Vacuum in the CLIC MDI and BDS Regions

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With thanks to:

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Introduction

- CLIC MDI and BDS Vacuum
  - Four separate systems: CLIC detector(s), QD0, post-collision line, plus the BDS
    - Significantly different geometry and functional requirements
  - Linked by the same CLIC vacuum system
    - Physically linked by vacuum chambers
    - Coupled by beam dynamics and pressure distributions
- Starting point
  - CLIC MDI Vacuum is at a conceptual level, but we are not starting from zero- We can learn from:
    - CLIC (and ILC) machine vacuum design for calculation tools and expertise
    - ILC design - particularly for detector layouts
    - LHC vacuum – particularly for technology
  - …but we need to be aware of the differences
    - The QD0 in CLIC is at room temperature, so has no inherent pumping speed
    - Different beam parameters, leading to different dynamic vacuum issues
  - CLIC BDS is at a very early conceptual level
    - First approximations of vacuum system based on optics layouts

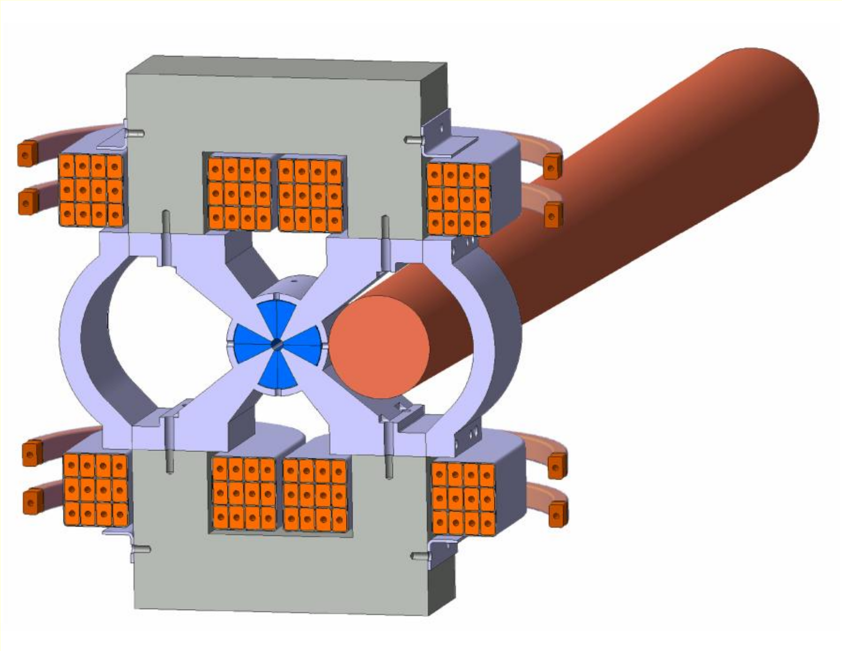
Pressure Requirements for BDS and Experiment

- Requirements from beam dynamics
  - Recent calculations from Rumolo [1] show that coherent instabilities are not an issue with pressures in the last 20m of the BDS upto 10^5 nTorr (~1.3×10^{-4} mbar)
  - He notes however that incoherent effects and emittance growth should be studied
- Requirements from the experiments
  - ILC simulations [2] suggest that beam-gas background is not an issue at 10^3 nTorr (~1.3×10^{-6} mbar)
    - Beam-gas background could be more significant if CLIC operates at lower than nominal luminosity (Re: LHC)
  - Requirement needs to be confirmed for the CLIC experiments
- These pressure requirements suggest that a non-baked solution could be adopted for the QD0, and possibly also the experimental sector

[1] G.Rumolo, CLIC-MDI meeting March 2010
[2] T.Maruyama, LCWA 2009 Albuquerque

Unbaked QD0 Vacuum

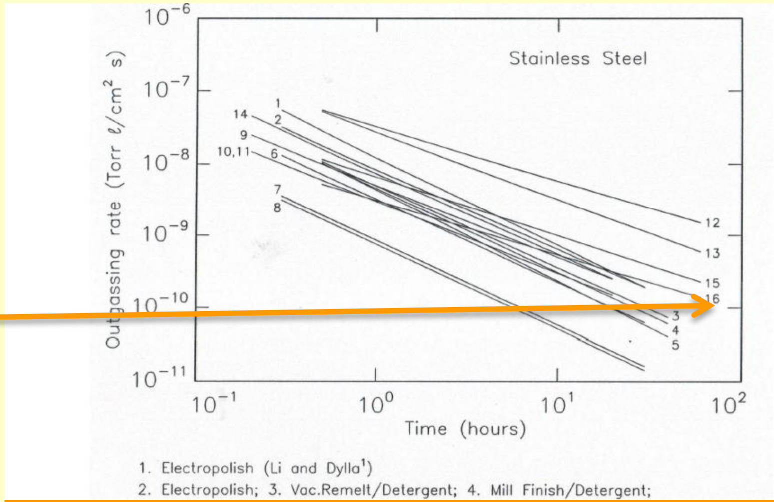
- Geometry
  - QD0 magnet beampipe ~7.6mm inner diameter, magnetic length ~2.75m giving a realistic pump separation of ~4 m
    - Post-collision beampipe with 10 mrad opening angle passes through magnet structure
  - The room temperature hybrid magnet design being proposed is not easily compatible with either bakeout or distributed pumping (eg, NEG) of the vacuum system
    - Permanent magnet materials are sensitive to bakeout temperatures
    - Small aperture with no clearance, so no room for insulation or heaters



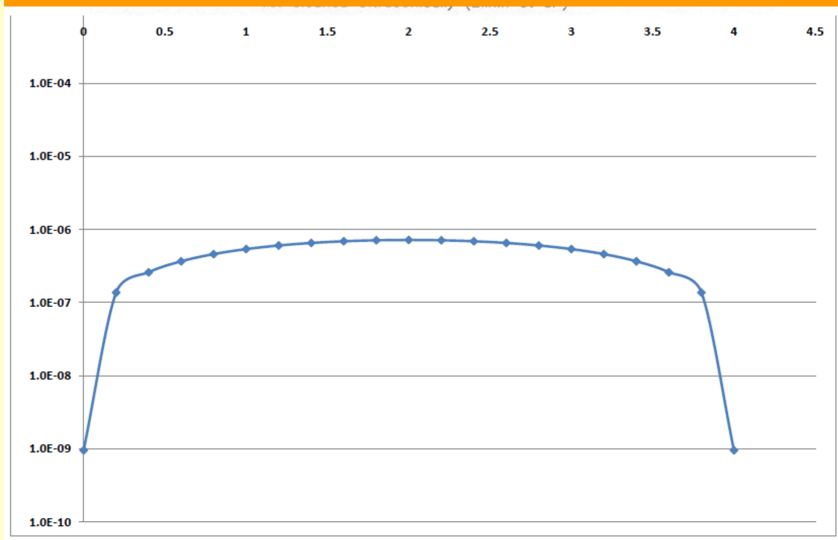
'Hybrid v2' QD0 cross-section, showing incoming and post-collision beamlines
M.Modena

Unbaked Pressure Profile in QD0

- Assumptions
  - Unbaked, but UHV clean system, dominated by outgassing of H_20
    - Outgassing rates for unbaked systems are variable – uncertainty on result
    - Assume 1×10^{-10} mbar.l.s.cm^{-2} after 100h
  - This means the system has to be pumped for 100h before beam
    - Incompatible with a ‘fast’ push-pull
  - … or it is not exposed to air during the push-pull operation
- Calculated static pressures
  - Average 4.8×10^{-7} mbar [~3.6×10^{2} nTorr]
  - Peak 8.1×10^{-7} mbar [~6×10^{2} nTorr]
  - Achievable pressure is dominated by the small conductance of the tube and the outgassing rate
- Dynamic pressure components
  - Additional gas load due to surface bombardment by ions, electrons and photons will increase these static pressures
    - Some data starting to arrive, but calculations are time-consuming



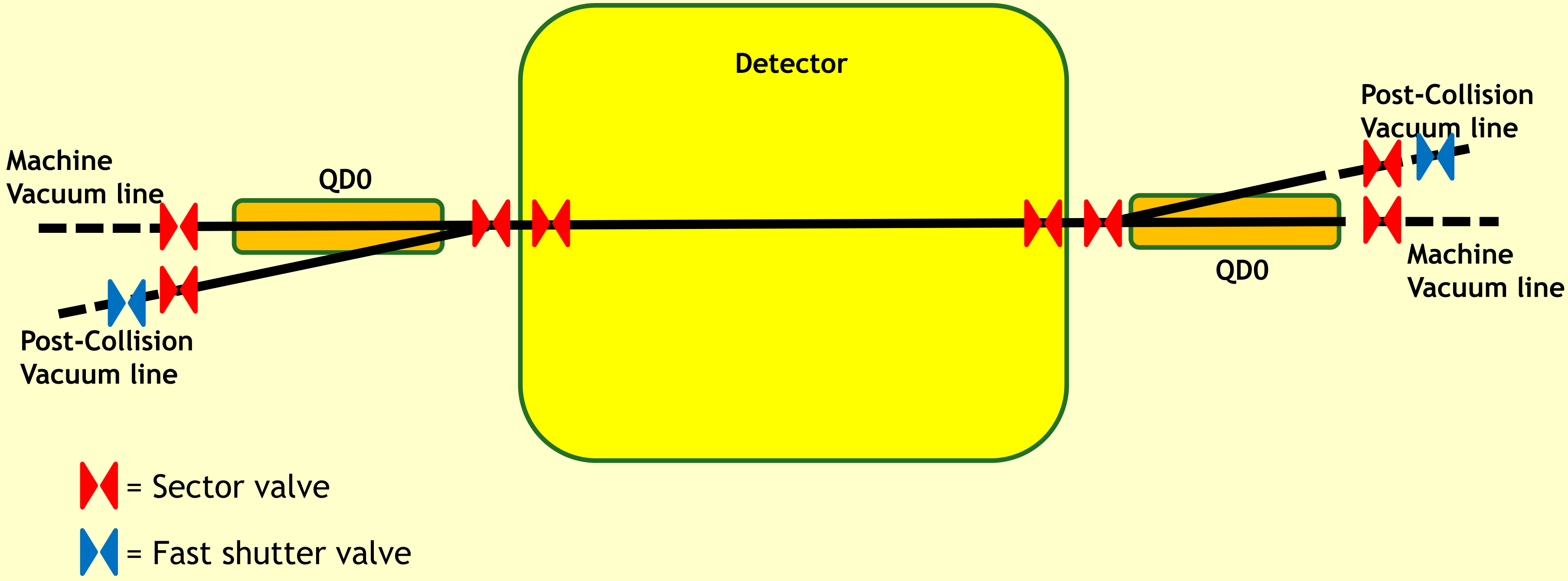
Outgassing rates of water on stainless steel [F.Dylla CAS 2006]



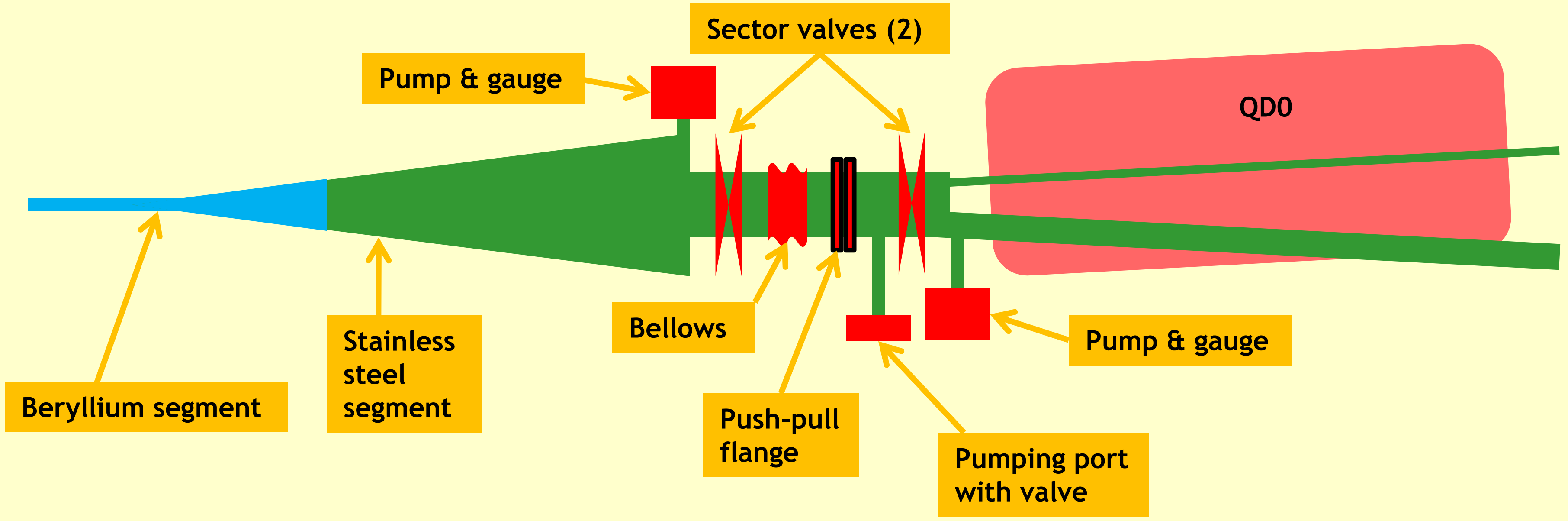
Static partial pressure of H_20 [mbar] along the QD0 beam tube [m]

Baseline Sectorisation Scheme

- Reasons for Sectorisation
  - Separate machine, QD0, Detector and post-collision for independence and safety during shutdowns
  - Add additional sector valve to maintain cleanliness in both QD0 and detector
    - Keep QD0 and experiment either under vacuum or dry gas during push-pull
    - Essential to reduce pump-down time after detector push-pull in a non-baked system
  - Possibly add fast shutter to protect detectors from incidents in post-collision



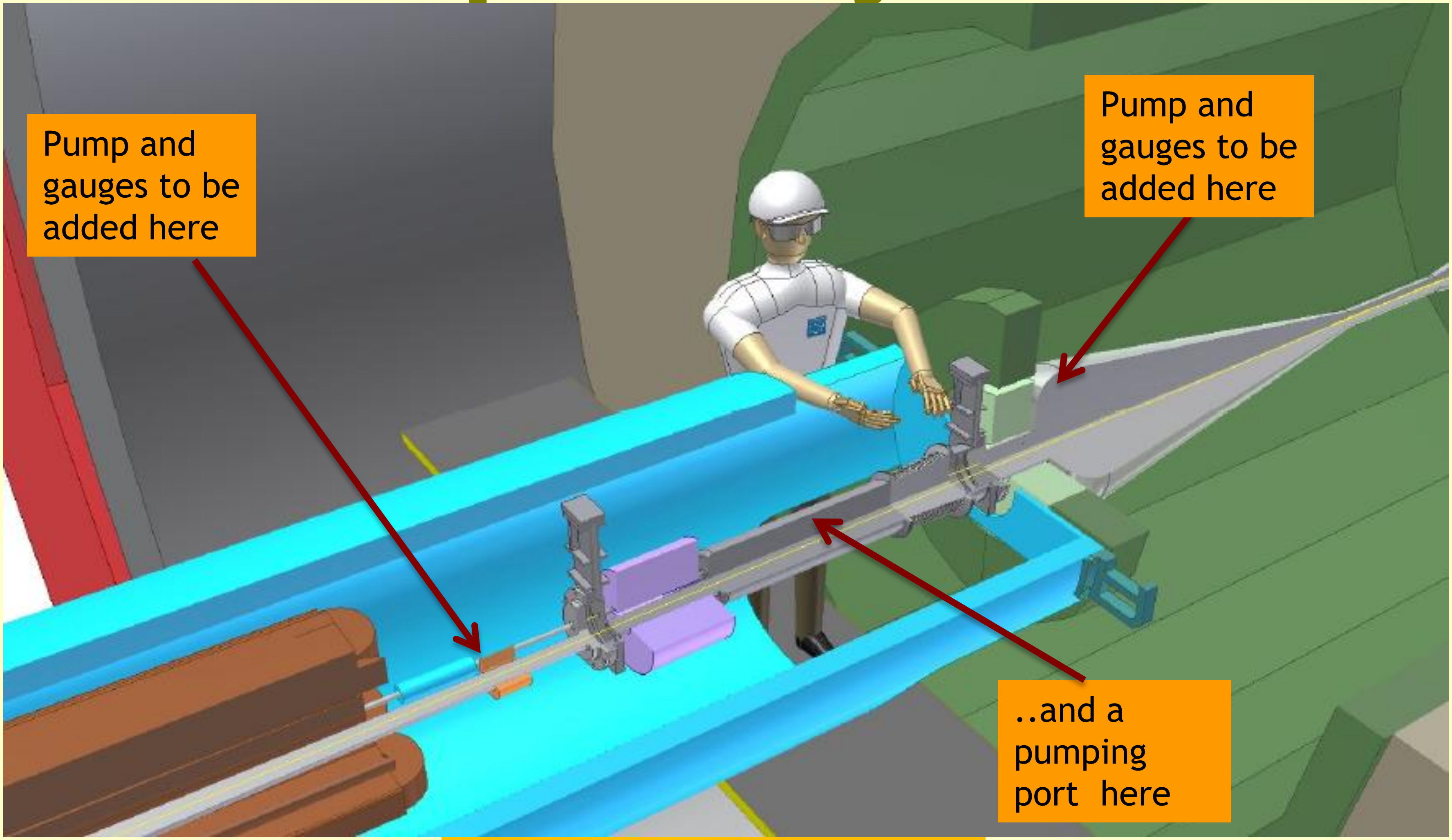
Vacuum Equipment on beamline (first draft)



- Features
  - 2 sector valves for push-pull
  - UHV Push-pull flange
    - will this need to be remote due to activation?
  - Bellows to allow the flanges to separate

- Features
  - Pumps and gauges on experimental and QD0 sectors
  - Port with valve to pump-down the connected sector
    - Connect mobile pumping station

QD0-Experiment Conceptual Layout

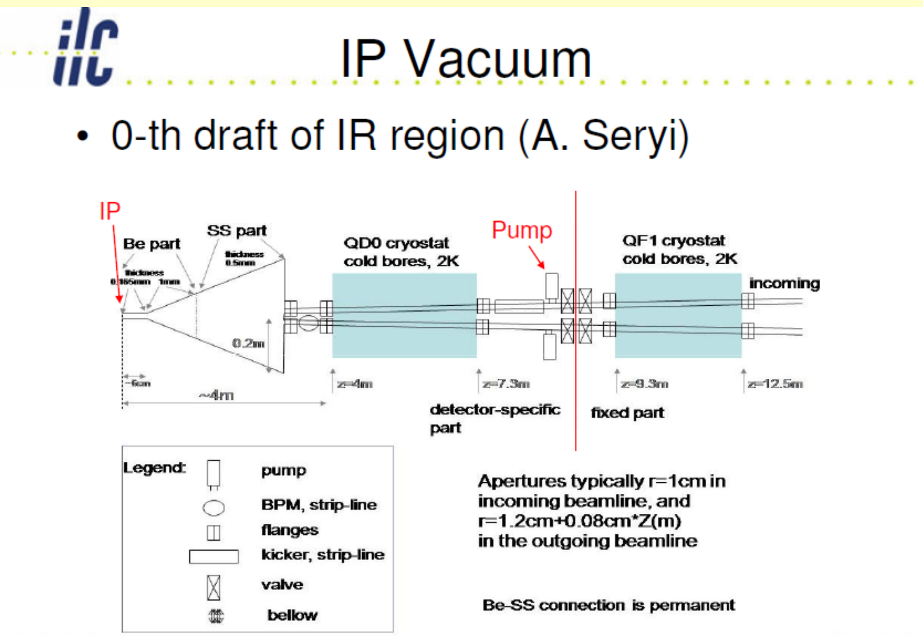


H.Gerwig, 8th CLIC MDI meeting

Experimental Beampipe Geometry

Beryllium segment 60 mm diameter plus conical segment

Stainless steel conical segment increasing to ~ 400 mm diameter



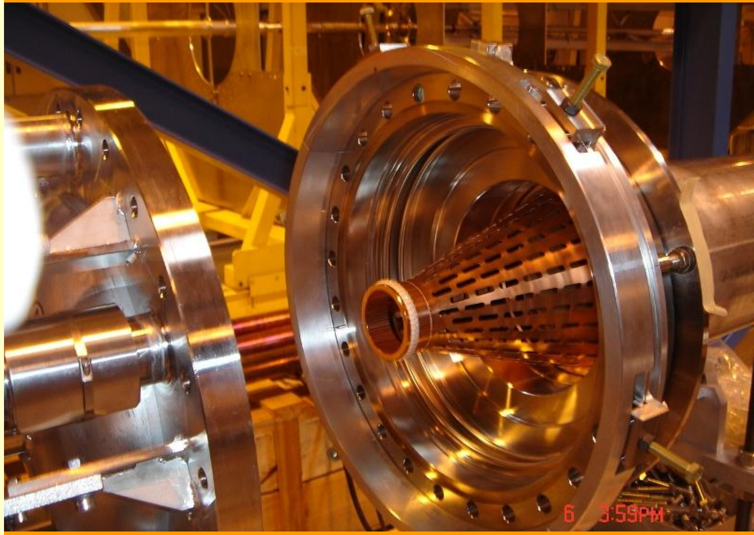
CLIC experimental vacuum geometry is based on the ILC

Chamber technology similar to LHC (LHCb-UX85/1 chamber shown)

Detector Beampipes

- Material
  - Baseline is beryllium
    - Best material in terms of transparency (radiation length, specific stiffness)
    - Uncoated beryllium has high desorption yields which can give beam dynamics and vacuum issues
    - Beryllium chambers may therefore need to be coated, which could also require bakeout
  - Alternatives
    - Carbon composite is not far behind beryllium for transparency, and should not be forgotten, particularly for non-baked designs
- Other issues
  - Impedance and trapped RF modes
    - Conical transitions or RF shields may be needed at the end of the large cone

LHCb UX85/3 Conical beryllium pipe

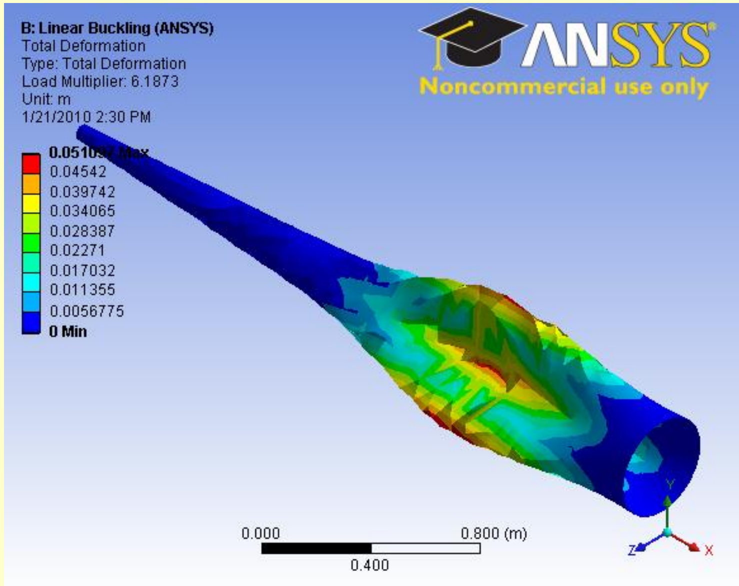


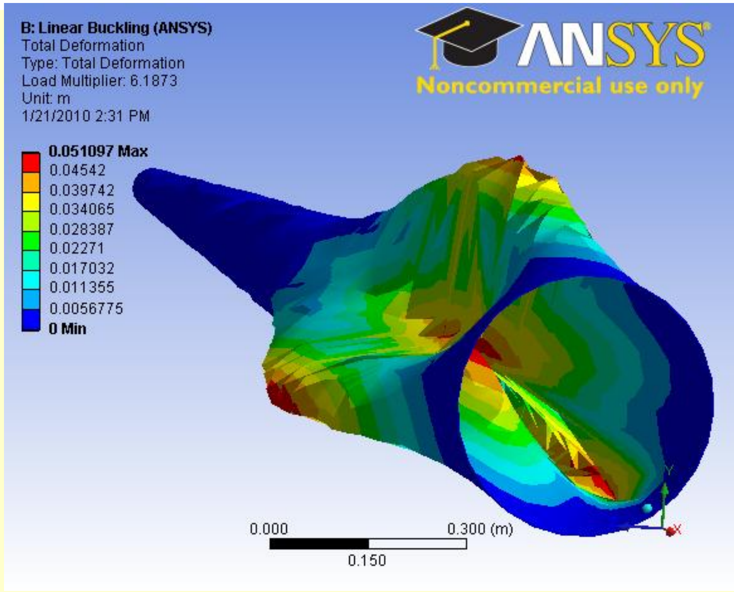
RF screen in the CMS end cap beampipe

Experimental Beampipe Thickness

- Beryllium Section thickness
  - Likely to be limited by
    - Construction technology (currently 0.5~0.7 mm for machined pipes)
    - leak-tightness limits
    - Risks of damage during handling

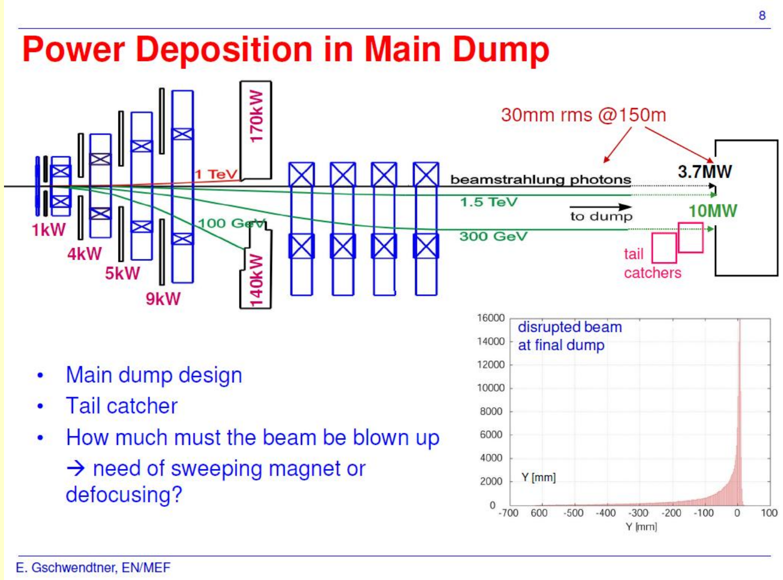
  … rather than mechanics
  - Conical chambers have been made for LHC
- Stainless cone
  - Limited by buckling under external pressure
  - Initial ANSYS calculations show realistic thickness in the range 2~3 mm at 400 mm diameter end
  - Optimisation by:
    - Stepping of wall thickness with diameter
    - Reinforcing ribs
    - Alternative materials (composites etc)

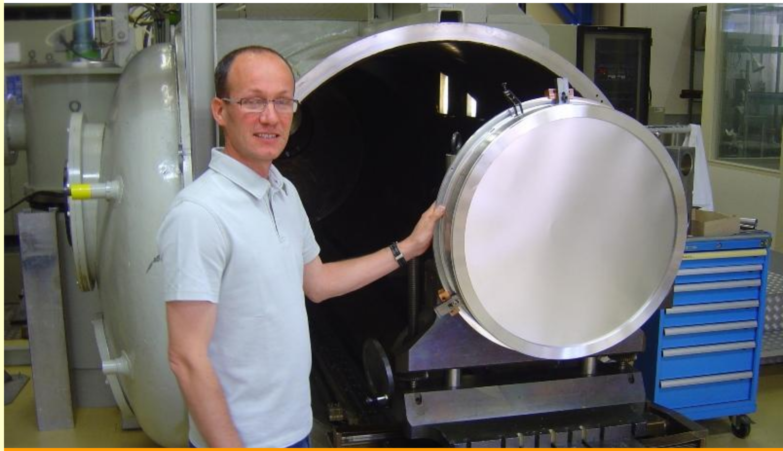




Post-Collision Line

- Geometry
  - 150m+ length of large diameter (~1m) vacuum chambers
- Absorbers
  - Several absorbers in the kW-200 kW capacity range outside the vacuum system
  - Will require a number of intermediate ‘windows’
- Vacuum system exit window
  - Large diameter (~1m) window
  - High continuous power (~10 MW)
    - ‘Transparent’ window
    - Cooling required?





LHC beam dump window: 600mm aperture, made from carbon-carbon composite supporting a leak-tight foil. Designed for 362 MJ of full LHC beam

Post-Collision Line

- Vacuum system issues
  - Large volumes at medium-high vacuum
    - Pressure requirement for CLIC operation?
    - Cf. LHC beam dump at 10^{-7} mbar (~100 nT)
  - High pumping speeds will be required
    - Outgassing of large surface areas
    - Local gas loads from heating close to absorbers
    - .. therefore large pumps
  - Radiation environment
    - Pumps need to be close to the chambers to maximise conductance
    - Need access to pumping systems for maintenance

LHC beam dump line, showing ion pump

BDS Vacuum

- Overview of vacuum system
  - 206 dipole magnets with 24mm beampipe radius
  - 70 quadrupoles with 8mm radius
  - Drift vacuum chamber sections
  - Special sections such as collimation and crab cavities
- Vacuum requirement
  - Average pressure of 10nT (~1.3×10^{-8} mbar) from beam dynamics [1]
  - Preliminary calculations show that:
    - Dipole chambers can be unbaked with lumped (ionisation) pumps at the extremities
    - Quadrupole chambers will require distributed pumping – could imagine to use the design from the CLIC main module chamber with NEG strip [2]

[1] G.Rumolo, 11th MDI meeting, March 2010
[2] C.Garion, this workshop

Conclusions

- CLIC MDI conceptual design
  - Medium vacuum requirement from beam dynamics means that unbaked DQ0 appears feasible
    - However, the push-pull detector layout means that vacuum pumpdown times must be short, so contamination of surfaces with water must be prevented
    - Leads to proposed sectorisation scheme
  - QD0 pressure is approaching background limit for ILC detectors
    - Dynamic pressure not yet included
    - QD0 magnet concept leaves no margin to improve pressures or surfaces
- Experimental vacuum system
  - Geometry based on ILC designs, with technology developed for the LHC
  - Requires confirmation of acceptable background and dynamic vacuum to see if bakeout of the sector is required
- Post collision and remaining BDS vacuum
  - Still in the preliminary design stages