Martin van Beuzekom, Clara Gaspar, Karol Hennessy, Eddy Jans, Malcolm John, Richard Jacobsson, Chris Parkes
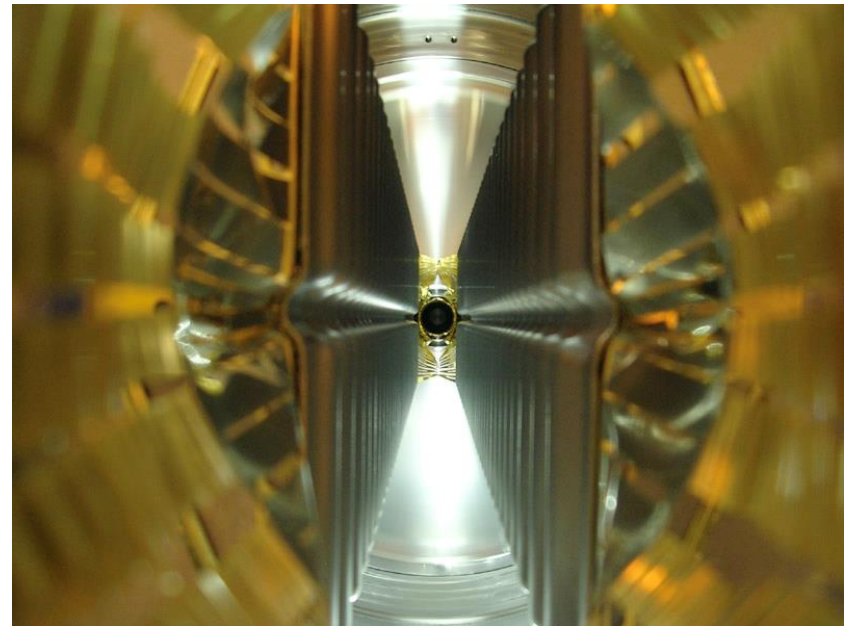
LHCb VELO Motion Control

- Intro motion system
- Low level control
- PVSS controls
- Reviewers comments

Beam's eye view of the open VELO

Machine Protection Panel Meeting, 11th March 2011

Review Context

- 2009/2010: VELO group maintained 24hr shift coverage during period of physics beam.
- 2011: move to automated closing overseen by the central LHCb shift crew.
- Aim: to consider readiness of motion control

- Review held 16th November 2010
- Reviewers: Rolf Lindner (LHCb Technical co-ordinator), Stefano Redaelli (machine protection group)
- Recommendations were received and implemented during the shutdown

LHCb VELO: movable Vertex detector
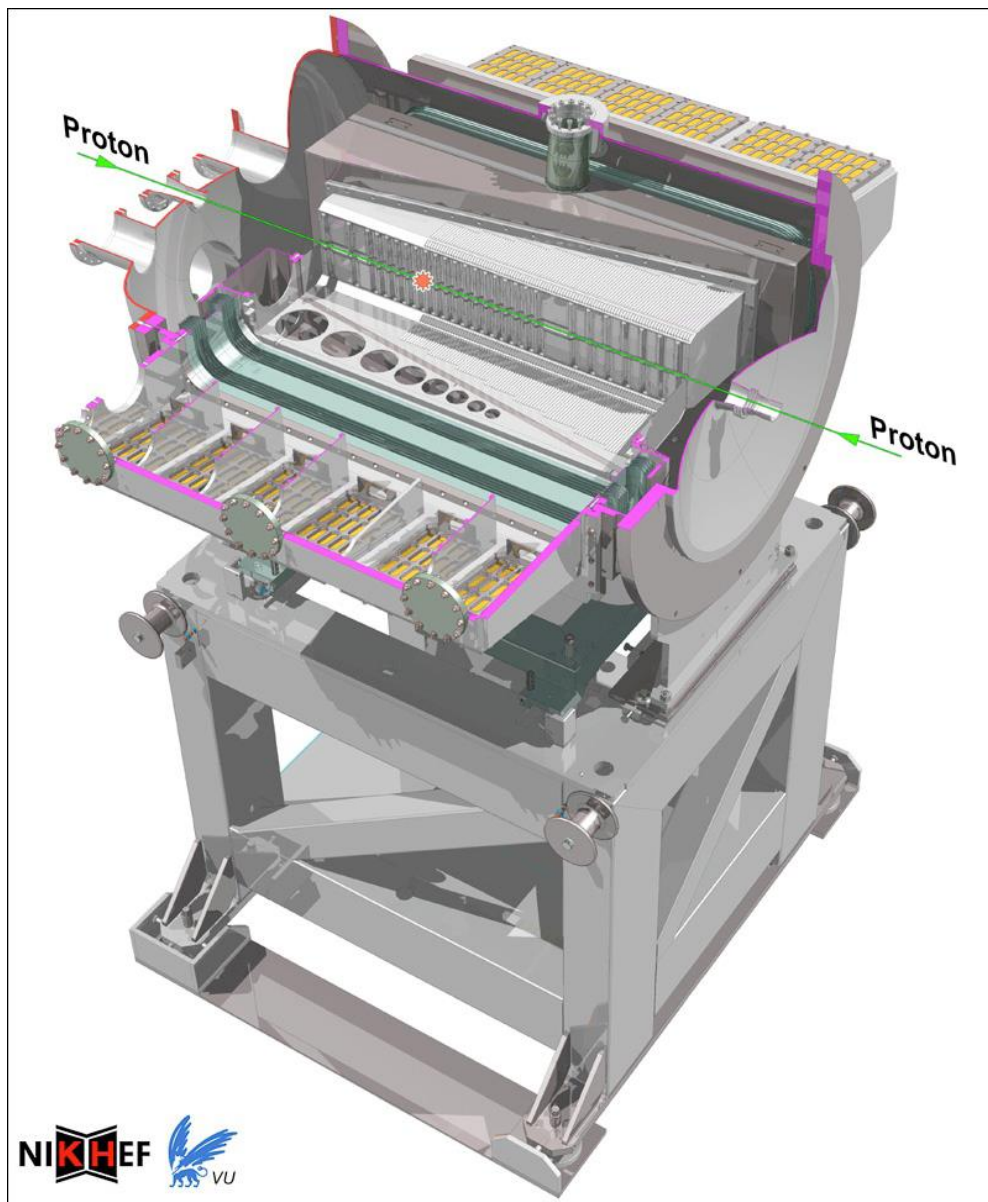
- Vacuum tank with 2 movable detector halves
  - A & C
- Independent movement in horizontal plane (X)
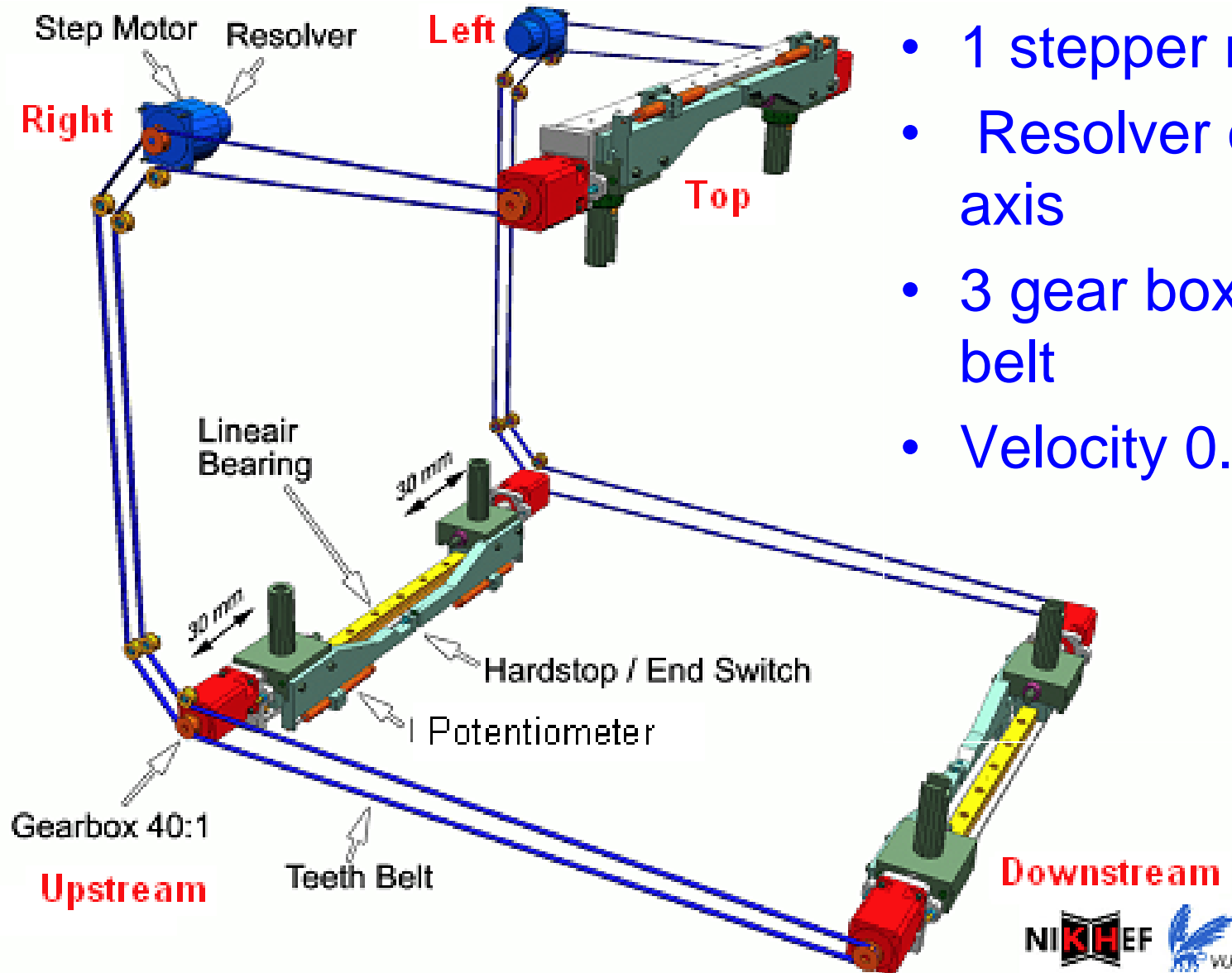- Common movement in vertical plane (Y)

VELO Position

- Detector retracted during beam injection.
  - 29mm aperture

- Close detector halves after stable beam.
  - Rf foil 5.5 mm from beam

- Centre on beam
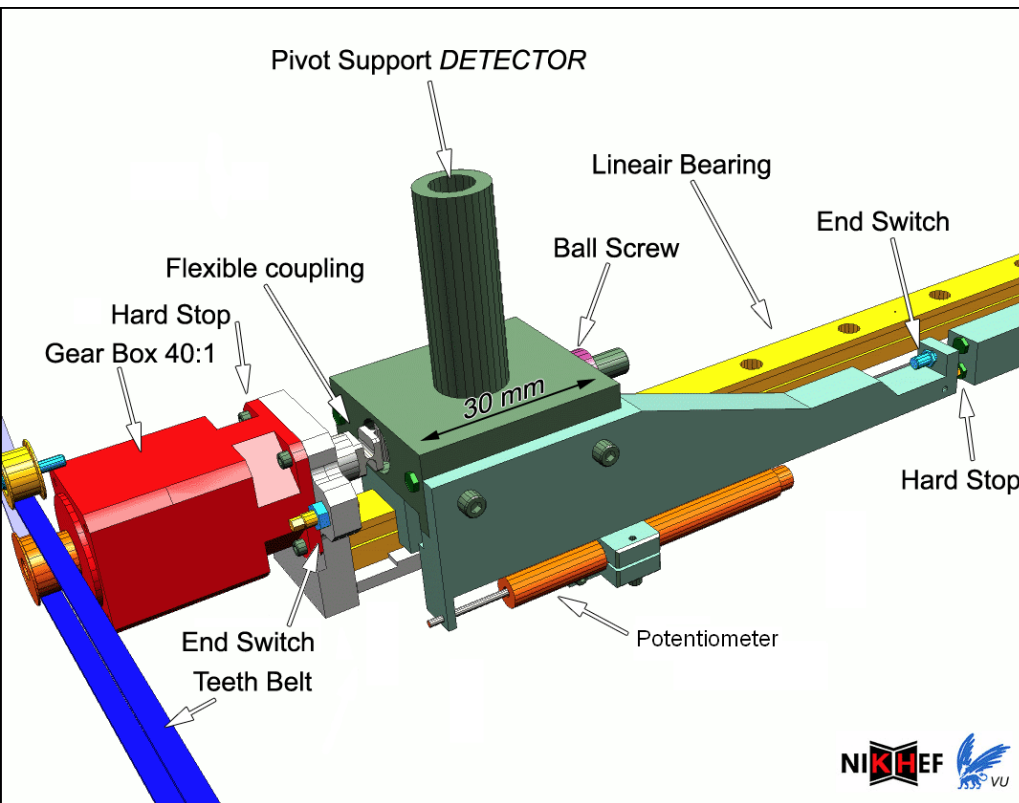 - Beam position determined per fill with detector
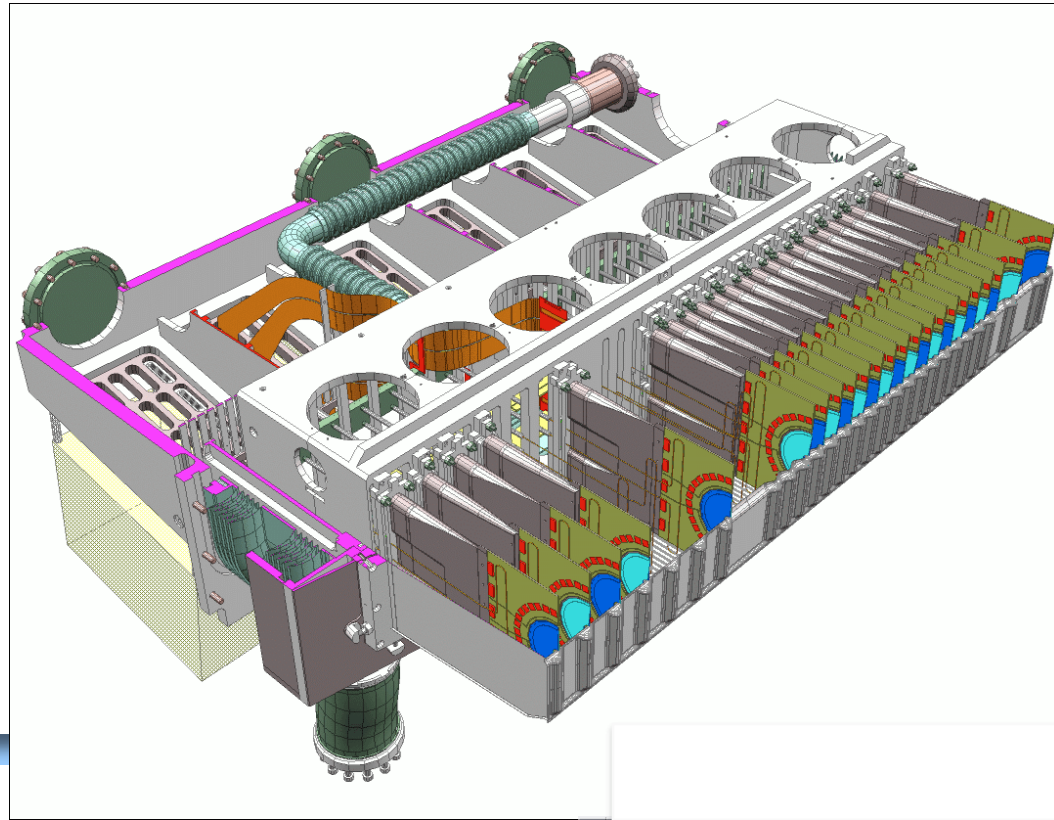
Motion System Hardware & Low Level Control (PLC)

Horizontal Movement Hardware

- 1 stepper motor / side
- Resolver on motor axis
- 3 gear boxes on teeth belt
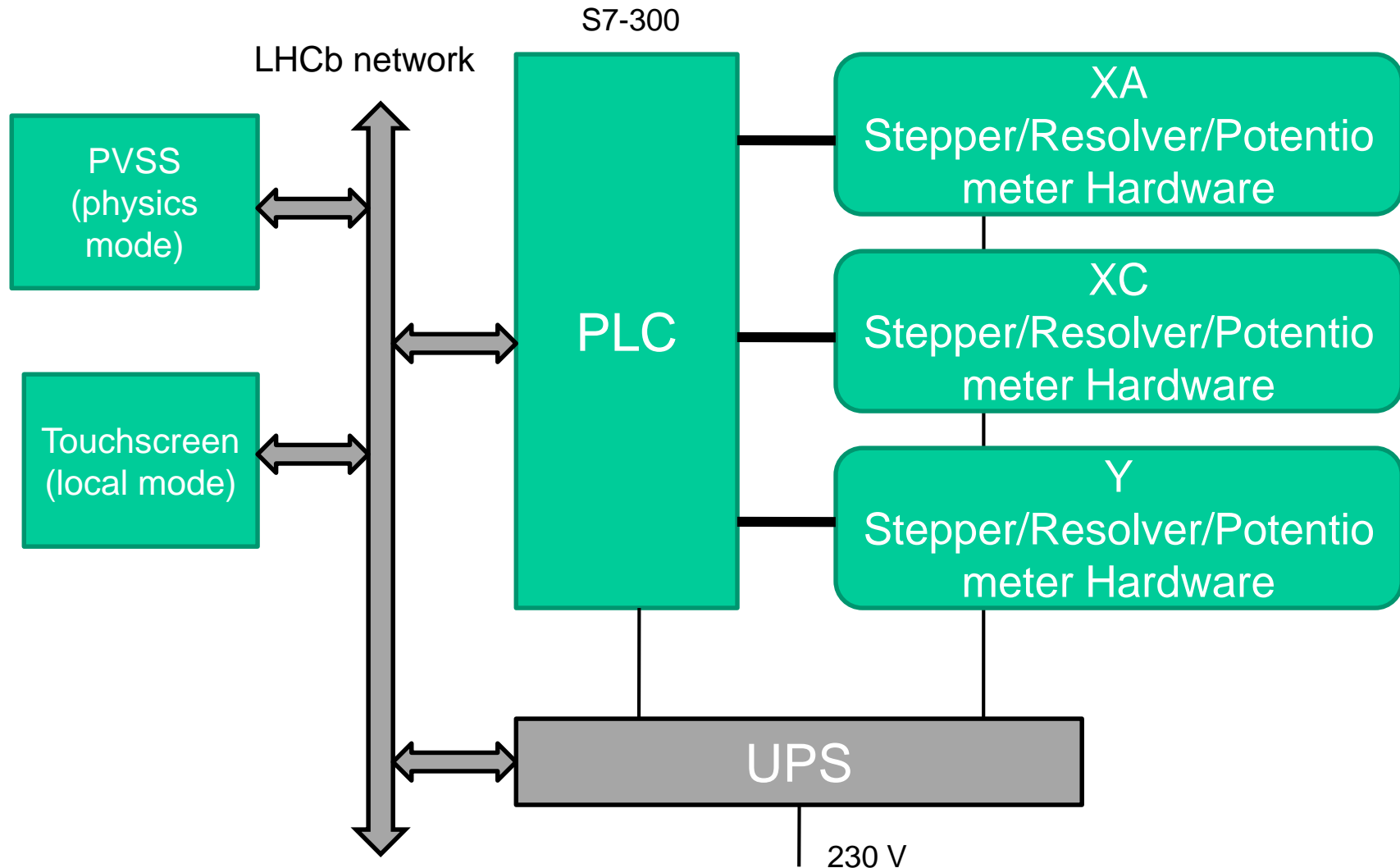- Velocity 0.2 mm/sec

Horizontal Movement Detail

- Switches at 'in' and 'out' position

- 'in' switch is for relative position of two sides

- One out switch used for referencing system
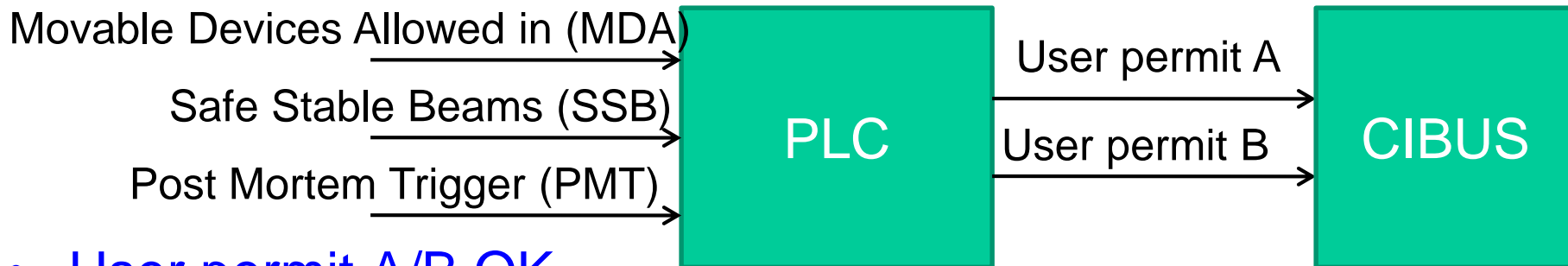 - Switch accuracy 2μm

Electronics overview

•Stepper, Resolver, Potentiometer agreement required

General flow of move procedure

- – Check system referenced and idle
- – Check system on mains (not on UPS)
- – Check no relevant alarms / interlocks
- – If OK, then set 'lock' (system -> not idle)
- – Read stepper, resolver

- Check stepper == resolver == average potentiometer
  - – Limits: resolver 50 um, potentiometer 1 mm

- Check requested destination versus limits

- If OK, send move command to stepper-CPU
  - – Start timer
  - – Wait for command to finish, or time-out
  - – Read stepper, resolver, potentiometers: check consistency
  - – If OK, 'unlock', end of move procedure

Interlocks to LHC

Movable Devices Allowed in (MDA)

Safe Stable Beams (SSB)

Post Mortem Trigger (PMT)

PLC

User permit A

User permit B

CIBUS

- **User permit A/B OK**
 - If VELO retracted
    - OR
  - If MDA==true
- **MDA==false does not prevent PLC to move in (PVSS does)**
  - But if MDA==false, moving in the VELO removes beam permit
- **Post Mortem Trigger: freezes internal logger**

- **Other hardware Interlocks, these retract VELO**
  - Beam Conditions Monitor,   - Emergency Retraction Button, Power Cut on UPS

Beam Monitoring and PVSS Control

Principal Safety Requirements

- The VELO safety is primarily provided by the LHC safety systems
- The VELO motion system is not intended to react dynamically to beam problems

- Nevertheless, define a parameter set that represents the environment which the VELO experiences and place requirements on them:

1. Require STABLE BEAMS and no persistent alarms from the VELO
2. The LHCb beam conditions monitor (BCM) far below dump-beams threshold
3. The current in the [biased] VELO silicon should be low
4. A measurement of the luminous region (where the beams collide) should be:
within the aperture of the machine, consistent with cross-checks, and stable
5. The LHC beam position monitors (BPM) should be consistent with the LHCb vertex measurement and be stable in time
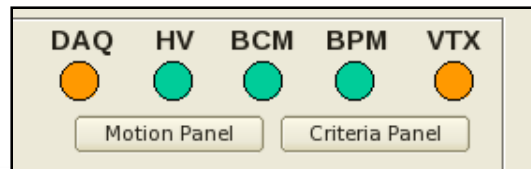
6. Review recommendation:
check beam position compared to position at previous closing

VELO Closure Criteria Panel

Reference Values

BPM: last update on 08-Nov-2010 at 11:20:20

BPV: waiting for Velo fully closed...

Plots and Trends

SELECTION ⬍

#	Quantity	ActualValue	Criterion	Status
1	BCM: S0.RS02	0.046 %	< 2.0 %	OK
2	BCM: S0.RS32	0.018 %	< 2.0 %	OK
3	BCM: S1.RS02	0.141 %	< 2.0 %	OK
4	BCM: S1.RS32	0.047 %	< 2.0 %	OK
5	BPM: D(B1L8H)	0.004 mm	< 0.2 mm	OK
6	BPM: D(B1L8V)	0.020 mm	< 0.2 mm	OK
7	BPM: D(B2L8H)	0.047 mm	< 0.2 mm	OK
8	BPM: D(B2L8V)	0.002 mm	< 0.2 mm	OK
9	BPM: D(B1R8H)	0.003 mm	< 0.2 mm	OK
10	BPM: D(B1R8V)	0.010 mm	< 0.2 mm	OK
11	BPM: D(B2R8H)	0.031 mm	< 0.2 mm	OK
12	BPM: D(B2R8V)	0.022 mm	< 0.2 mm	OK
13	BPM: |B1 Xav|	0.153 mm	< 4.0 mm	OK
14	BPM: |B1 Yav|	0.154 mm	< 4.0 mm	OK
15	BPM: |B2 Xav|	0.233 mm	< 4.0 mm	OK
16	BPM: |B2 Yav|	3.042 mm	< 4.0 mm	OK
17	BPM: |B1 Xdr|	0.001 mm/s	< 0.1 mm/s	OK
18	BPM: |B1 Ydr|	0.000 mm/s	< 0.1 mm/s	OK
19	BPM: |B2 Xdr|	0.000 mm/s	< 0.1 mm/s	OK
20	BPM: |B2 Ydr|	0.000 mm/s	< 0.1 mm/s	OK
21	VTX: |XVA + XVC|	0.000 mm	< 0.2 mm	OK
22	VTX: |XA+XVA-XC-XVC| - 310um	0.310 mm	< 0.2 mm	NOT OK
23	VTX: SXVA	0.100 mm	< 0.6 mm	OK
24	VTX: SYVA	0.100 mm	< 0.6 mm	OK
25	VTX: SXVC	0.100 mm	< 0.6 mm	OK
26	VTX: SYVC	0.100 mm	< 0.6 mm	OK
27	VTX: D(XVA)	999.000 mm	< 9999.0 mm	OK
28	VTX: D(YVA)	999.000 mm	< 9999.0 mm	OK
29	VTX: D(XVC)	999.000 mm	< 9999.0 mm	OK
30	VTX: D(YVC)	999.000 mm	< 9999.0 mm	OK
31	HV: bias current (A-side)	0.000 uA	< 1150.0 uA	OK
32	HV: bias current (C-side)	0.000 uA	< 1620.0 uA	OK

BCM (%)

S0.RS2	S0.RS32	S1.RS2	S1.RS32
0.046	0.018	0.141	0.047

BPM (mm)

B1L8(hor)	B1L8(ver)	B2L8(hor)	B2L8(ver)
2.268	-0.831	-1.288	1.784

B1R8(hor)	B1R8(ver)	B2R8(hor)	B2R8(ver)
-2.574	0.524	1.753	4.299

B1 Xav	B1 Yav	B2 Xav	B2 Yav
-0.153	-0.154	0.233	3.042

B1 Xdr	B1 Ydr	B2 Xdr	B2 Ydr
0.001	0.000	-0.000	0.000

Velo Resolvers (mm)

XA	XC	YAC
29.000	-29.000	0.001

VeloHalves distance (mm)

Δ X	Δ Y
0.000	0.000

ver. 4.0

Beam Position A-side (mm)

XVA	YVA	ZVA
-1000.000	-1000.000	-1000.000

SXA	SYA	SZA
-1000.000	-1000.000	-1000.000

time elapsed

******

Beam Position C-side (mm)

XVC	YVC	ZVC
-1000.000	-1000.000	-1000.000

| SXC	SYC	SZC
-1000.000	-1000.000	-1000.000

Red =failure, Green = OK, Blue = Not checked

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Collision Vertices

- Beam position from real time reconstruction of collision vertices with detector

  – Tracks and vertices reconstructed and displayed in LHCb online monitoring system

  – Gaussian fits performed and positions transmitted as PVSS data points

- This determines the position to which the VELO closes, and checks for any drifts during fill

- New vertex position obtained approx. every 5s

- If the data taking is interrupted rely on BPMs

  – Up to 15minutes, then open

Screenshot of Online Vertex Monitor

- The Gaussian fit is superimposed (until next 400 vertices arrive) to permit visual check of the fit
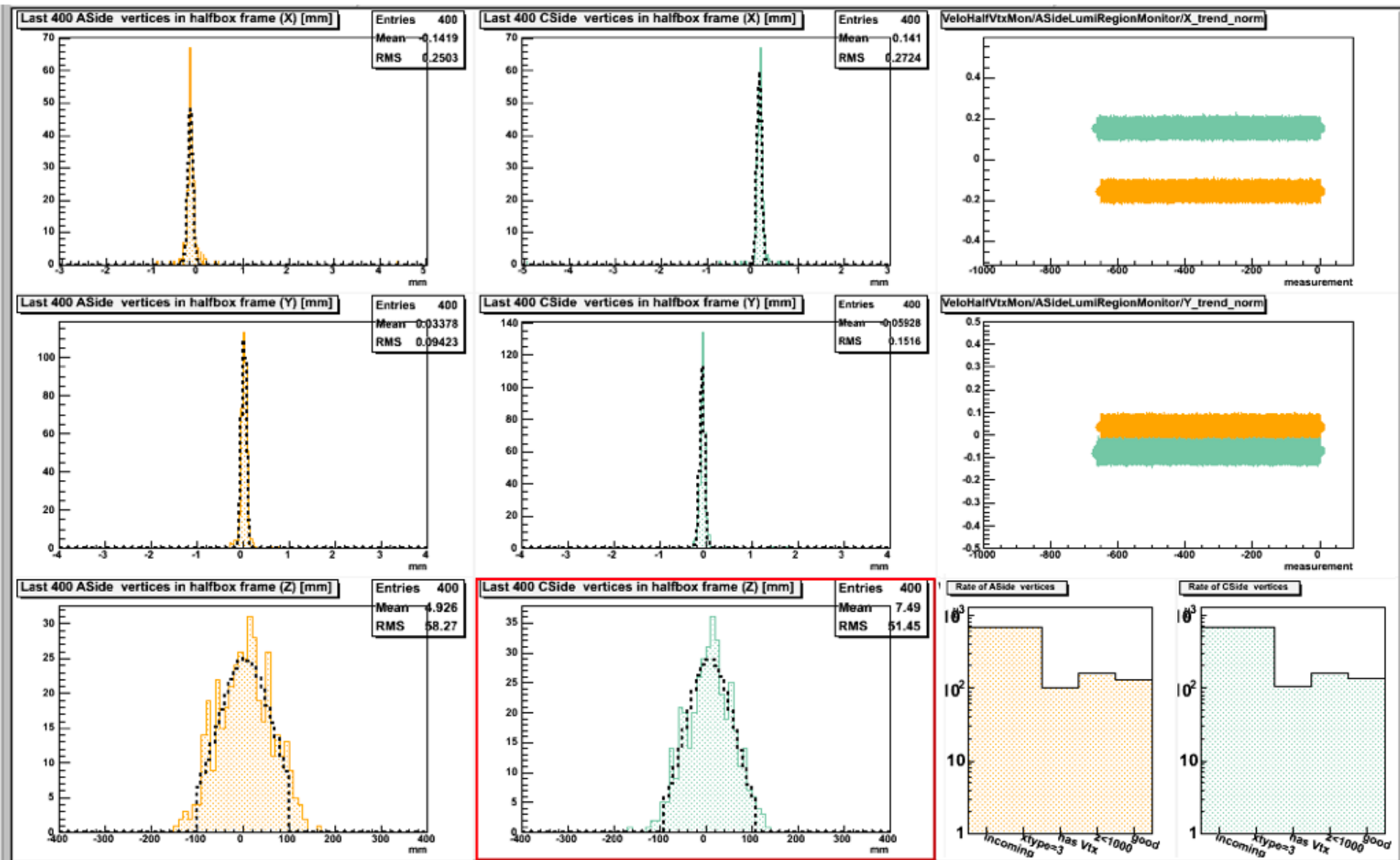
VELO Closing Manager

- Closing proceeds in several stages
    - Redetermine vertex position at each stage
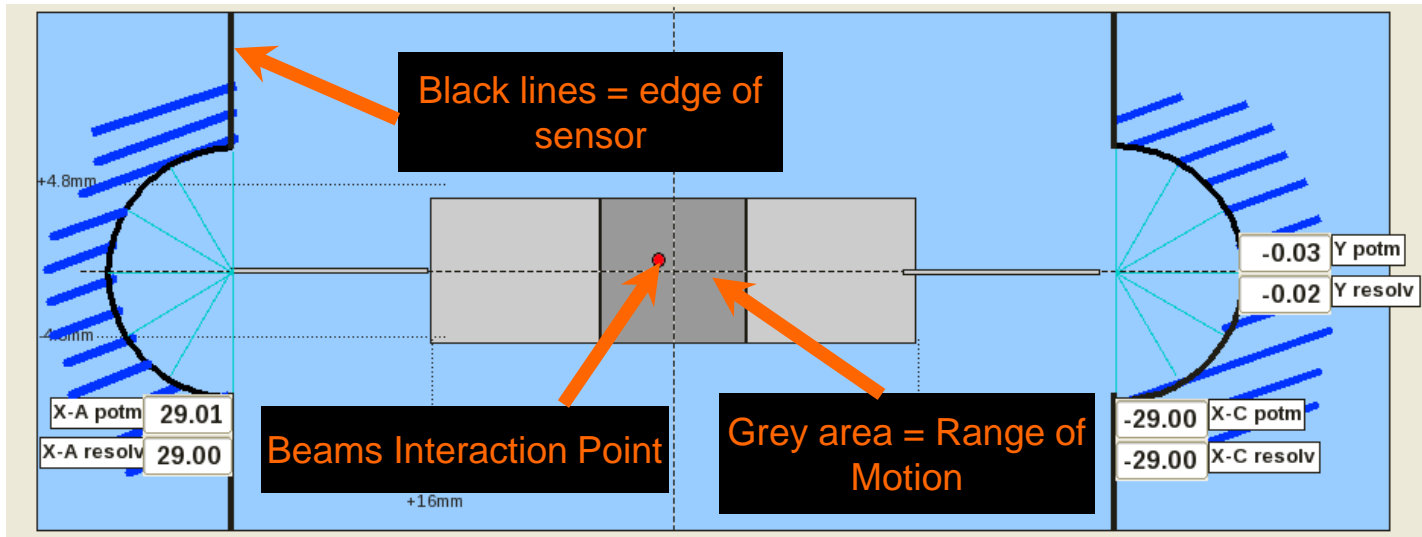- Requires user confirmation to start (29mm), and at 5mm from vertex

Open/Close

Criteria Checks

Log Messages

Position of Motion system in absolute frame

VELO Motion Graphic

⦿ A Motion graphic panel with a visual representation of the VELO halves and the beam position


- Red dot shows beam spot position as calculated using VELO monitoring

- Grey area shows range of motion. Left VELO half can move as far as right hand side of dark grey box and vice-versa. [comment: needs updating for new limits]

Main Review Recommendations & Summary

2010 Experience

- Efficient data taking in LHCb
- Highest precision vertex detector at LHC
  - Proximity to beam critical to LHCb physics potential
  - Best point 4μm resolution
- PVSS motion control evolved over 2010
  - No major issues with motion control operation
- Closing takes approximately 5 minutes

FULLY ON: 89.6 (%)
HV: 0.8 (%)
VeLo Safety: 2.3 (%)
DAQ: 5.2 (%)
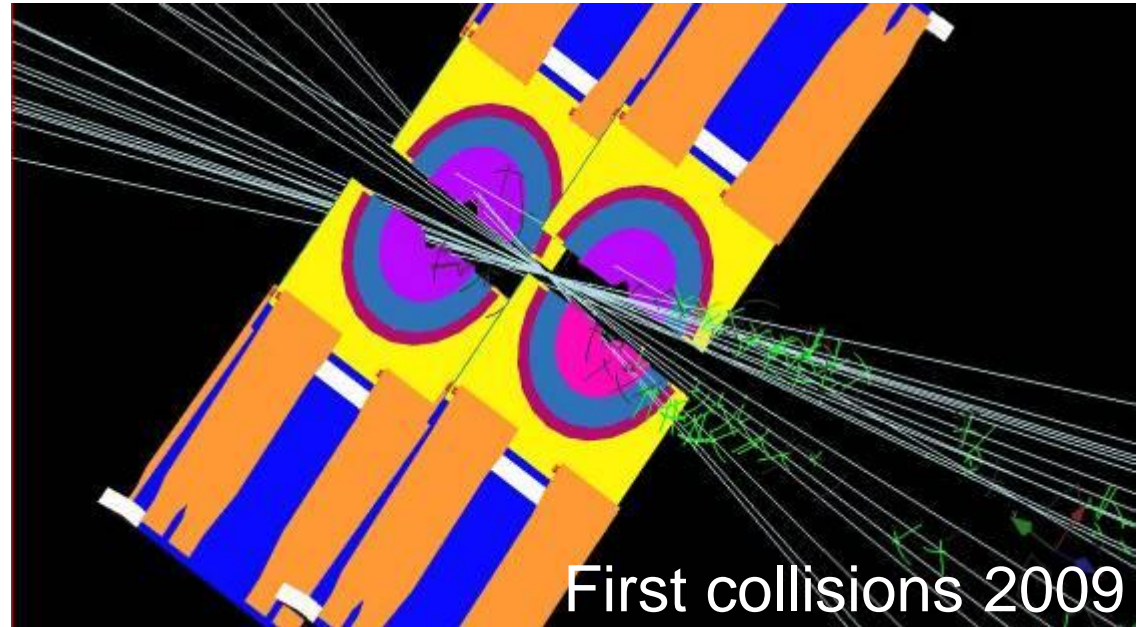Deadtime: 2.0 (%)
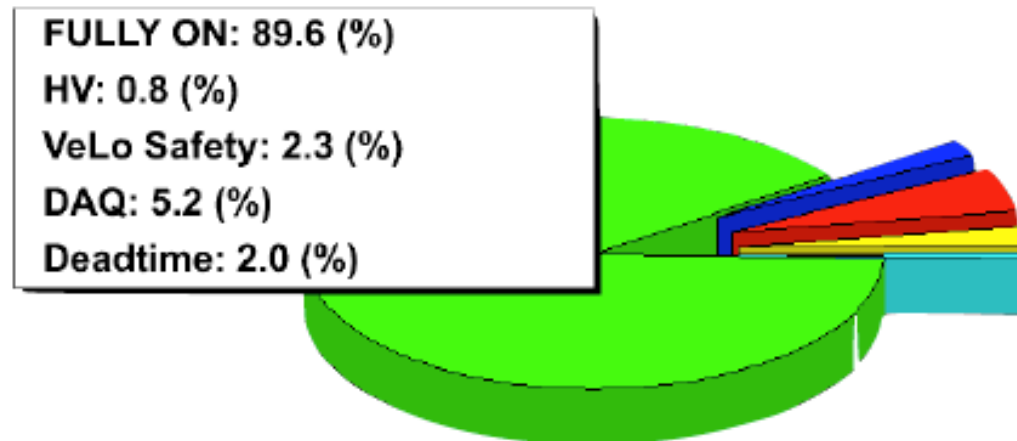
Main Review Recommendations -1

- Document available in EDMS 1111979
  - Full replies made to referees this week
- Main recommendation: change of horizontal position limits when moving 'across' zero.
  - Implemented and tested in PLC during shutdown
- If position beyond limits obtained motor should be stopped, consider beam dump
  - Implemented and tested in PLC.
  - Motor is stopped, and also power cut.
- Check determined vertex position with previous value
  - Implemented in PVSS during closing

Main Review Recommendations -2

- Suggest slow speed of vertical motion
  - Will consider, but not possible in this shutdown.
- Training/closing support for LHCb Shift Leaders
  - Training performed
  - VELO piquets will support closings of the VELO for start of 2011
- Velo expert present during van der Meer scans
  - Agree.
- Provide write-up of effect of hardware failures on LHC operations
  - Done.
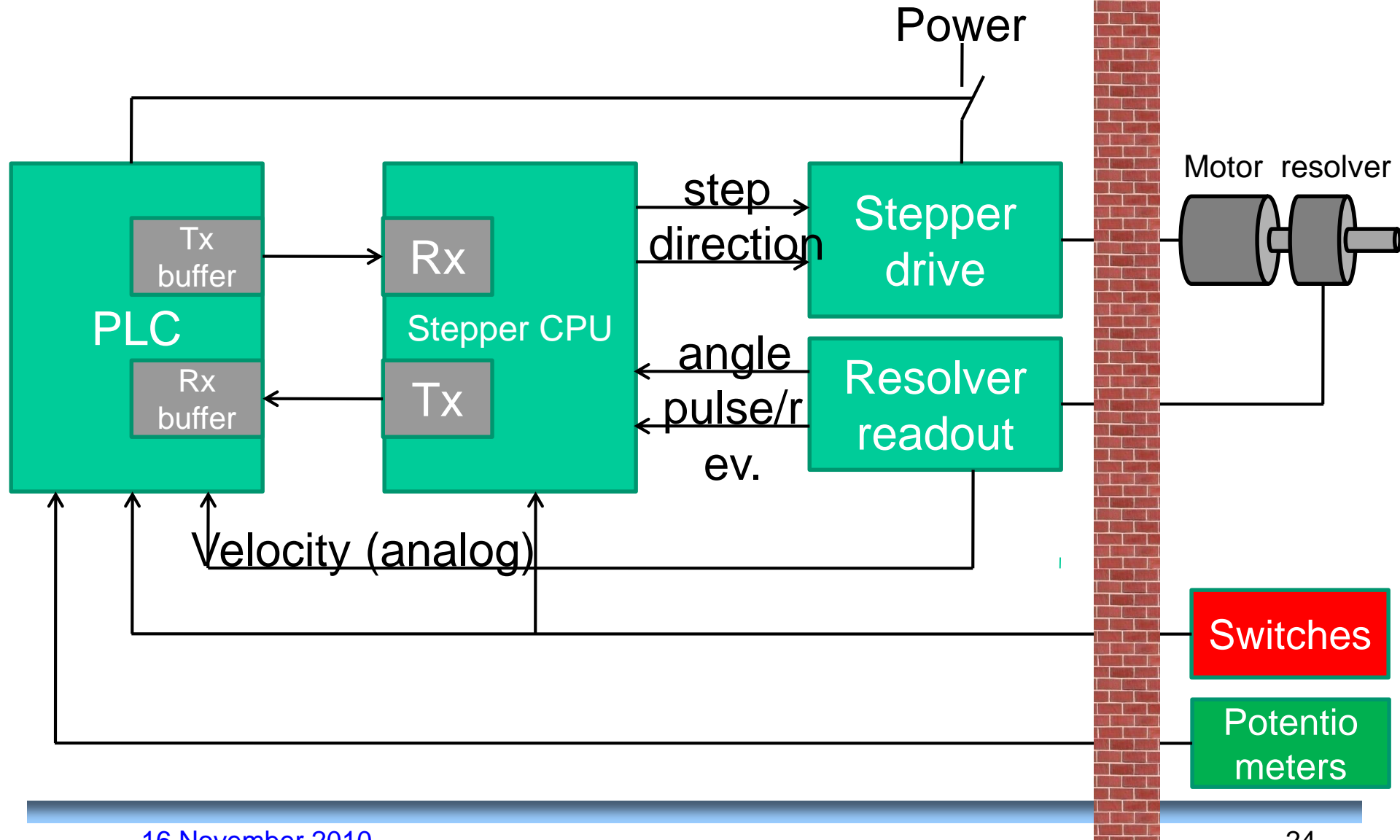- Present review summary at this meeting

Summary

- First successful year of VELO motion operation

- Review proposed a number of changes, the main ones have been implemented during the shutdown

- Many Thanks again to the referees

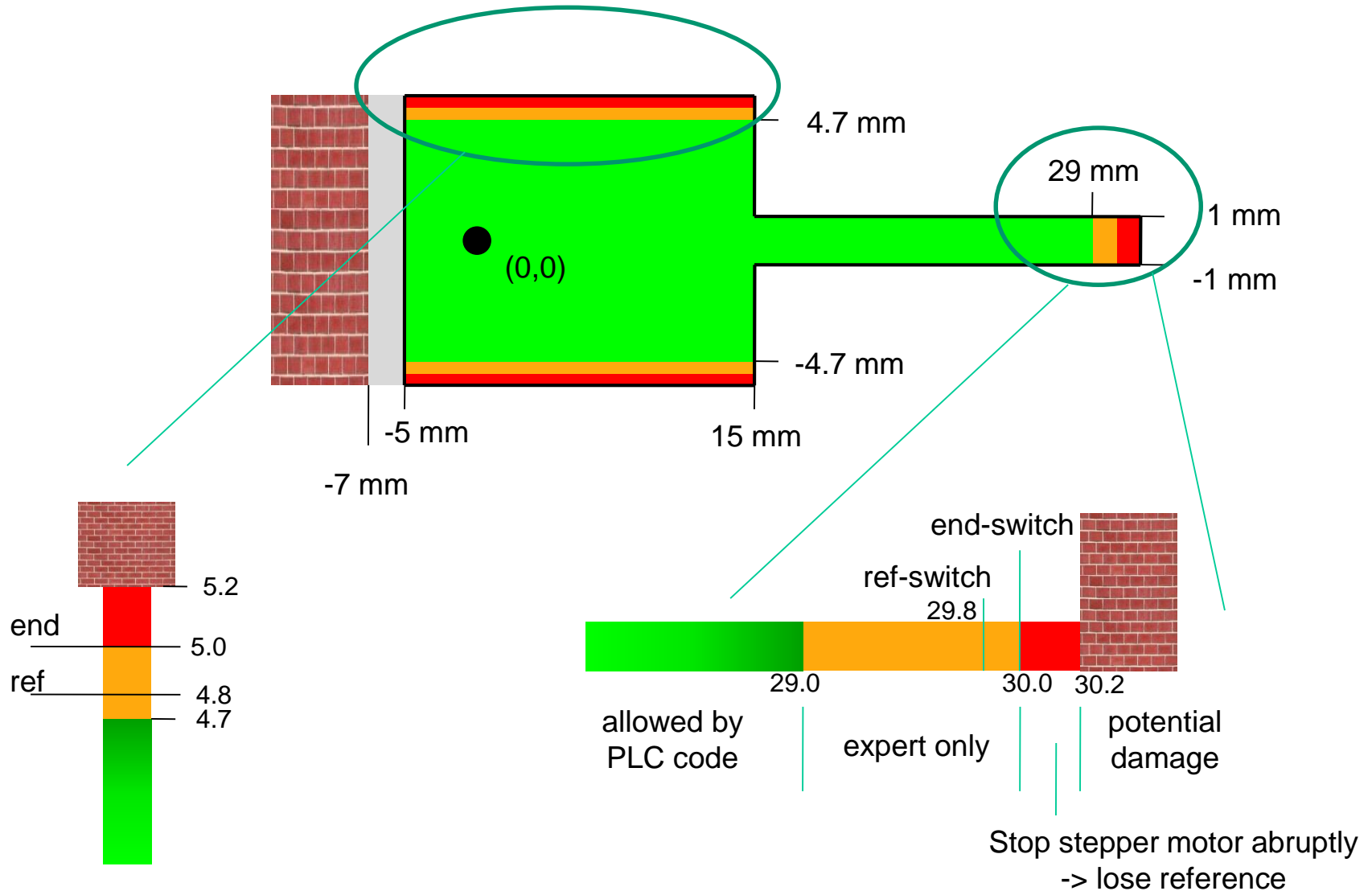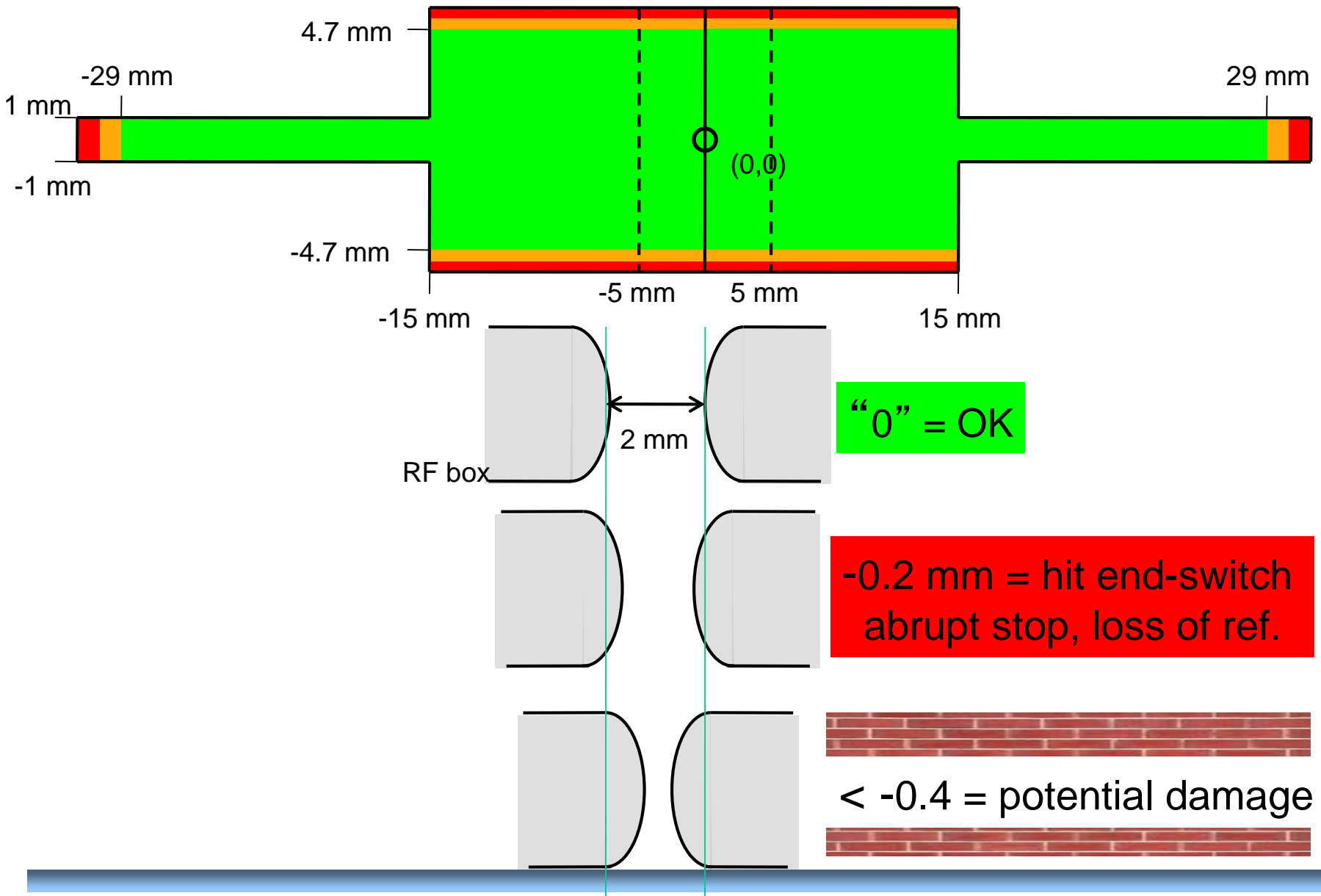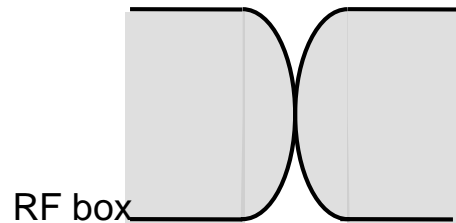- Looking forward to a successful year of data taking

First collisions 2009

Backup

HW per axis

Power

Tx buffer

PLC

Rx buffer

Rx

Stepper CPU

Tx

step

direction

Stepper drive

angle

pulse/rev.

Resolver readout

Motor resolver

Velocity (analog)

Switches

Potentio meters

Movement limits, single side

4.7 mm

29 mm

1 mm

(0,0)

-4.7 mm

-1 mm

-5 mm

15 mm

-7 mm

5.2

end

5.0

ref

4.8

4.7

end-switch

ref-switch

29.8

29.0

30.0 30.2

allowed by
PLC code

expert only

potential
damage

Stop stepper motor abruptly
-> lose reference

relative limits (design)

4.7 mm

-29 mm

29 mm

1 mm

-1 mm

(0,0)

-4.7 mm

-5 mm   5 mm

-15 mm   15 mm

2 mm

RF box

"0" = OK

-0.2 mm = hit end-switch abrupt stop, loss of ref.

< -0.4 = potential damage

relative limits (in reality)

4.7 mm

-29 mm

1 mm

-1 mm

29 mm

4.7 mm

-4.7 mm

(0,0)

-5 mm

5 mm

-15 mm

15 mm

RF box

"0" = OK

-0.2 mm = hit end-switch abrupt stop, loss of ref.

< -0.4 = potential damage