LHeC Experimental Beam Pipe

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(based on LHeC presentations, CDR and inputs from R.Veness, J.Bosch & P.Kostka)

LHeC CDR – 'Vacuum' Chapter

- **9.8 Vacuum**
  - Vacuum Requirements
  - Synchrotron radiation
    - Synchrotron radiation power
    - Photon-induced desorption
    - Vacuum cleaning and beam scrubbing
  - Vacuum engineering issues
    - Vacuum pumping
    - Vacuum diagnostics
    - Vacuum protection
    - HOM and Impedance implications
    - Bake-out of vacuum system
    - Shielding issues
    - Corrosion resistance
- **9.9 Beampipe Design**
  - Requirements
  - Choice of materials for beampipes
  - Beampipe geometries
  - Vacuum instrumentation
  - Synchrotron Radiation Masks
  - Installation and Integration

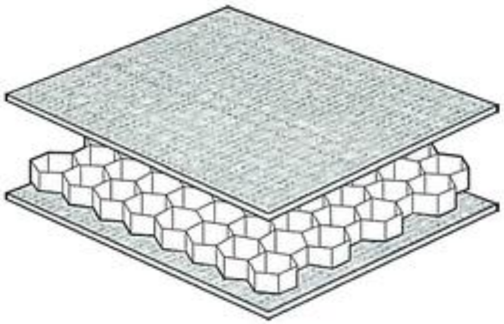
Today

LHC/LHeC Experimental Vacuum Requirements

- **Machine Requirements**
  - The LHC/LHeC 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
- **Experimental Vacuum**
  - LHC/LHeC experimental chambers require low Z materials (transparency, background)
  - 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 ~220°C
- **Radiation**
  - LHC experimental interaction chambers are designed for in the order of 1 MGy per year (at nominal luminosity), mainly from collisions
  - Low Z results in lowest possible residual activation of the highly exposed chamber.

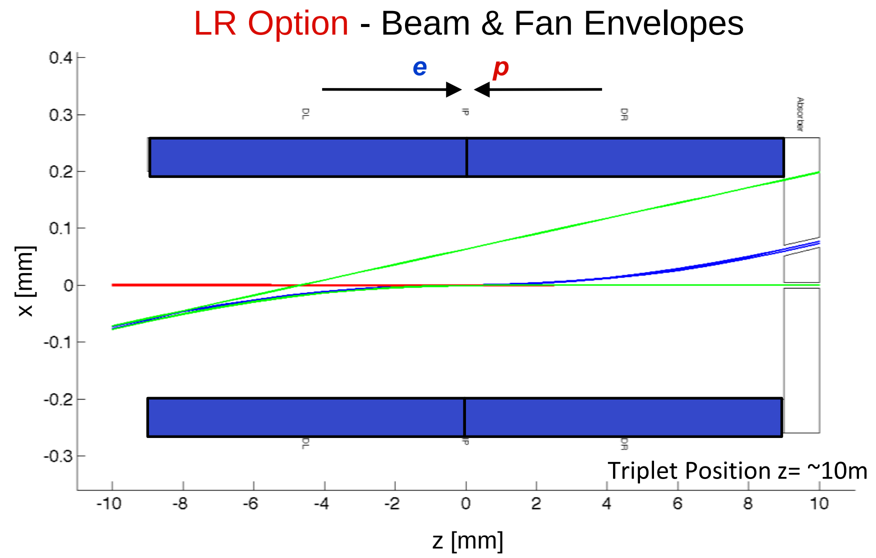
Preliminary Analysis

- **Beampipe material choice**
  - The combination of transparency, temperature resistance, radiation resistance, UHV compatibility, 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 limited in supply!

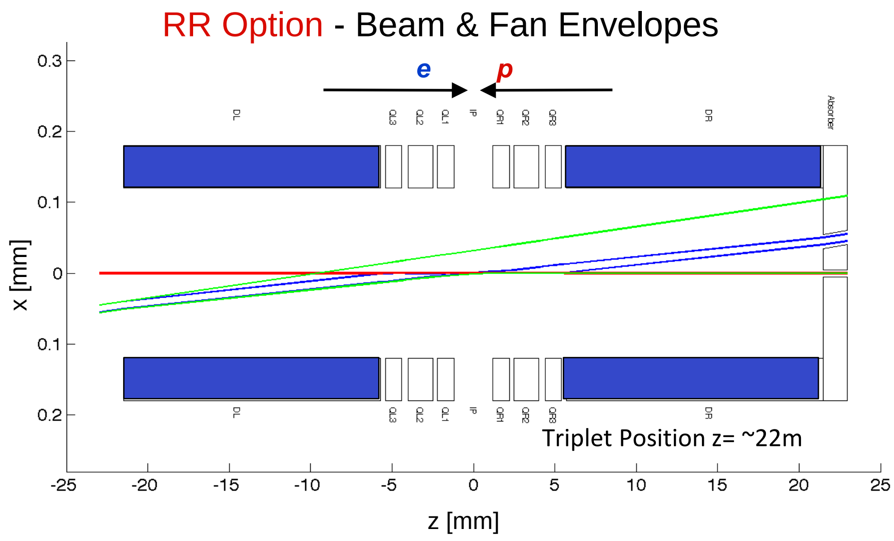


  - Composite beam pipes are not excluded but much more R&D is necessary

LR, RR option – Beams & SR



SR Fan growth with z



Legend : Dipole

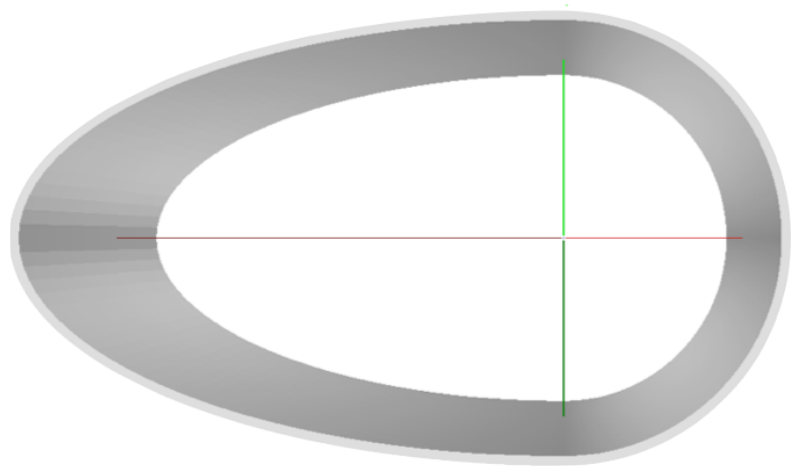
SR Fan growth with z (high luminosity case)

Beam Pipe RR Variant[1]

LR - Inner Dimensions

Circular(x)=22 mm; Elliptical(-x)=-55 mm, y=22 mm

housing beam/SR envelopes;
beam pipe dimensions reduced - using static / movable masks;
10 mm safety margin (mech tol, alignment, sag, cavern, etc)



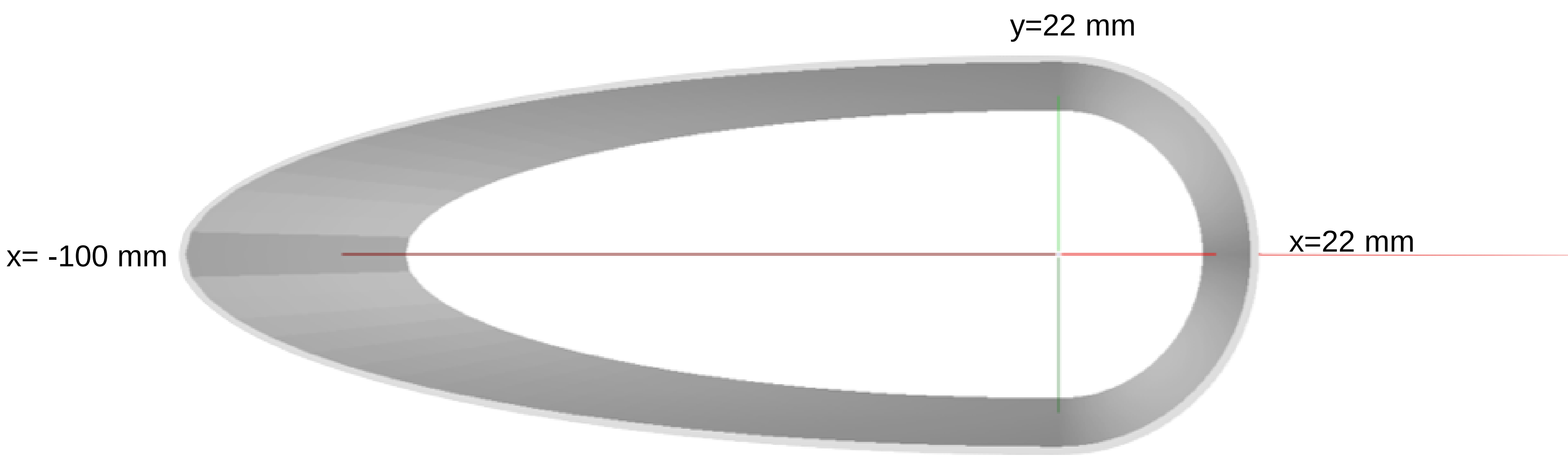
1. Peter Kostka. *et al*

Beam Pipe LR Variant[1]

LR - Inner Dimensions

Circular(x)=22 mm; Elliptical(-x)=-100 mm, y=22 mm

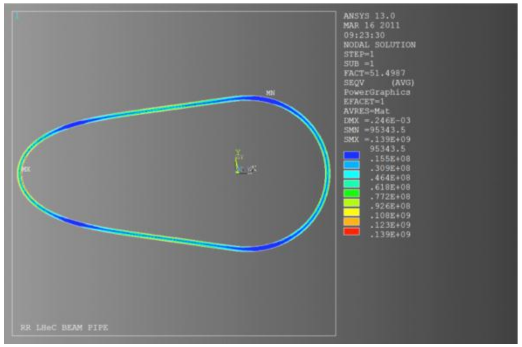
housing beam/SR envelopes;
beam pipe dimensions reduced - using static / movable masks;
10 mm safety margin (mech tol, alignment, sag, cavern, etc)



1. Peter Kostka. *et al*

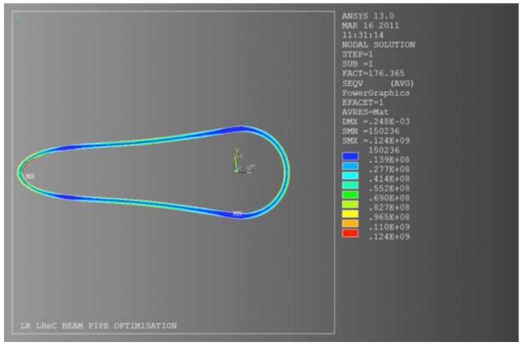
LHeC Beampipe Geometry

Proposed LHeC experimental chamber geometries[1]



RR – 1.3 to 1.5 mm Be wall

Analysis:
R.Veness,
J.Bosch



LR – 2.5 to 3.0 mm Be wall

– Assumptions:
  – Beryllium
  – Central beam pipe ~ 6 meters
  – Constant x-section
  – TiZrV NEG coated
  – Periodic bakeout/NEG activation at ~220C (permanent system?)
  – Wall protected from primary SR (upstream masks)
  – Minimised end flanges, minimised supports

1. Peter Kostka. *et al*

Composite Pipes

- **Composites**
  - Motivation to reduce cost in materials and manufacture
  - Possibly improve radiation transparency
    - Sandwiches constructions – but increased wall thickness
  - Long-term R&D on low Z composite chambers is under way at CERN which may provide an alternative.

  - Carbon-fibre composites (aluminium, glass/ceramic in matrix)
  - Carbon-carbon composites (with/without metal liners)
  - Glassy (vitreous) carbon
  - Sandwich constructions (honeycombe & metal foam cores with thin skins)

  - Recent development of unbaked coatings may be advantageous wrt to known temperature limitations of some composites – a-C coating used in SPS.[1]

1. Amorphous Carbon Coatings for mitigation of electron cloud in the CERN SPS, C. Yin Vallgren *et al.*

Alternative Beam Pipe Solutions

CHAMBER COST

½ cylinder, ½ ellipse tapering

Variable wall thickness

½ cylinder, ½ ellipse

Ellipse

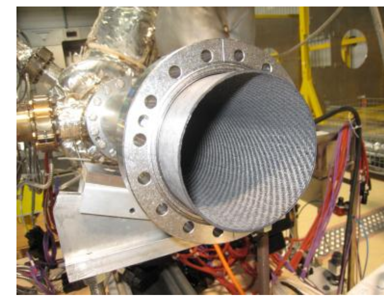
Racetrack

Cone

Cylinder

LHCb UX85/1
Bi-conical Be

C-C with ext liner



Carbon-fibre, Carbon-Carbon
Sandwich structures, Glassy carbon

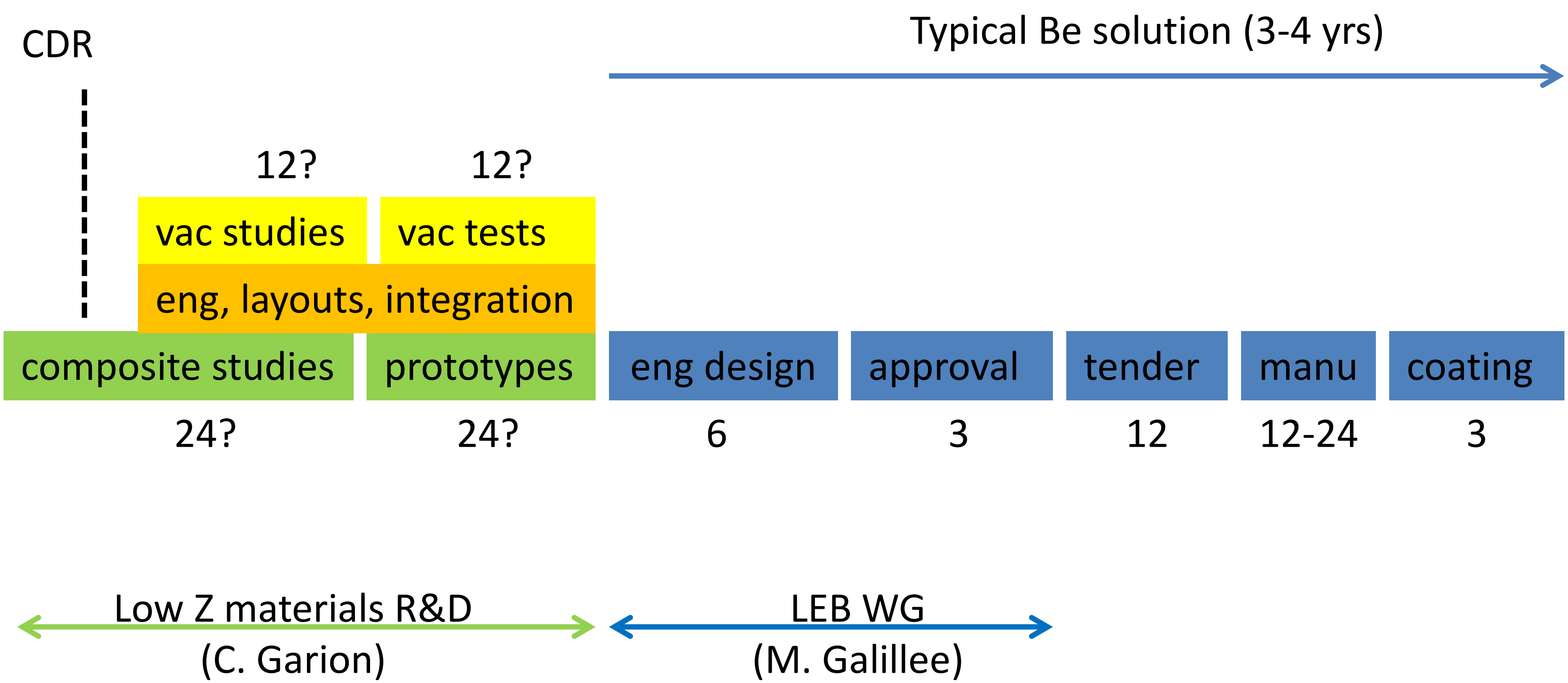
Beryllium

Composites

EXECUTION TIME, RISK

LHeC Beampipe Timescale

A tentative timescale (months)...........



Additional manpower is necessary to advance on LHeC eng & vacuum physics issues

How to advance on vacuum system?

- **The next steps for LHeC experimental area**
  - Additional VSC engineering resources
    - Layouts, Integration, Supports, Instrumentation, Alignment, Heat Loads, Masks, Bakeout, Pumps, Gauges, etc. (triplet to triplet)
    - Parallel engineering studies with other detector technologies.
  - Additional vacuum physics resources
    - Vacuum stability, simulations, experimental validations, coatings, etc.

- **The next steps for the LHeC machine**
  - Additional VSC engineering & vacuum physics resources
    - SR heat loads, vacuum stability, dipole chamber design, heat extraction, etc.

⇨ **Fellows support in 2013 & 2014**

⇨ **Budget for design & prototyping work**

Beampipe Summary

- The combined requirements of LHC/LHeC machine and experiments place a serious limit on the choice of materials for beampipes
- The baseline for the central beampipe can be considered as a solid beryllium chamber, NEG coated and in-situ baked.
- Preliminary calculations have been made for simple 'solid', half-cylindrical half-elliptical geometries.
- In beryllium, thickness in the order of 1.3 to 1.5 mm (RR) and 2.5 to 3 mm (LR) appear feasible.
- Experience with LHCb conical chambers does not rule out complex shapes.
- Ongoing R&D for new materials and coatings may give other options, but will require several years.
- Vacuum physics & engineering studies must be made in parallel with detector (& machine) studies.
- Additional vacuum resources (personnel & material) are required to continue with the these studies.

Thanks for listening

Any Questions?

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Acknowledgements – R.Veness, J.Bosch, P.Kostka

Material	Radiation length X_0 [cm]	Notes
Beryllium	35	
Epoxy	30-36	Very low E !
Carbon	29	Includes C-C & Glassy
Carbon/Al (90/10)	24	Impregnated C matrix
Carbon/Al (60/40)	17	Impregnated C matrix
AlLi	10-11	
Al	9	
Al2O3	7	
SiC	8	