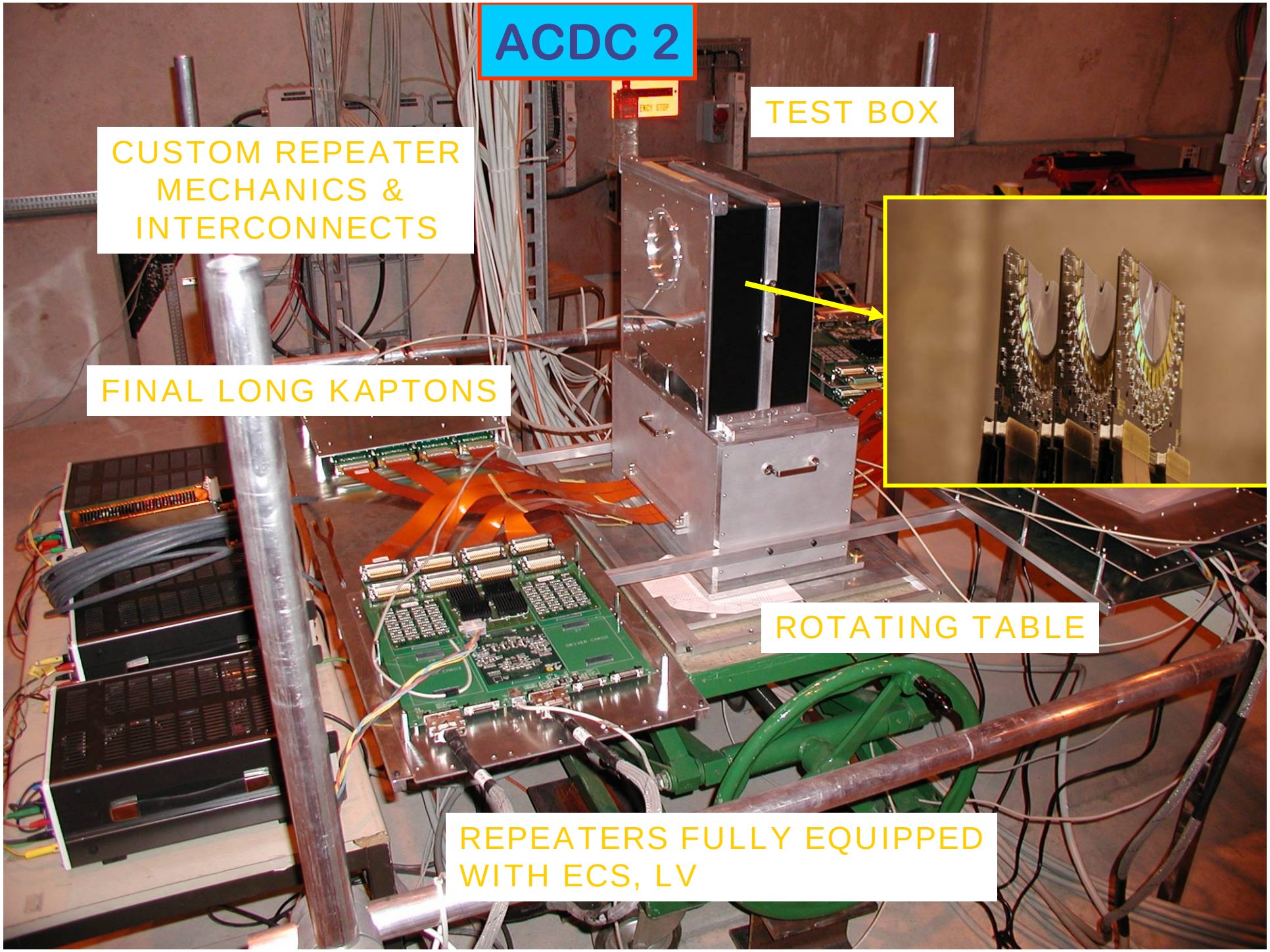
- Two steps has involve a testbeam at the North Area testbeam facility at CERN.

- As final components are available, the thoroughness of the commissioning increases. It involves hardware and software components.

- In July 2006 part of the DAQ was commission.

- In August 2006 ACDC 2 involved 3 production modules and readout electronics.

- In November 2006 ACDC 3 will test the right half of the VeLo with 16 production modules and off detector electronics.


ACDC 2
TEST BOX
CUSTOM REPEATER MECHANICS & INTERCONNECTS
FINAL LONG KAPTONS
ROTATING TABLE
REPEATERS FULLY EQUIPPED WITH ECS, LV

Preliminary Results (ACDC2)

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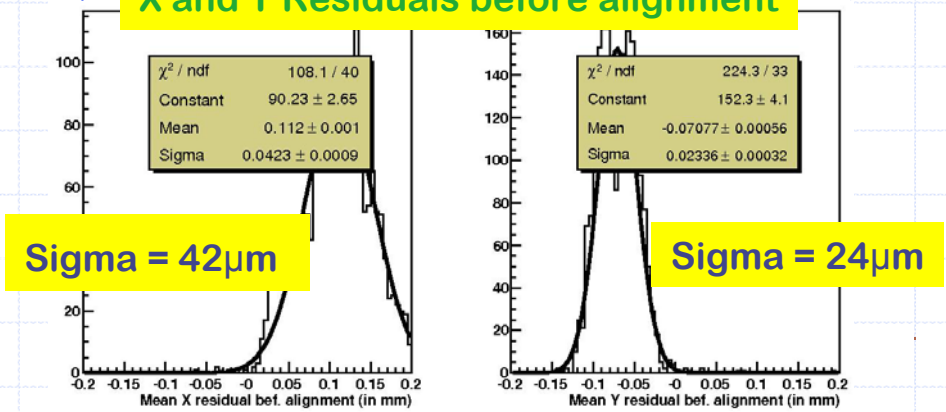
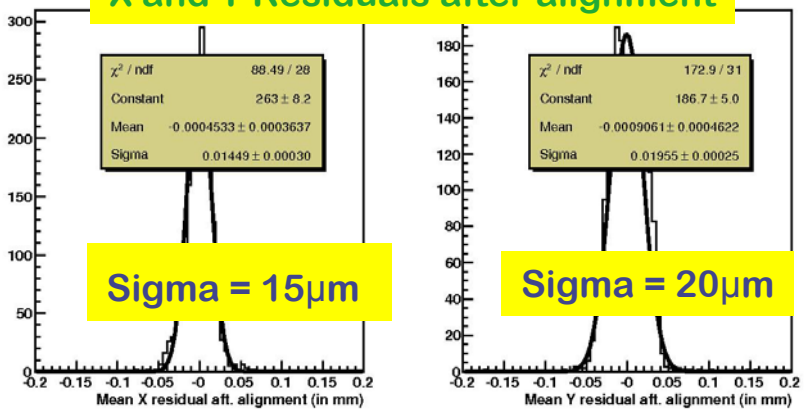
LHCb

The first 'real' VeLo alignment:

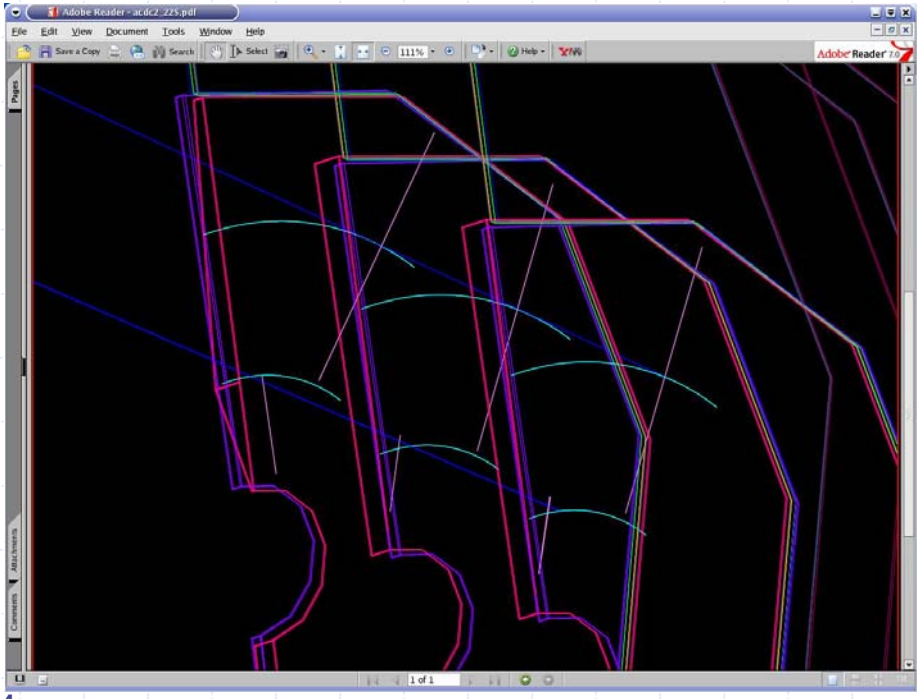
X and Y Residuals before alignment



X and Y Residuals after alignment



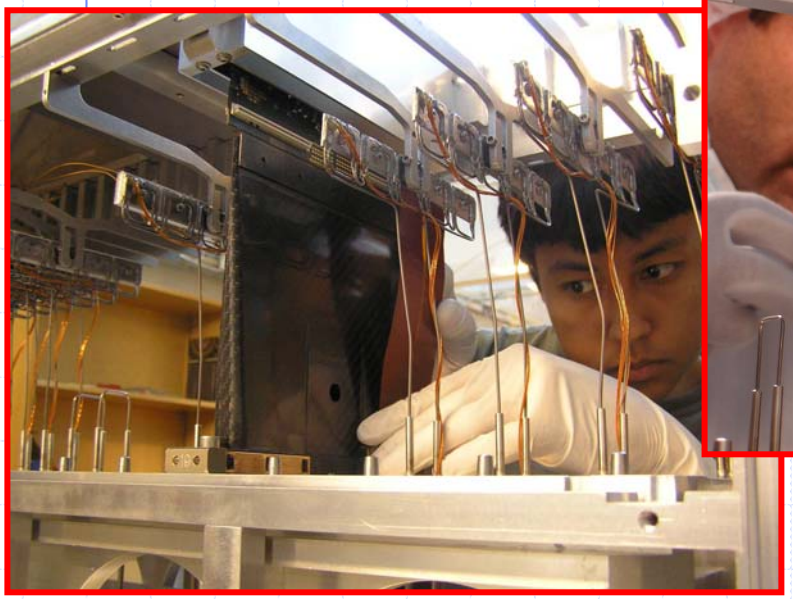
- The algorithm developed is based on Millepede.
- Mean value after alignment is close to zero, as expected, the code is doing his job…
- Silicon to silicon misalignment not taken into account.



Conclusion

- The VeLo is a key component of the LHCb Experiment.
- Its design goals are expected to be met by the current implementation.
- The VeLo module production is in full swing. Four modules a week are delivered to CERN for assembly.
- First half to be installed in the pit in February 2007 with the second half to follow 2 months later.
- The third ACDC will start on 6th of November and will be a dress rehearsal for the commissioning of the detector in the pit.

Thank you



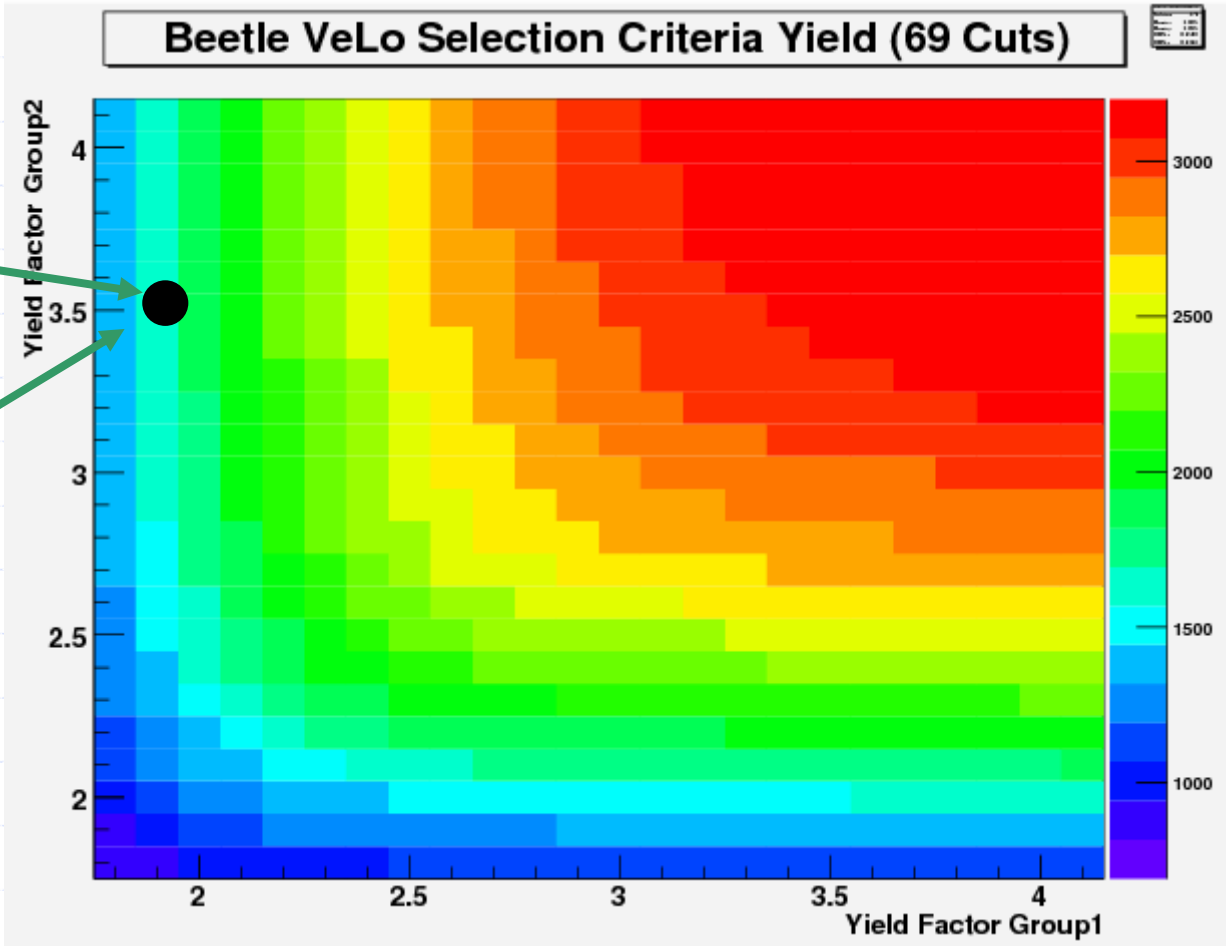
Back up slides

A contour map of the yield as a faction of yield factor 1 and 2.

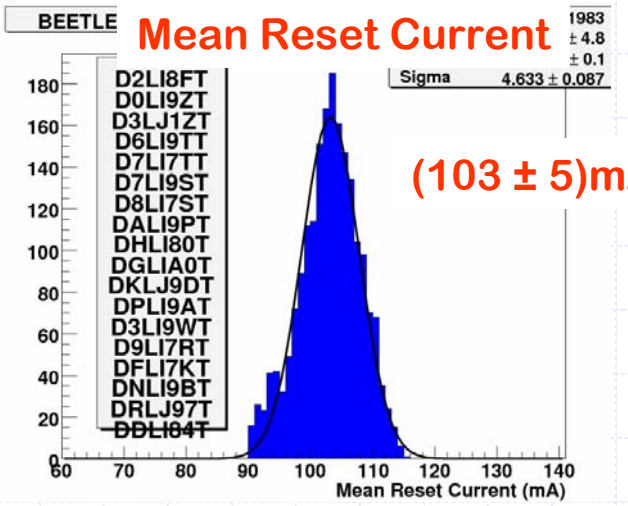
Factor1 = 2.2

Factor2 = 3.5

Yields 2092 chips
(Total sample 5092)



The total number of Fes is 5012. Each yield factor was stepped from 1.80 to 4.10 using of 0.1 steps


BEETLE
Mean Reset Current
1983
± 4.8
± 0.1
Sigma 4.633 ± 0.087
D2LI8FT
D0LI9ZT
D3LJ1ZT
D6LI9TT
D7LI7TT
D7LI9ST
D8LI7ST
DALI9PT
DHLI80T
DGLIA0T
DKLJ9DT
DPLI9AT
D3LI9WT
D9LI7RT
DFLI7KT
DNLI9BT
DRLJ97T
DDLI84T
(103 ± 5)mA
Mean Reset Current (mA)

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A typical event has 72 tracks
On average Velo contains 13 hits, 3 TT , 11 IT 22 Outer

Different version of Beetle chips.. The difference? Gain

What is the average angle of the tracks