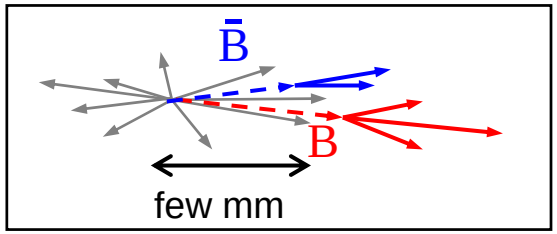
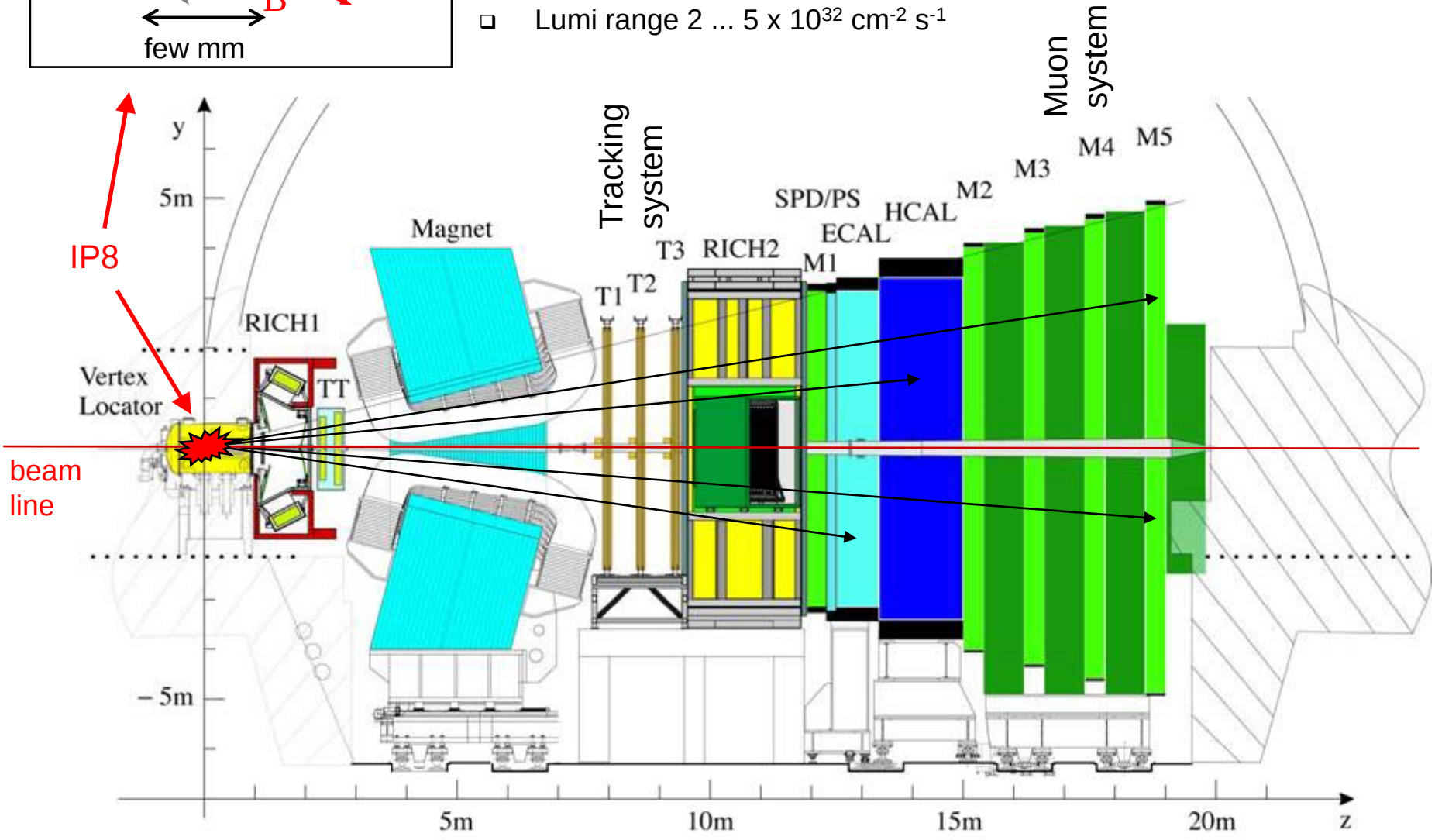
LHCb VELO: Positioning, Alignment, Beam-finding and All That

- What is LHCb ?
- What is VELO ?
- How do we position the VELO ?
- How de we find the alignment parameters ?
- How do we find the beams and move the VELO to them

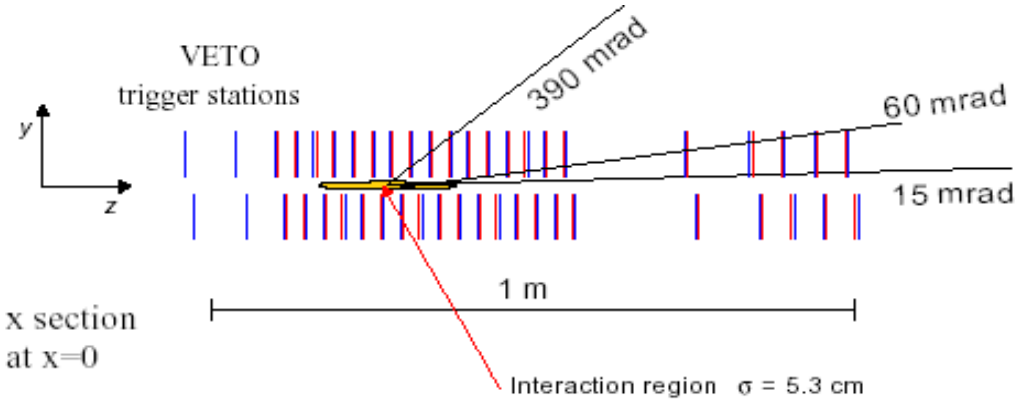
LHCb Experiment

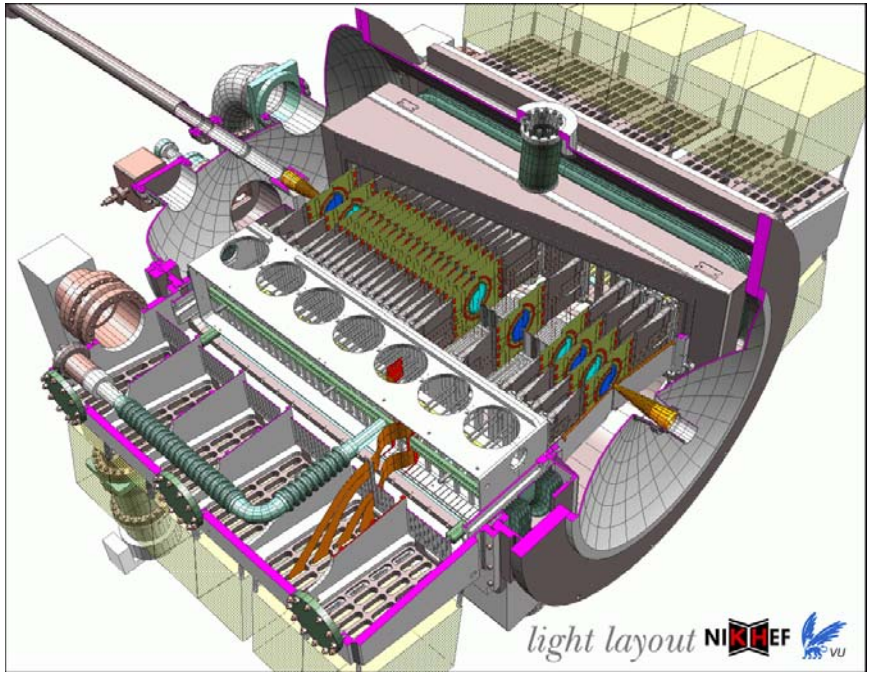


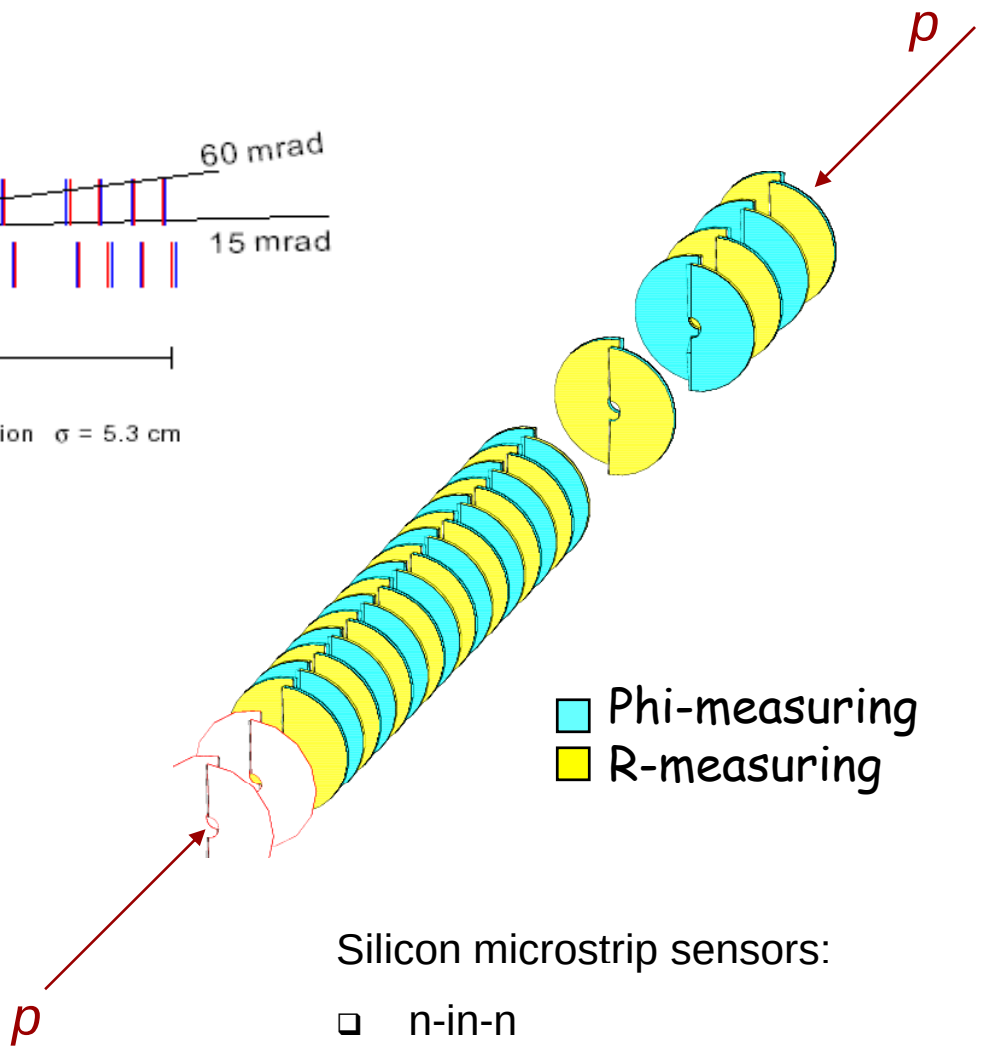
- LHC used as a B-meson factory
- displaced IP, spectrometer field (dipole, B vertical)
- Lumi range 2 ... 5 x 10^{32} cm^{-2} s^{-1}



VELO detector







Silicon microstrip sensors:

- n-in-n
- varying pitch 40...100 um
- 2048 strips / sensor

Some important VELO specifics

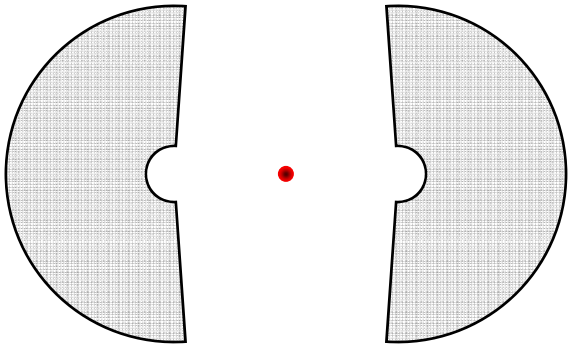
- VELO detector halves must be retracted during beam filling and repositioned once beams are declared stable

  ⇒ positioning system (see later)

- VELO is used in early trigger, starting with 2D tracking (RZ, no Phi)

  ⇒ requires axial symmetry around beam axis

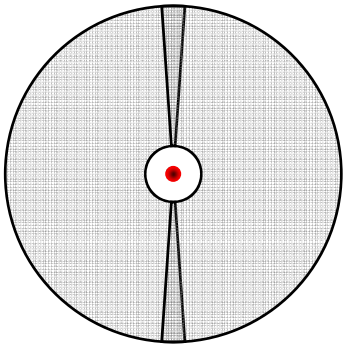
- Open ("Out", "Garage") position retracted by 30 mm each side



Silicon:

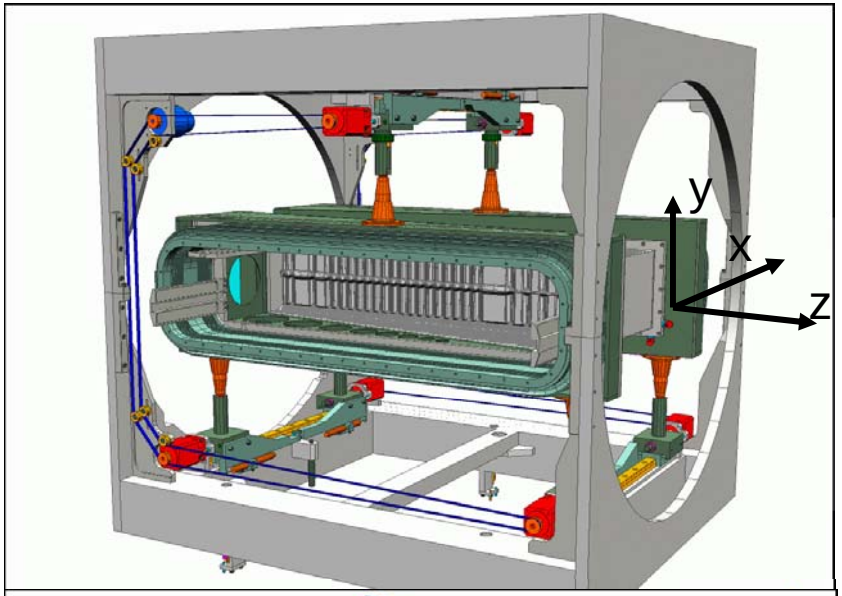
- inner radius 7 mm
  (sensitive at 8 mm)
- outer radius 42 mm

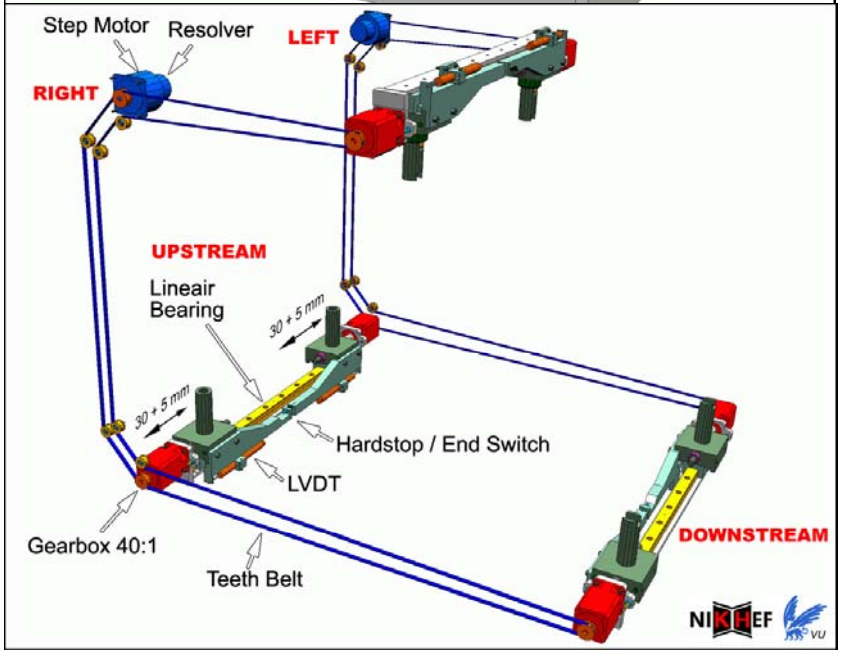
Nominal position (physics) note the L/R overlap



VELO Positioning: X Motion

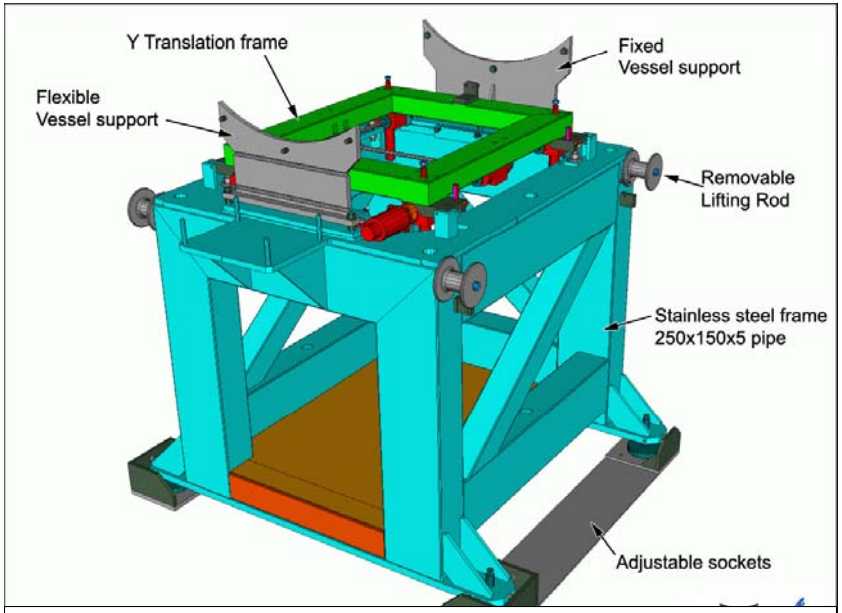
- Mechanics decoupled from vacuum vessel by bellows
- 2 step motors (X_L, X_R) outside vacuum, independent for each detector half
- Range is -30...+5mm from nominal (and -5...+30mm)
- Speed: about 9 s/mm
- Use combinations of Reference Switches, End Switches, Hard Stops
- "Out" (or "Garage") position interlocks with LHC status

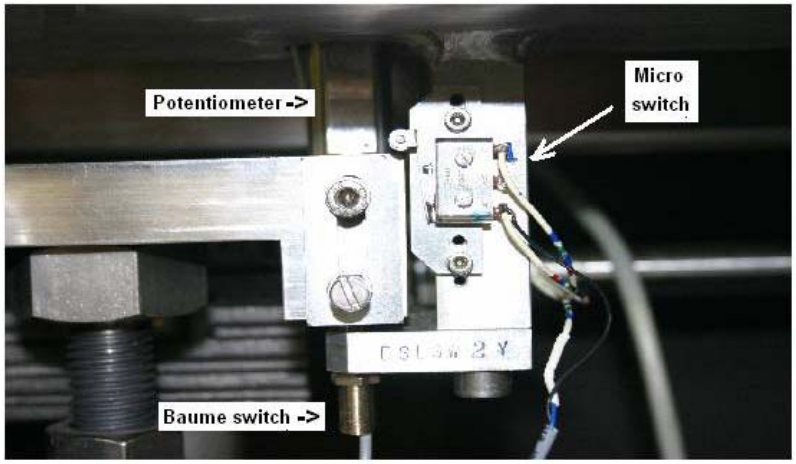


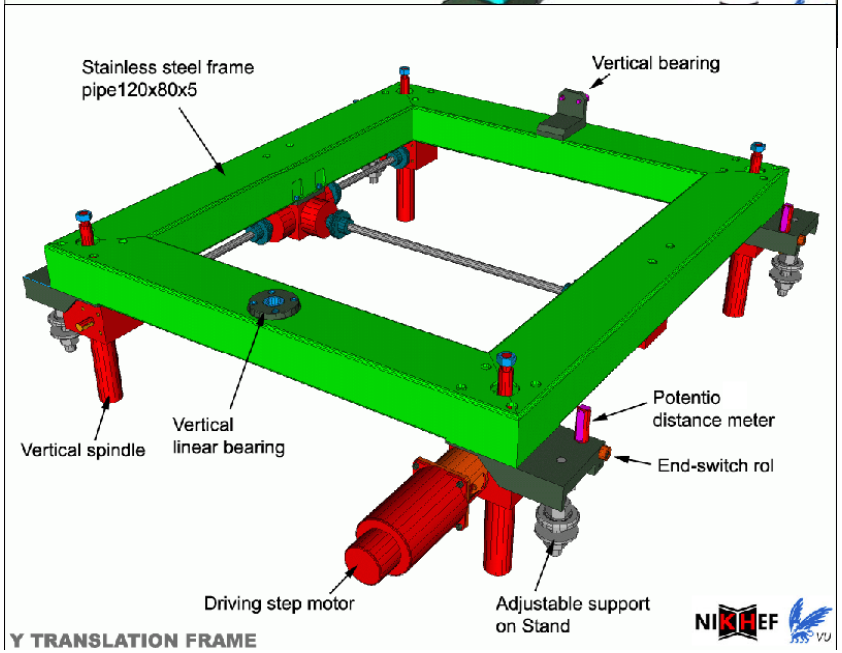


VELO Positioning: Y Motion

- Common for both halves (Y table)
- Mechanics decoupled from vacuum vessel by bellows
- Range is +/- 5mm from nominal center
- Speed: about 3 s/mm
- Pitch is 4 mm/revol
- Reduction gearing is 1 : 16
- Step motor: 2000 steps/revol
- Resolver :1024 pulses/revol

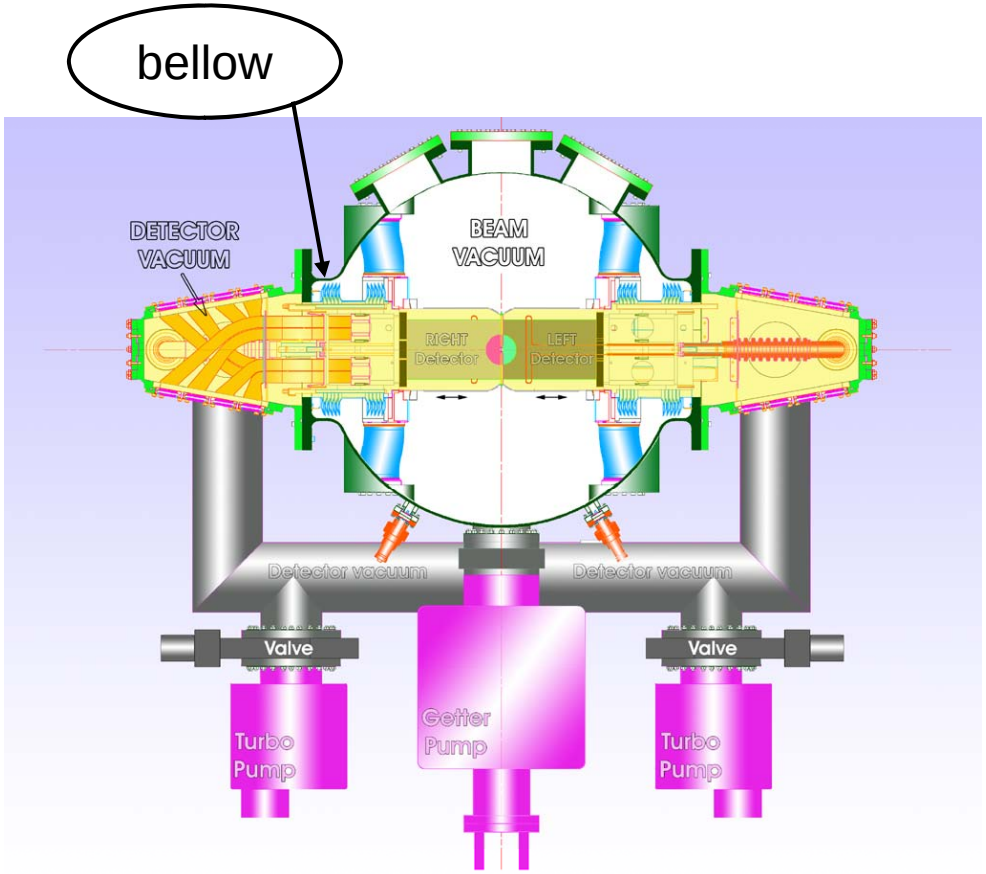


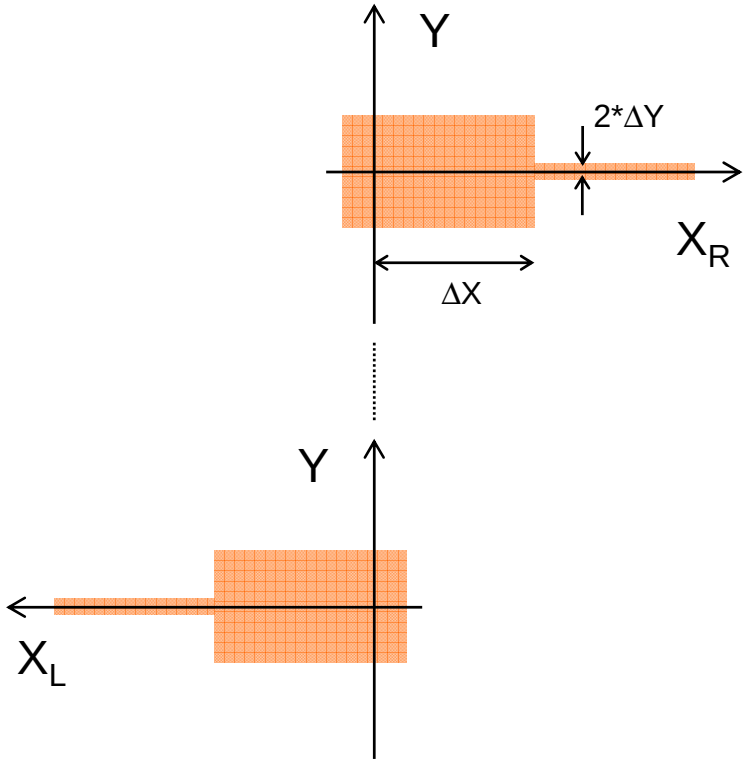




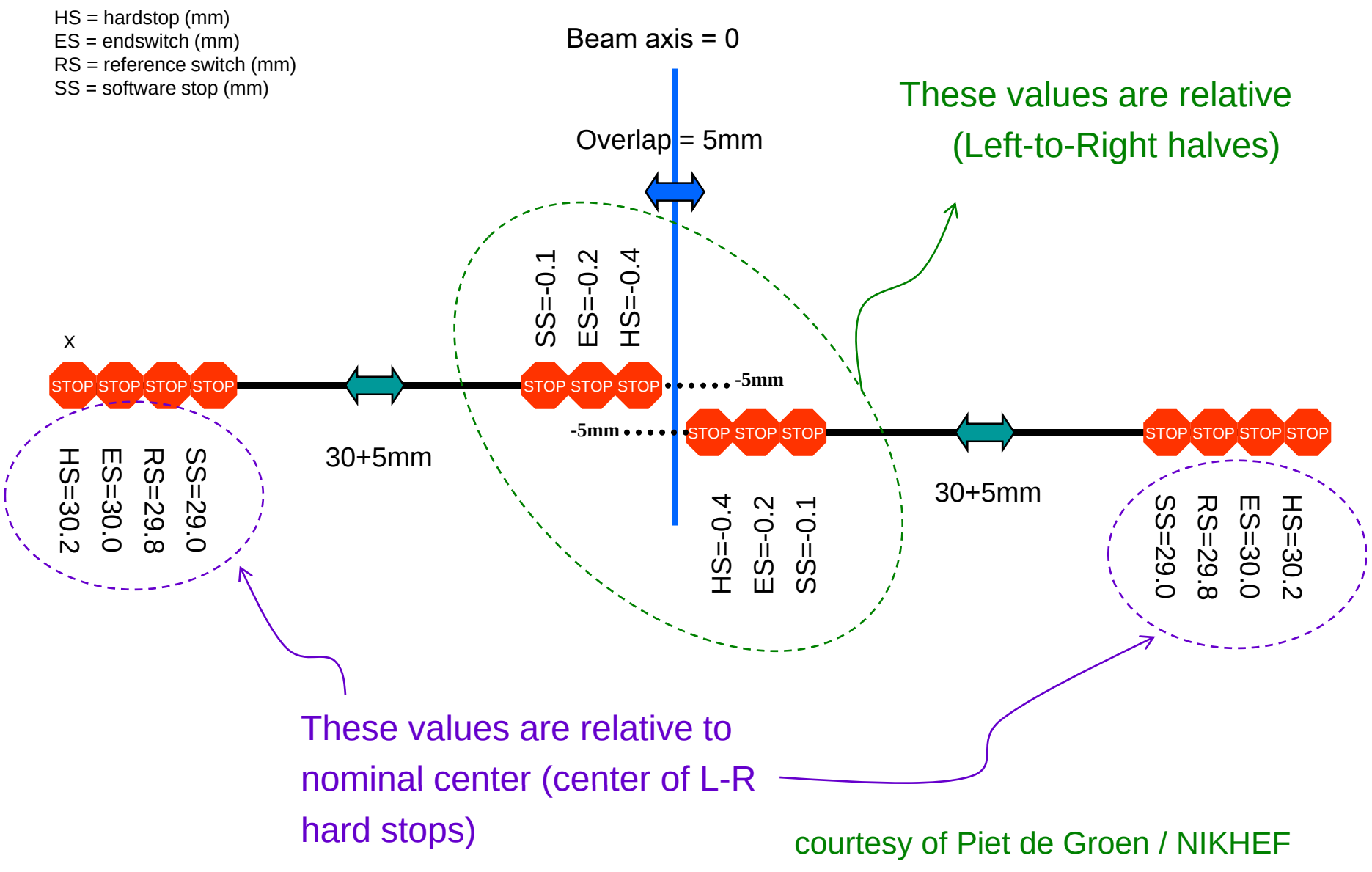
XY motion range limitation

- Because of bellow compression, Y and X motion ranges are coupled: Y must be within ΔY of nominal zero if X_L or X_R is to be moved more than ΔX away from nominal zero



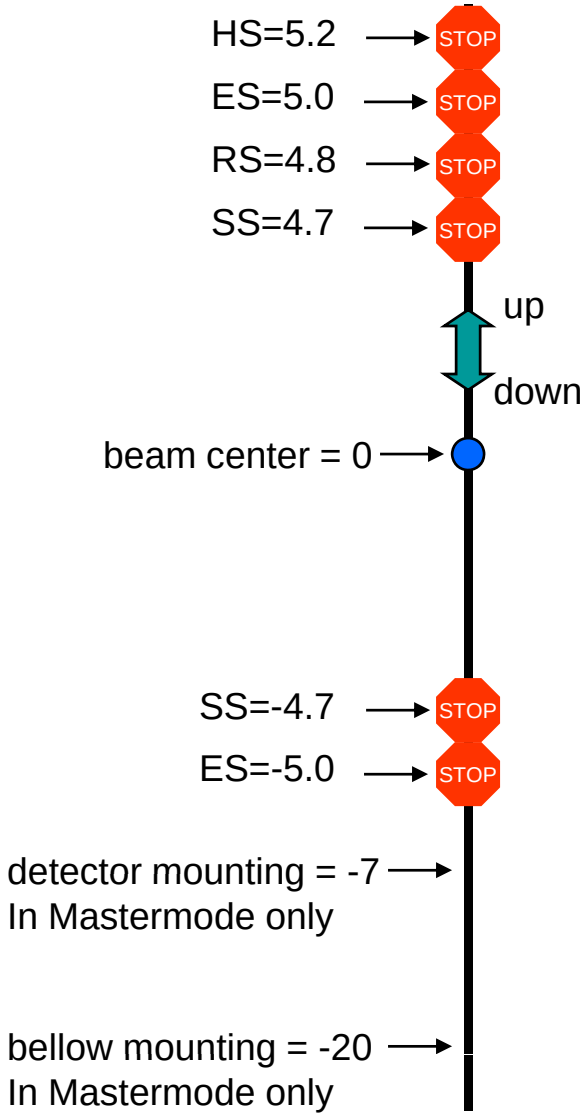


Sketch of X motion ranges



Sketch of Y motion range

HS = hardstop (mm)
ES = endswitch (mm)
RS = reference switch (mm)
SS = software stop (mm)



Control Hardware

- Siemens PLC
  - Safe control of motion
  - Interlocks with LHC state
    - LHC state from Safe LHC Parameters, combined with VELO state
    - if { (VELO ≠ OUT) and (LHC state ≠ [stable OR unstable]) }
      then LHCb User_permit = false
      (dump and prevent injection!).
- Power back up: UPS
  - go to "Garage" by UPS
- Local touch panel display (experts)
- PVSS interface for user control

VELO Positioning: measurements and precision

Used for independent measurement in case resolver would loose count

Measurements:

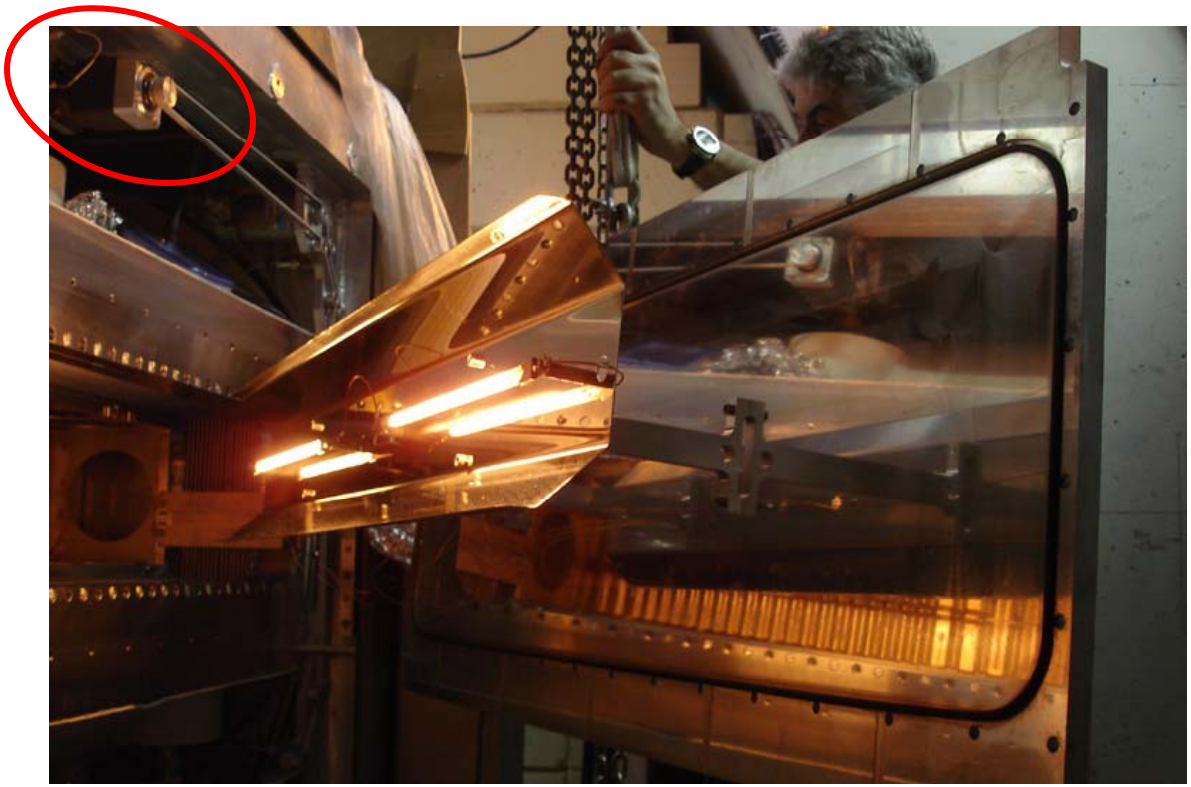
- 3 resolvers, 1 per step motor
- 9 potentiometers (3 per motion, each 0.1 mm accuracy)

Precision:

- Detector halves positioning must be correct to about 100 um and 0.1 mrad
- Angles and Z offset can only be corrected by intervention, while X-Y can be adjusted remotely
- Hysteresis (due to slack):
  - Measured without load: about 3 um
    1. goto X_1
    2. then to $X_2 > X_1$
    3. then to $X_3 < X_1 - \Delta X$
    4. then back to X_1 (giving actually X_1') => difference $|X_1 - X_1'| < 3$ um
  - yet to be measured precisely once loaded with full detector halves (spring load due to kapton readout cables and cooling bellow)

It's all at point 8

- Given the space constraints, it's practically impossible to make a nice overview photograph of the VELO motion system at point8. But, believe me, it is there ...



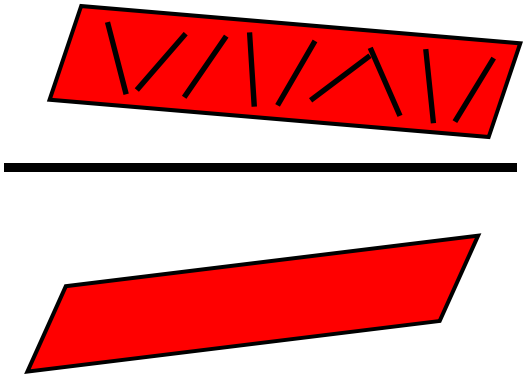
- If you want to know more or see the actual system, do not hesitate to contact me

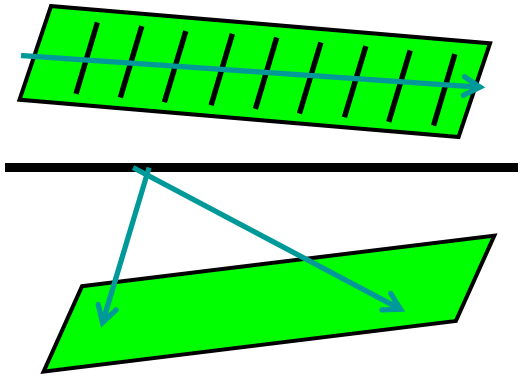
More Info

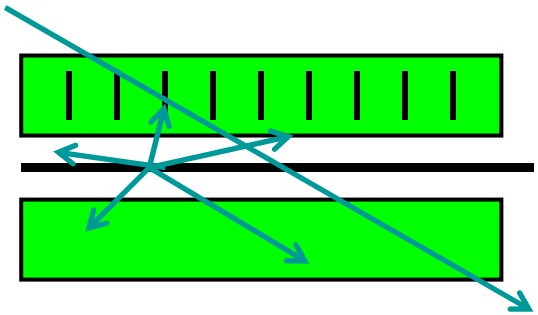
- Mechanical drawings in EDMS/CDD
  - Try keywords VELO, CENTER FRAME, MECHANICS, etc.
  - Or try this link
- Many 3D views at NIKHEF site:
  - http://www.nikhef.nl/pub/departments/mt/projects/lhcb-vertex/
  - http://www.nikhef.nl/pub/departments/mt/projects/lhcb-vertex/design/STAND/
  - http://www.nikhef.nl/pub/departments/mt/projects/lhcb-vertex/design/CENTERFRAME/
  - http://www.nikhef.nl/pub/departments/mt/projects/lhcb-vertex/design/TOTAL/

Now let's move to tracks...

Getting the VELO Alignment Parameters from Tracks







Step 0

Misaligned VELO

→

Step 1

Internally-aligned VELO

Millepede* applied on tracks (**classic, halo, beam gas**) in the two boxes

→

Step 2

Aligned VELO

Align the boxes using Millepede again on primary vertices, overlapping tracks,...

* See V. Blobel and C. Kleinwort, hep-ex/020821

Done

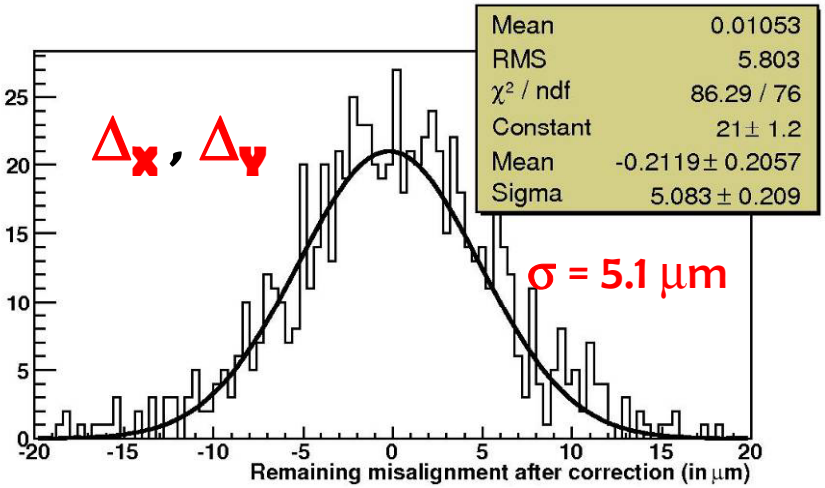
See a first VELO alignment note by **S. Viret**: CERN-LHCb-2005-101

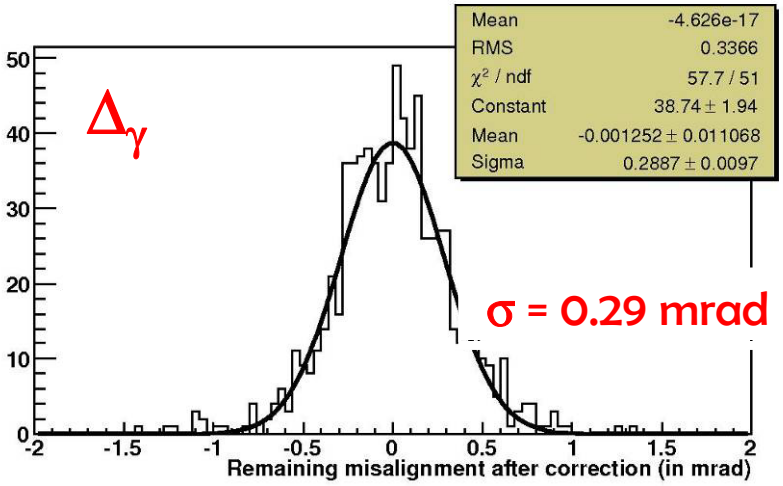
Almost done

What type of tracks for internal alignment?

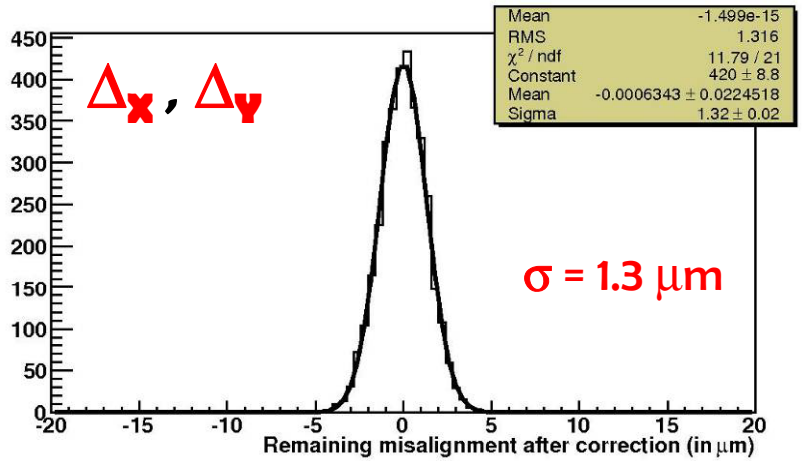
Simulation of a few thousand MinBias events and halo tracks

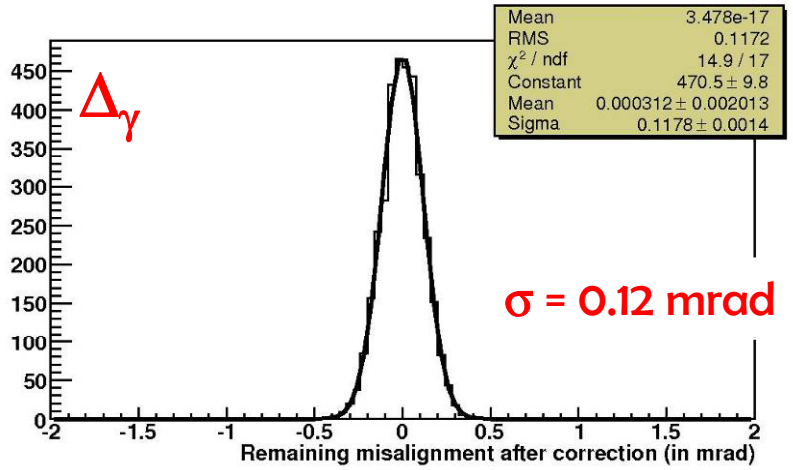
Sebastien Viret





STEP1 with min. bias only





STEP1 with min. bias + halo tracks

beam-gas tracks can help too (like halo tracks)

Vertexing

- Once the VELO alignment parameters are calculated, we can do precise tracking/vertexing

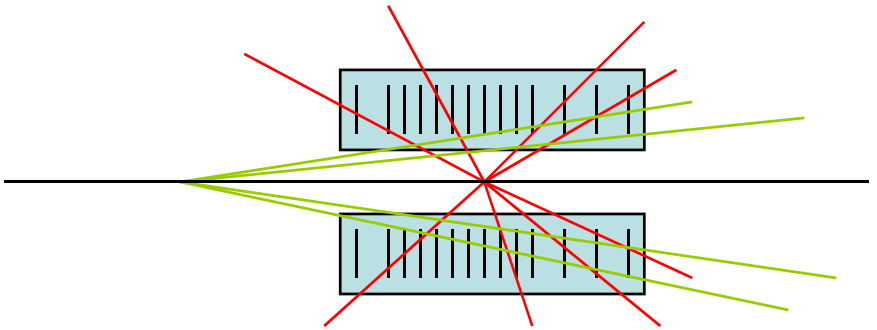
  $\Rightarrow$ reconstruct

  - luminous region, the "cigar", with pp interactions ($s^{1/2}$ = 14 TeV)
  - image the two beams with beam-gas interactions ($s^{1/2}$ = 114 GeV)

- Small complication (that's where the fun is):

  beams and VELO detectors halves may (will) move

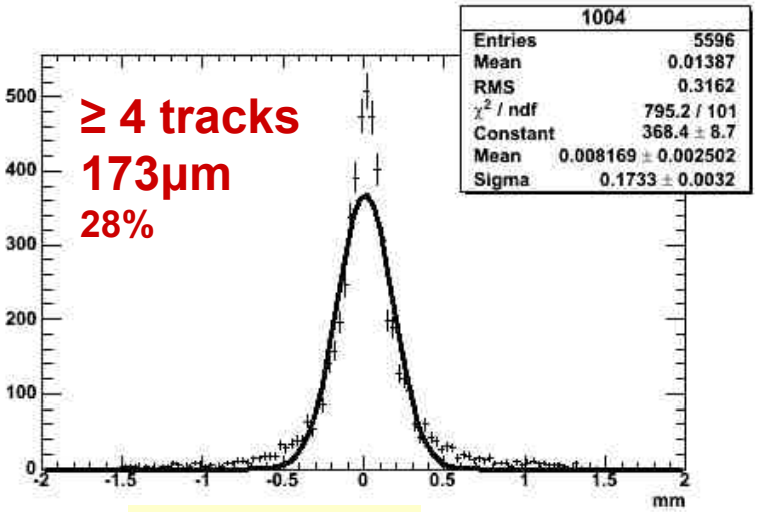
  - In-fill variations
  - Fill-to-fill variations

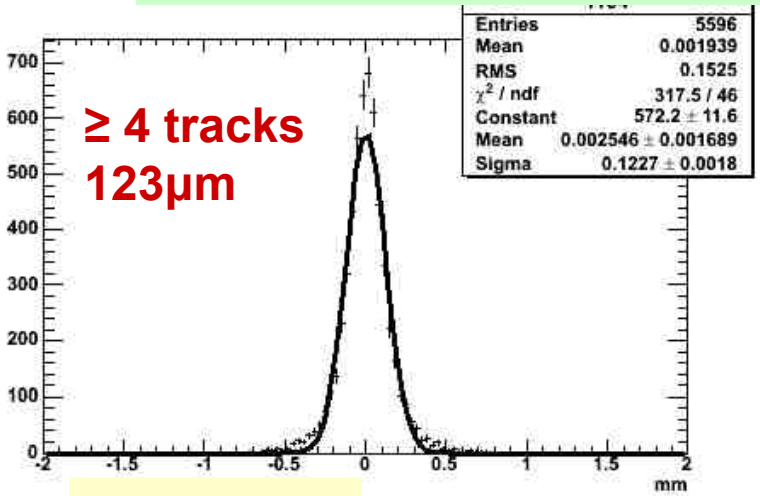


pp Vertex Resolution in X with Open VELO

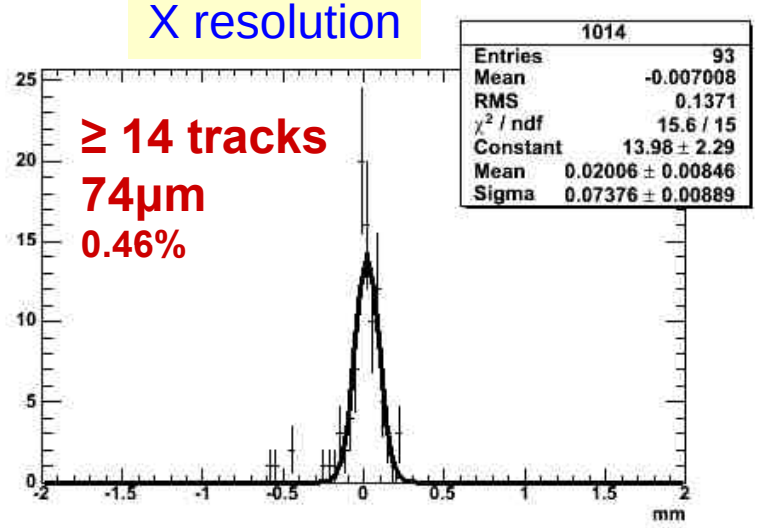
- Simulation with VELO halves 30 mm away (i.e. in "Garage")
- Minimum bias pp (7 TeV)

Tomas Lastovicka, Malcolm John

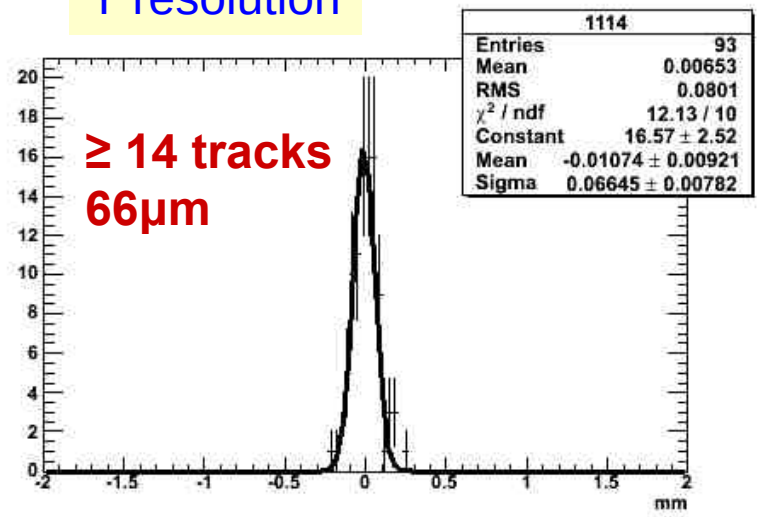




X resolution

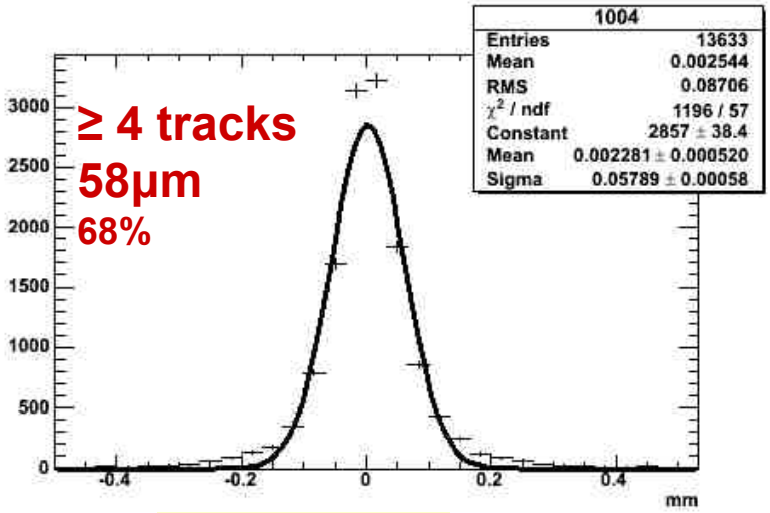


Y resolution

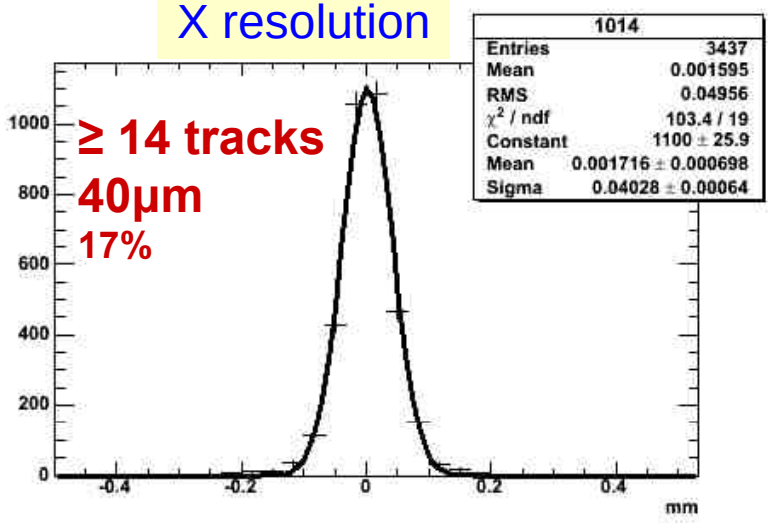


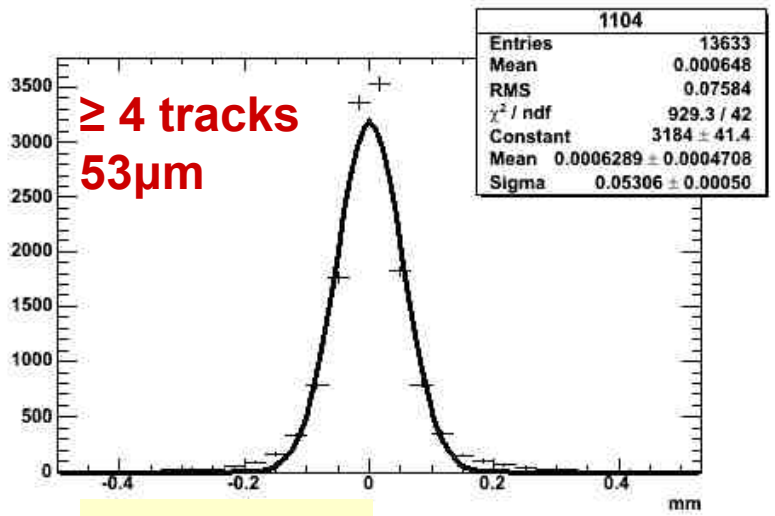
pp Vertex Resolution in X with Almost closed VELO

- As before but one half at 5mm from closed and other at 6mm

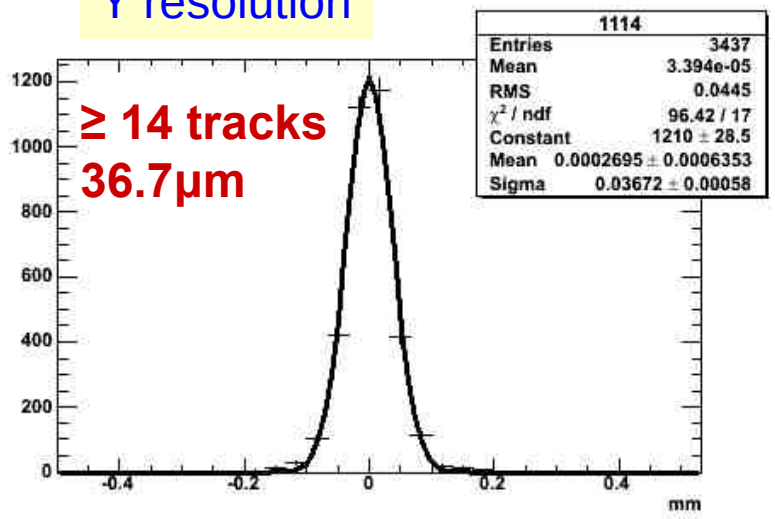


X resolution



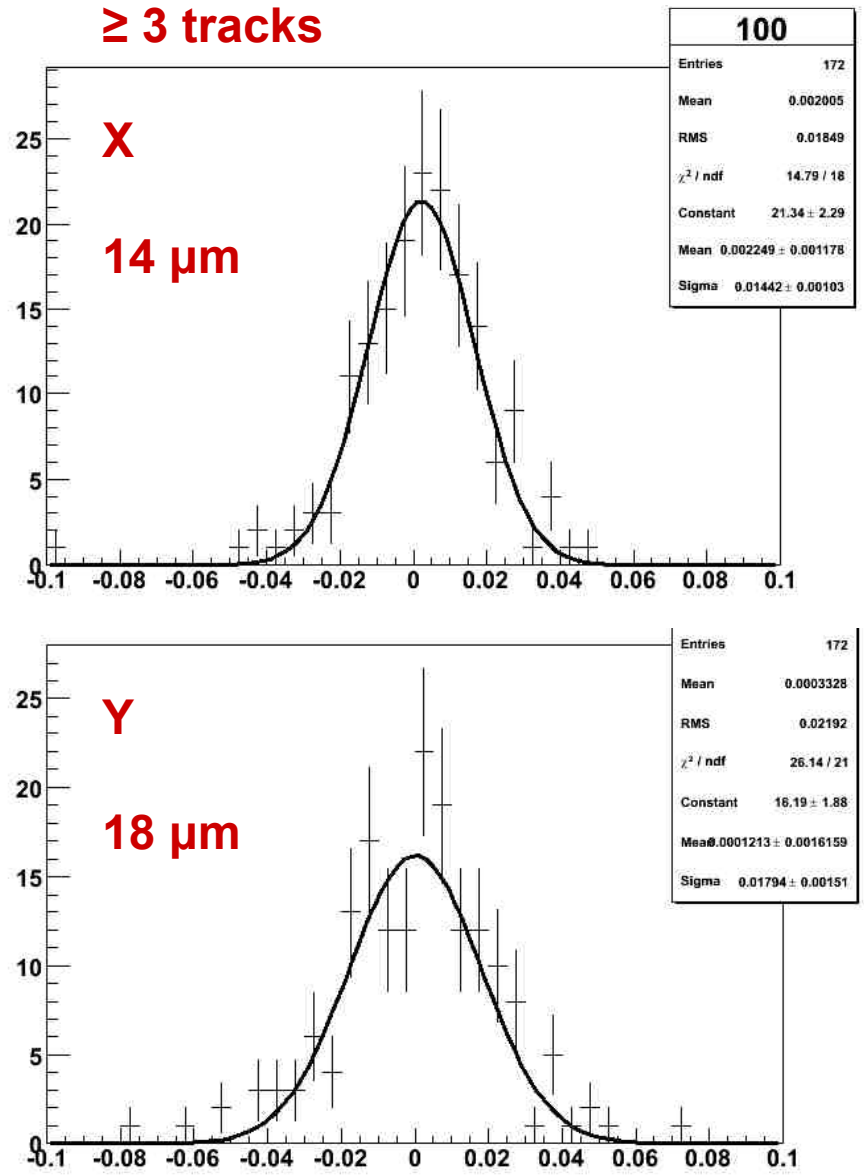


Y resolution



pp Vertex Resolution in X with closed VELO

- Fully closed VELO
- Remember:
  - no momentum info
  - starting from a minimum bias event sample

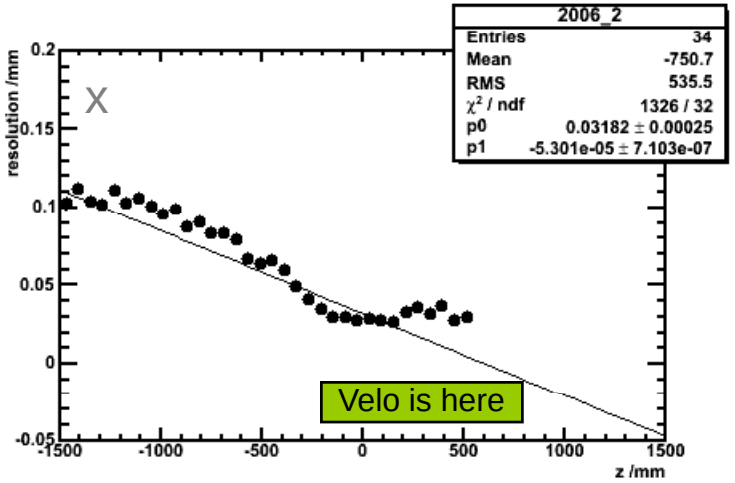


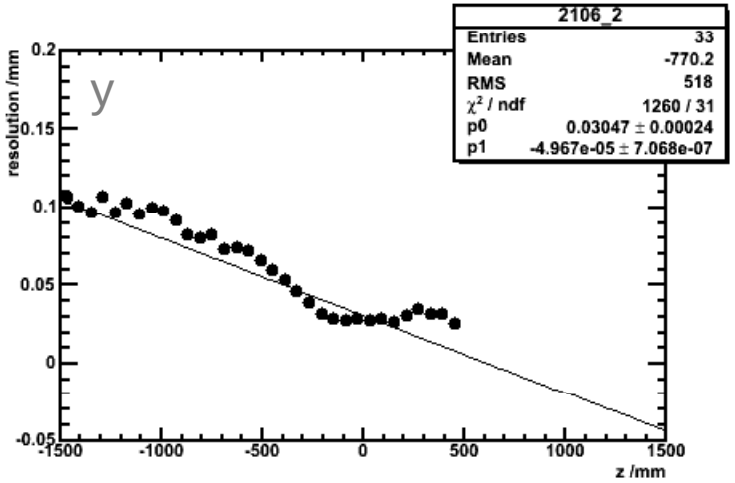
Beam-gas vertices in the VELO

Tomas Lastovicka, see e.g. here

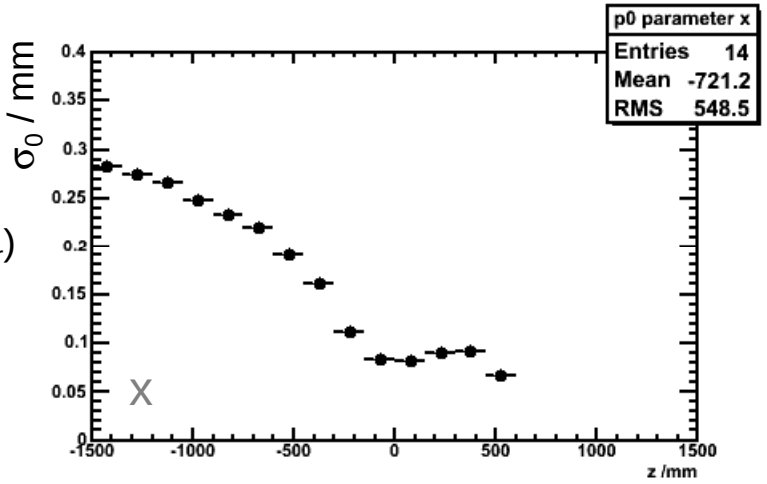
- Simulation of beam$_1$ - hydrogen interactions (7 TeV)

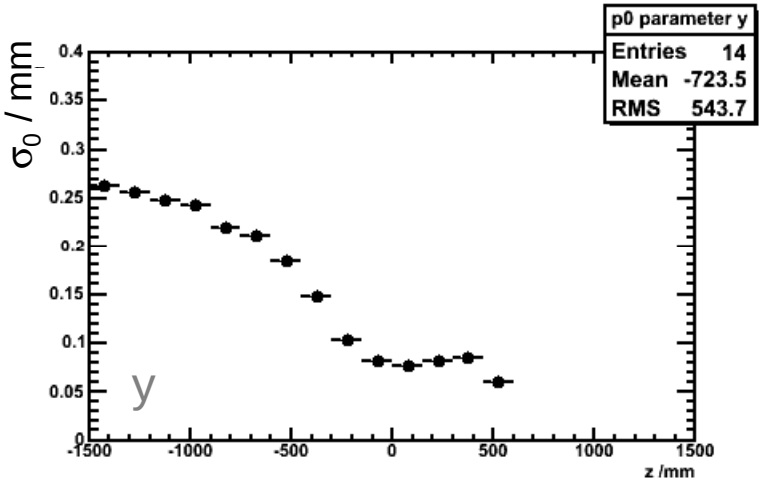
$N_{tr} > 5$





resol= $\sigma_0/\sqrt{N_{tr}}$





How we will operate (work in progress)

- Get beam and beeam overlap parameters from tracks
  - cigar parameters from pp: 3 coordinates of center, 3 spreads, 2 angles
  - beam parameters from p-gas, per beam: beam position and angles, 2 transverse spreads (as function of Z => hourglass, waist shape)
- Compare with resolver values
- Compare with LHC values (from BPM)

Some rate considerations (7 TeV)

beam-beam (pp)

- σ_{pp} = 65 mb "visible"
- Assume: N = 5 10^{10} protons/bunch, k_b = 2808 and β^* = 6 m

  $\Rightarrow$ L_{pp} = 2.1 10^{32} cm^{-2} s^{-1}

  R_{pp} = 13.6 MHz
- Moderate rate reduction when open (depending on cut on N_{tracks} per vtx)

beam-gas

- σ_{pH} = 40 mb "visible"
- Assume 10^{-9} mbar(H_2) over 40 cm => 10^9 p/cm^2

  $\Rightarrow$ L_{pH} = 1.6 10^{27} cm^{-2} s^{-1}

  R_{pH} = 63 Hz
- Stronger rate reduction when open

Summary

- LHCb VErtex LOcator is a complex movable device
- Will rely on own track and vertex reconstruction to align itself and center around the beams
- Will use all possible tracks (pp, halo, beam-gas) to achieve this