Preliminary View on the LHeC Experimental Vacuum Chambers

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Contents

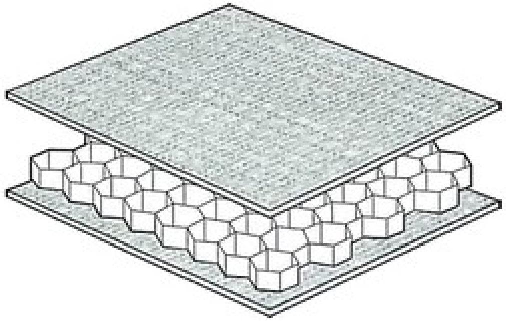
- Requirements for the LHC experimental vacuum systems
- Choice of beampipe materials and sections
- Preliminary calculations of LHeC geometries
- Conical beampipes
- Summary

LHC Experimental Vacuum Requirements

- **Machine Requirements**
  - In addition to standard vacuum system requirements, the LHC beam vacuum system design requires control of a number of dynamic vacuum issues
    - Ion induced desorption, electron stimulated desorption & electron cloud, photon stimulated desorption
  - The primary factor in this control is low desorption yields from vacuum chamber surfaces
- **Additional requirements from experiments**
  - LHC (and LHeC) experimental chambers require low Z materials
  - Low Z, ultra-high vacuum compatible materials (e.g. aluminium, beryllium) have high desorption yields
    - Titanium would be a possible exception
  - LHC overcame this by using thin-film TiZrV NEG coatings, but these require activation by heating the chamber to 180~220°C
- **Radiation**
  - LHC experimental interaction chambers are designed for ~1 MGy per year (at nominal luminosity), mainly from collisions.
  - This places additional limitations on choice of material for chambers, supports and vacuum equipment
    - LHeC Luminosity expected in range 10^{33} compared with 10^{34} in LHC

LHC Experimental Beampipe Materials

- **Beampipe material choice**
  - This combined requirement for temperature resistance, radiation resistance, UHV compatibility and transparency, plus mechanical requirements resulted in the choice of NEG coated beryllium and/or aluminium for the critical central parts of LHC detector beampipes
    - However, Beryllium is expensive, toxic and with limited suppliers!

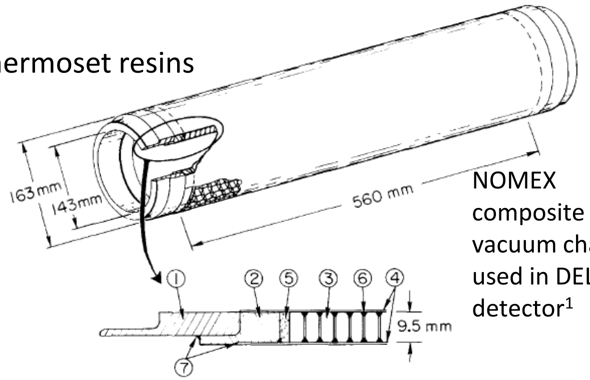


  - Sandwich structure or composite beam pipes were considered at the design stage but have been rejected due to limitations in the bonded assembly.(cont)

Composite Pipes

- **Sandwich structure composites**
  - Motivation to reduce cost in materials and manufacture
  - Possibly improve radiation transparency
  - Limitations include:
    - Differences in thermal expansion of bonded materials (CTE offset)
    - Less radiation resistance
    - Lower temperature limit

  } Limitations of thermoset resins



NOMEX composite vacuum chamber used in DELCO detector[1]

However…

- Long-term R&D on carbon-carbon composite chambers is under way at CERN which may provide an alternative.
- Recent development of unbaked coatings – a-C coating used in SPS.[2]

1. A Sandwich Structure Beam Pipe For Storage Rings, G. Bowden *et al.*
2. Amorphous Carbon Coatings for mitigation of electron cloud in the CERN SPS, C. Yin Vallgren *et al.*

Preliminary Calculations of LHeC Beampipes

LHeC proposed elliptical experimental chamber geometries[1]

Two preliminary, elliptical geometries analysed;
72 x 58mm
120 x 50mm

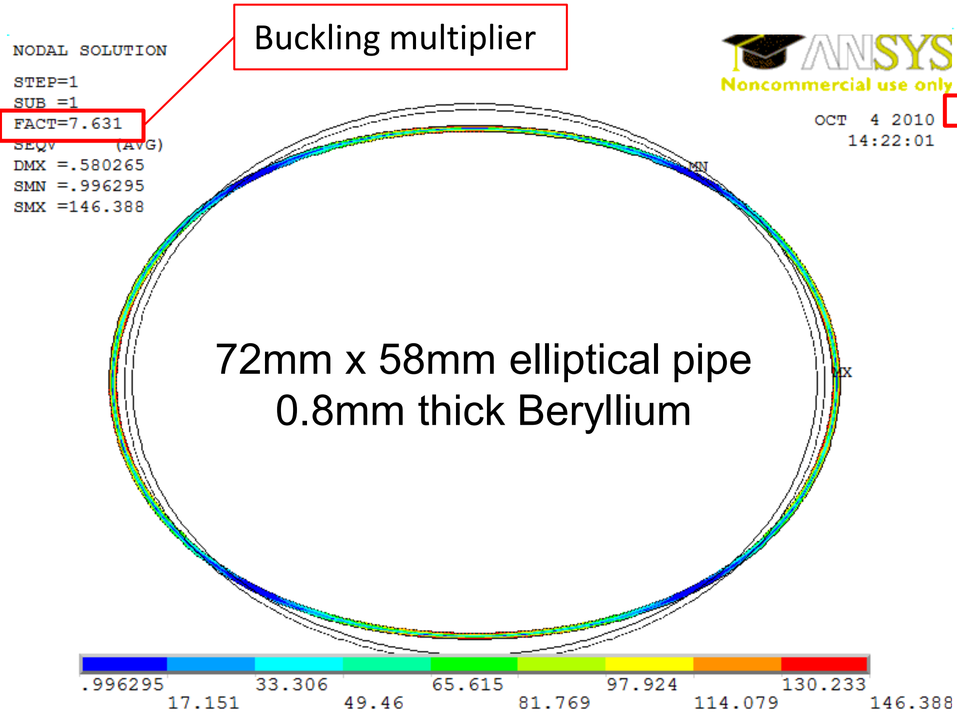
- Finite element stress analysis using ANSYS
- Infinitely long chamber of constant cross-section
  - Effects of supports and axial bending not included
  - Ideal geometry assumed
- Eigen value buckling and stress analysis

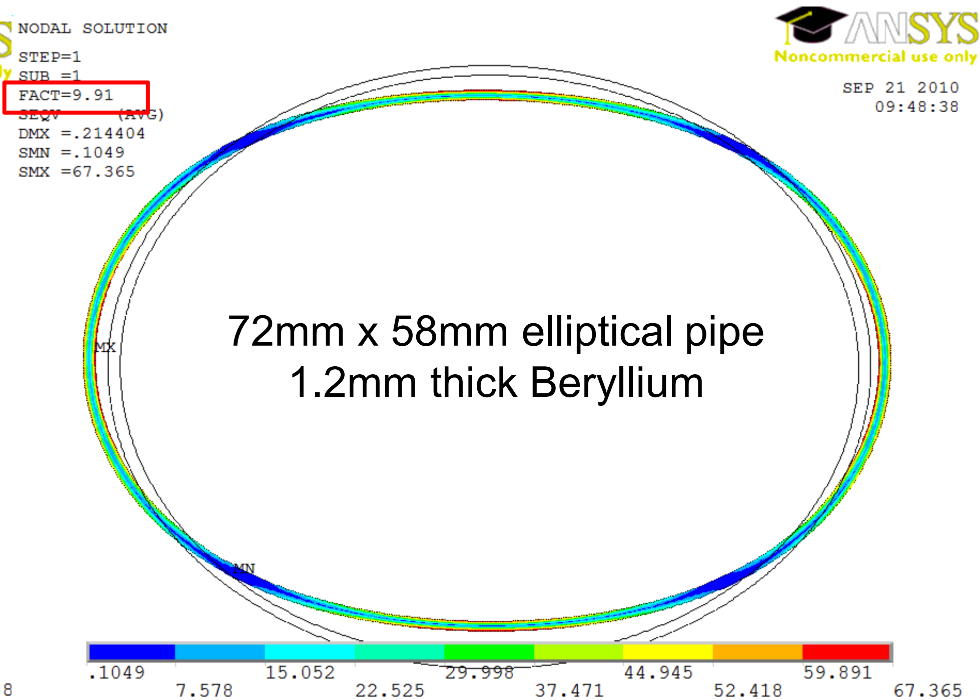
Results

- The first (72x58) is prone to failure by elastic collapse (buckling)
- The second (120x50) will fail by plastic yielding

1. Peter Kostka. *et al* DIS2010, Florence

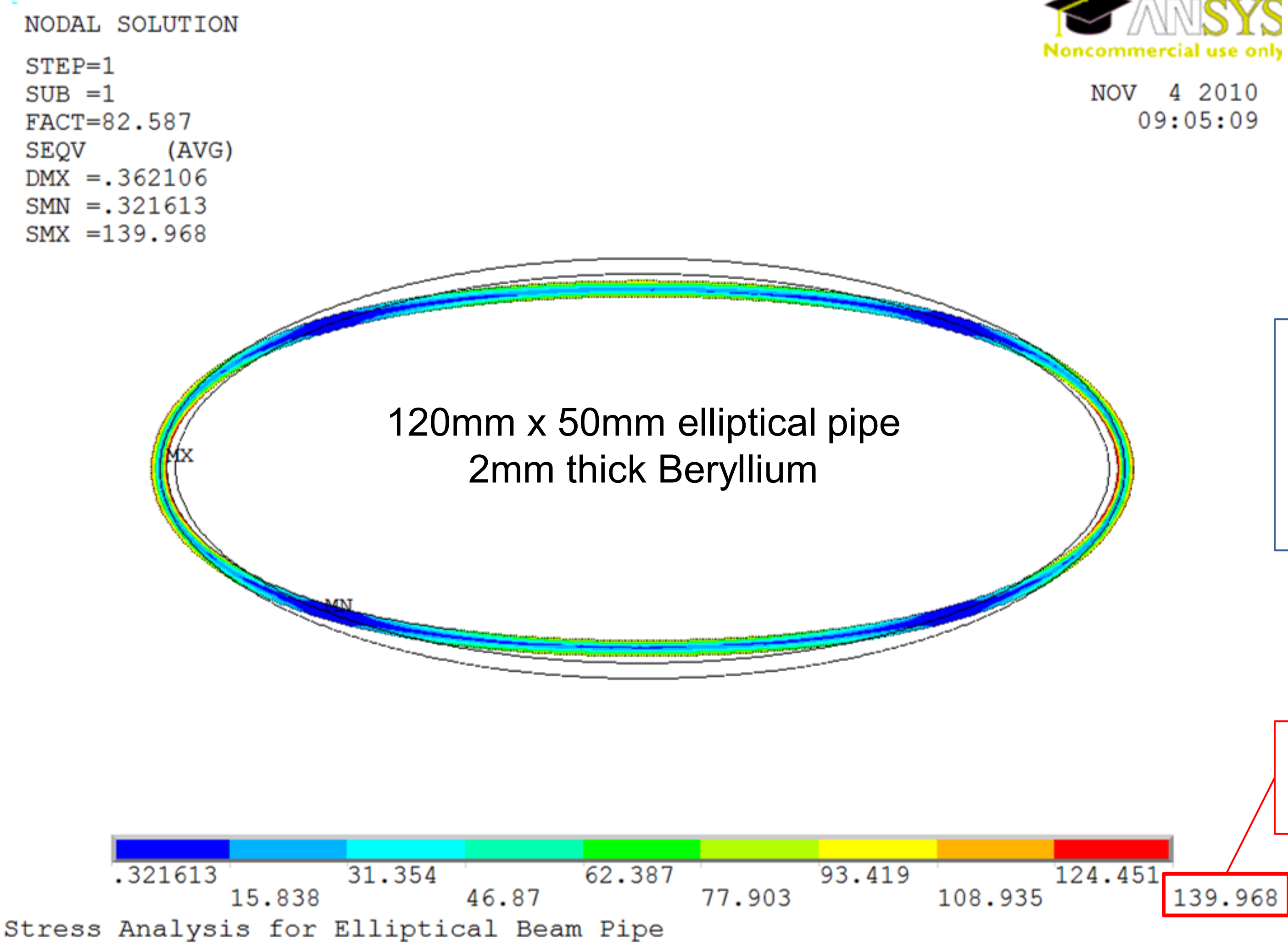
ANSYS Stress Analysis





Equivalent Stress Contours
+
Deformed/Undeformed Shapes

Minimum thickness for Be, elliptical (constant geometry) pipe in order of 1mm



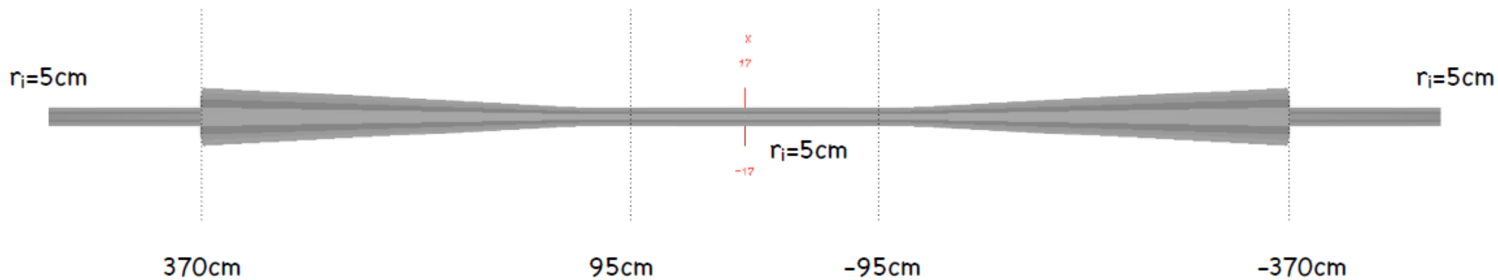
Nominal yield strength of Be, 240MPa

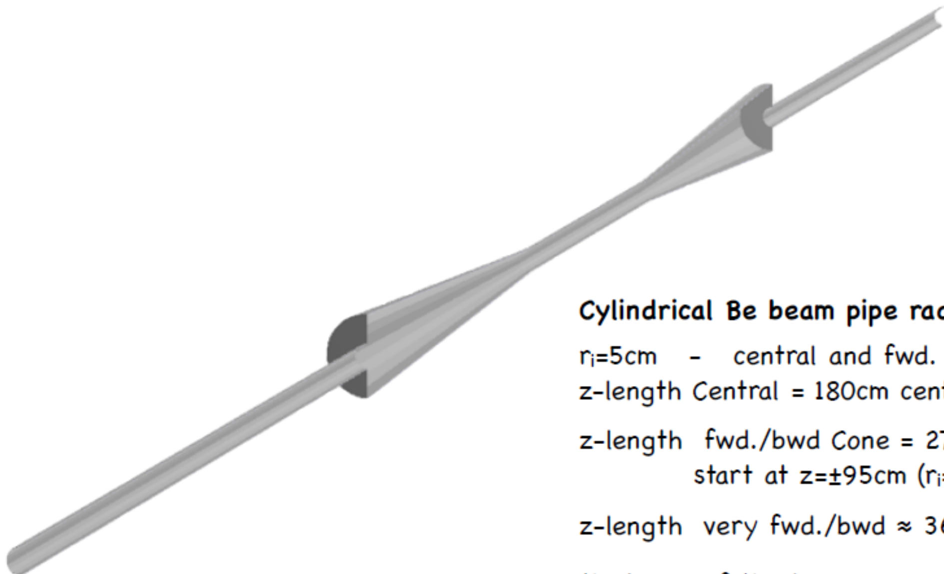
Max. Stress (MPa)

Equivalent Stress Contours
+
Deformed/Undeformed Shapes

Conical Pipe Option

Fwd./Fwd.Cone/Central/Bwd.Cone/Bwd. Beam Pipe





Cylindrical Be beam pipe radii:

r_i=5cm – central and fwd. bwd. beam pipe parts

z-length Central = 180cm centered symmetrically to the the IP

z-length fwd./bwd Cone = 275cm
start at z=±95cm (r_i= 5cm); end at z=±370cm (r_i=16.7cm)

z-length very fwd./bwd ≈ 360cm

thickness of the beam pipe = 1mm (may be thinner?)

Slide Courtesy of Peter Kostka

LHCb Conical Pipe

LHCb UX85/3 Chamber

- Beryllium Chamber
- Length 6m
- Maximum diameter 262mm
- NEG coated
- Operating in LHC

LHCb UX85/1 Chamber

- Bi-Conical chamber (Beryllium)
- With “Window”
- Length 2m
- Maximum Diameter 110mm

Summary

- **LHC requirements**
  - The combined requirements of LHC machine and experiments (of which not all have been considered here) place a serious limit on the choice of materials and forms for beampipes.

- **Preliminary analysis**
  - Preliminary calculations have been made for simple ‘solid’, elliptical geometries made from aluminium, titanium and beryllium.
  - In beryllium, thickness in the order of 1 mm (for 72x58mm) and 2 mm (for 120x50mm) appear feasible.
  - Experience with conical chambers at LHCb does not rule out development of “Fwd/Central/Bwd” beampipe design.
  - Ongoing R&D for new materials and coatings may give other options

Thanks for listening

Any Questions?

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