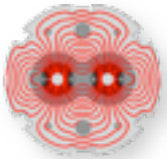
Considerations for the Ring-Ring option

- **Introduction and baseline assumptions, relevant for the layout**
- **By-pass - principles**
- **Larger, fully de-coupled by-pass**

Acknowledgements :

many discussions and input from my CERN colleagues and in particular
John Osborne, John Jowett, T. Linnecar, O. Brüning

e-ring energy, power and intensity



f_{rev} = 11245. 5 Hz given by LHC circumference #bun = 2800

high collision frequency f = #bun × frev = 31.5 MHz and high beam current

beam current I = n e f $e = 1.60218 \times 10^{-19}$ As

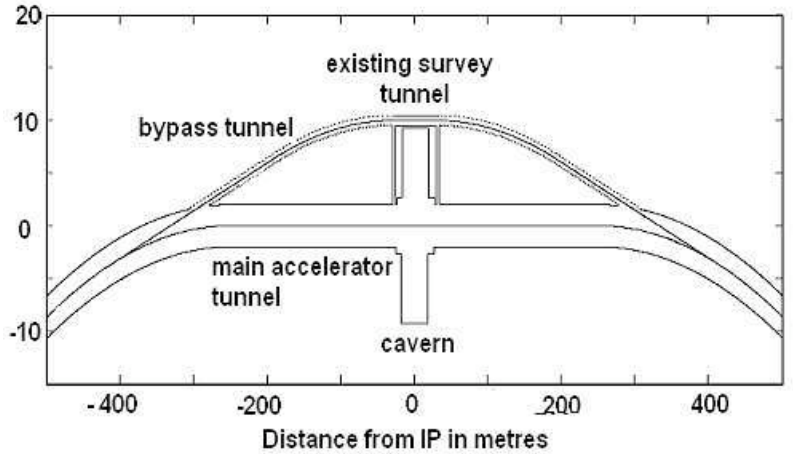
Ring : loss in SynRad $U_0 = C_\gamma E_b^4 / \rho$ ρ = 2997 m LEP had ρ_{eff} = 3026.42 m

$$E_c = \frac{3}{2}\frac{\hbar c \gamma^3}{\rho} = 2.96 \times 10^{-7}\text{eV m}\,\frac{\gamma^3}{\rho}$$

machine	N / bun	#bun	Ntot / beam	I beam	E_b [GeV] V [GV]	P_{acc}= V I [MW]	U_0 [GeV]	Psyn [MW]	γ	E_c [keV]
Baseline LHeC	1.40E+10	2800	3.92E+13	70.63 mA	50	3531	0.184	13.0	97847	91.6
Ultimate LHeC					70	4944	0.7087	50.05	136987	251.4
LEP 2	4.16E+11	4	1.67E+12	4×0.75 mA	100	300	2.923	8.77	195694	733

By-pass for large experiments

schematic layout
Dainton / Willeke et al.

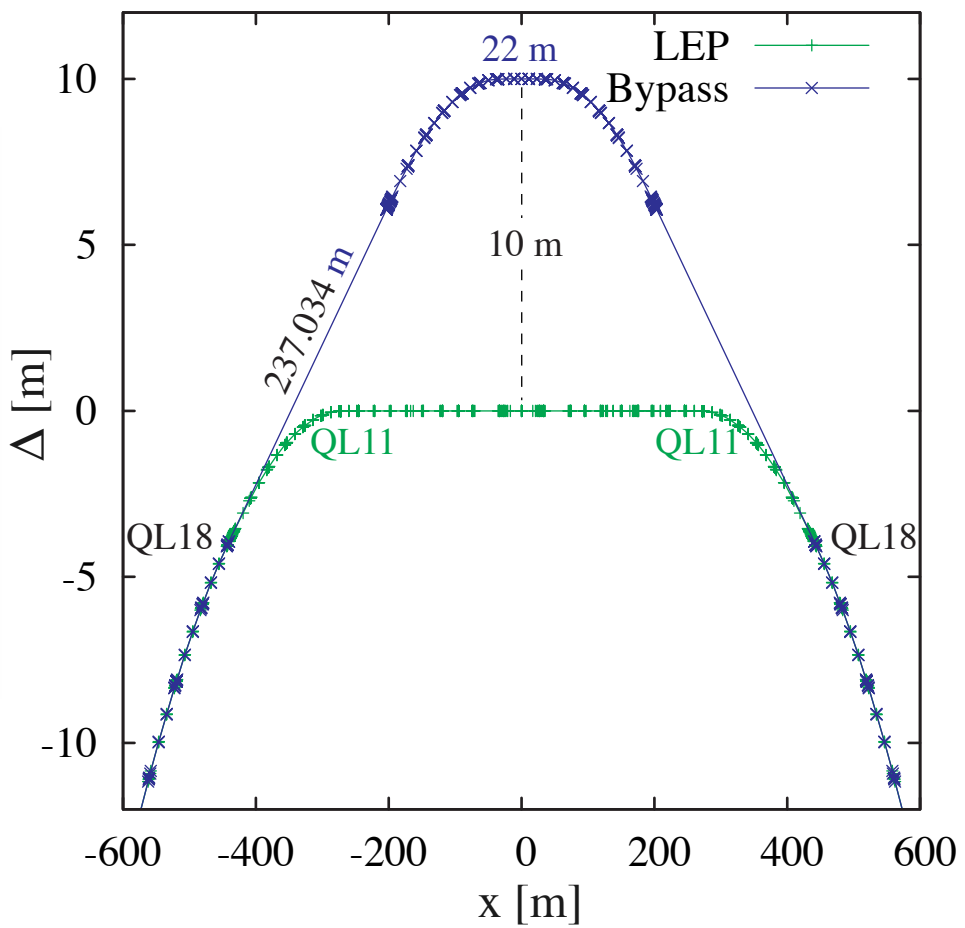


Option without extra bends

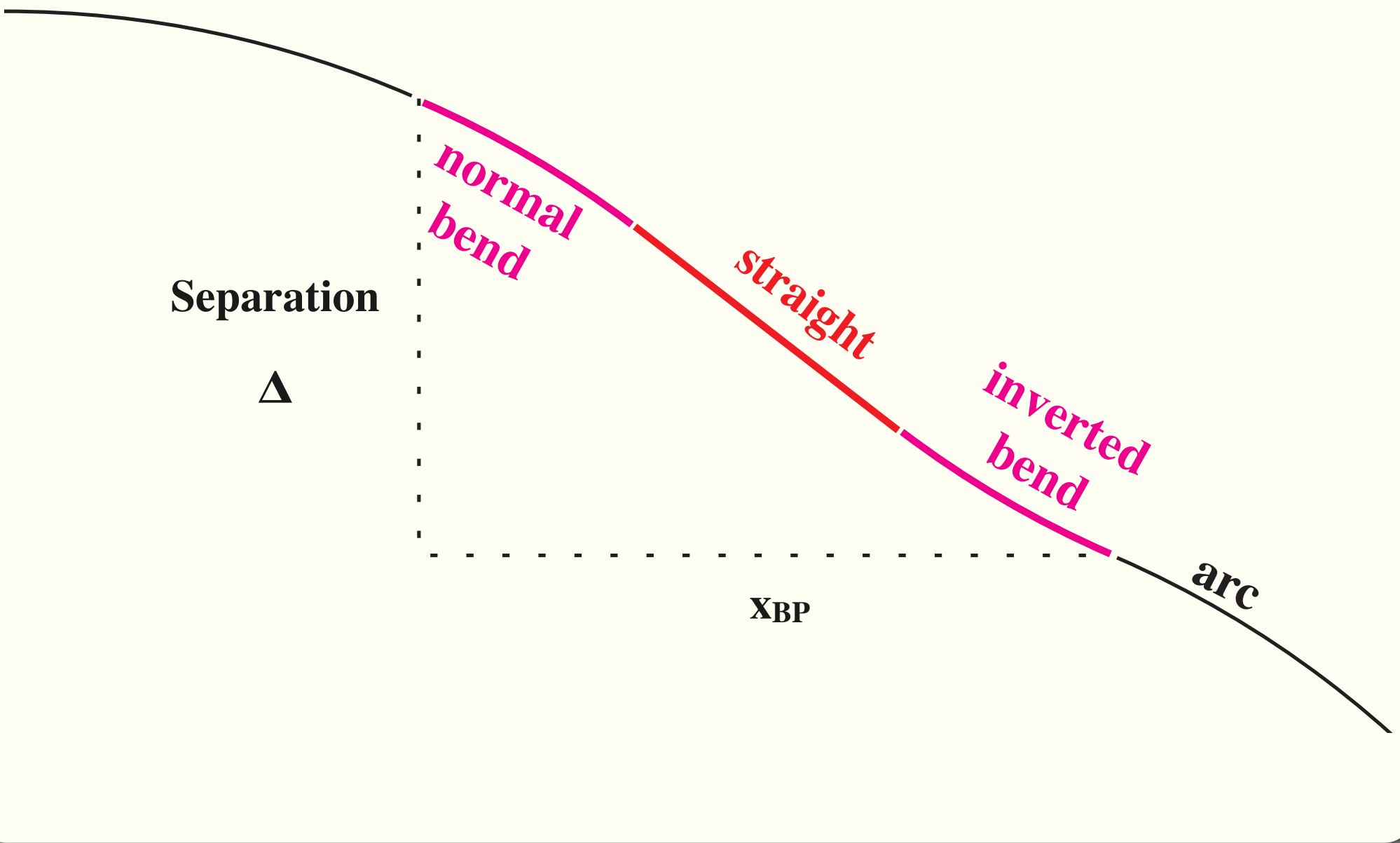
0-th iteration MAD-X lattice layout :

Δ = 10 m bypass.

Advantage : no extra power / radiation,
rather long, already about a 1 km !
for only 10 m separation



Bypass with few extra bends



Combined bypass layout for Δ = 13.35 m

1 inverted LEP cell (79 m) **+ straight + 1 normal bend cell**

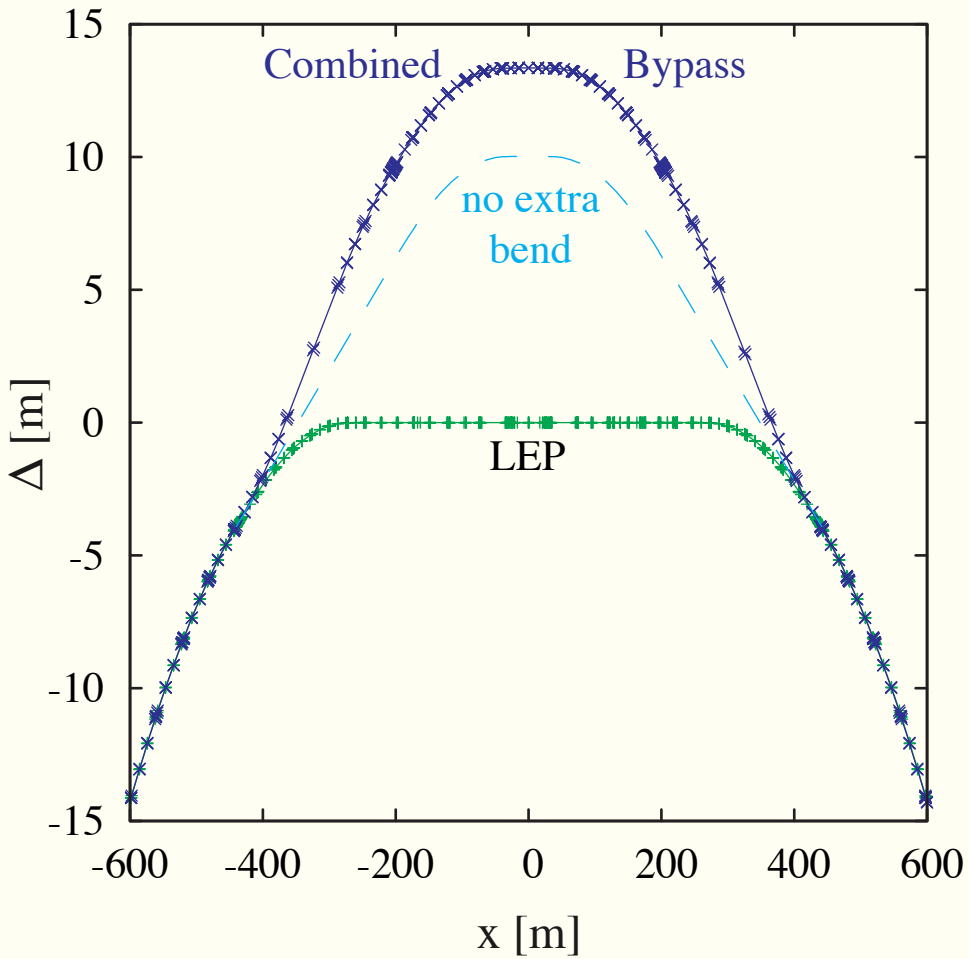
Per bypass 4 extra LEP cells.

Modest 4/244 = 1.6% increase in cells and energy loss.

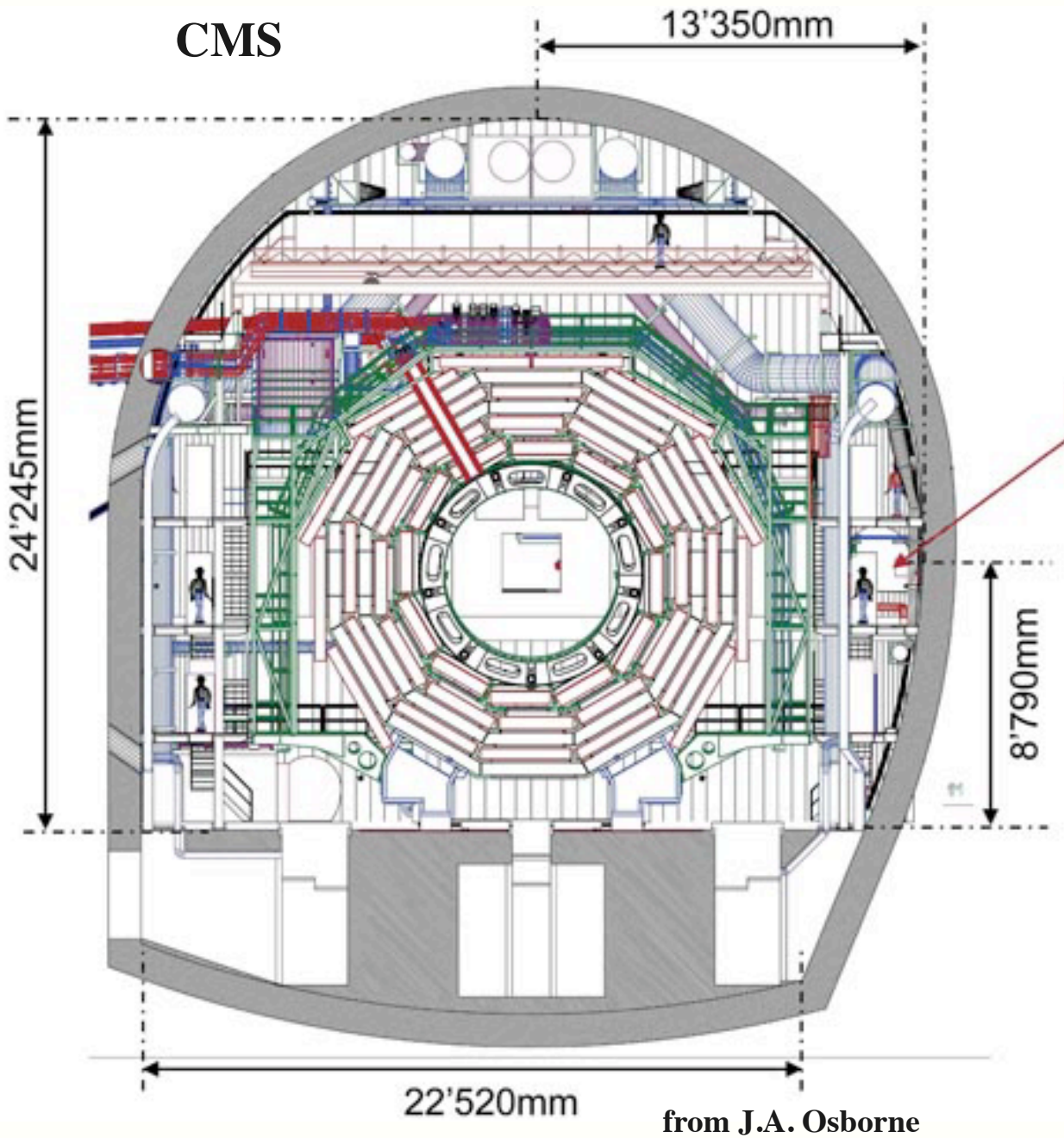
Starting bypass with QL18.L5
Total bypass length 880 m.
Full 13.35 m separation
29.5 m straight part at IP5.

β-functions well behaved with extra quad in inserted straights

Potential to further optimise - using full bends instead of 10 % bends at the arc ends.
Then full match including dispersion.



By-pass for IR1 and IR5



from J.A. Osborne

Transverse distance.
From proton to electron beam axis :

Δ = 13.35 m

using an existing survey gallery.

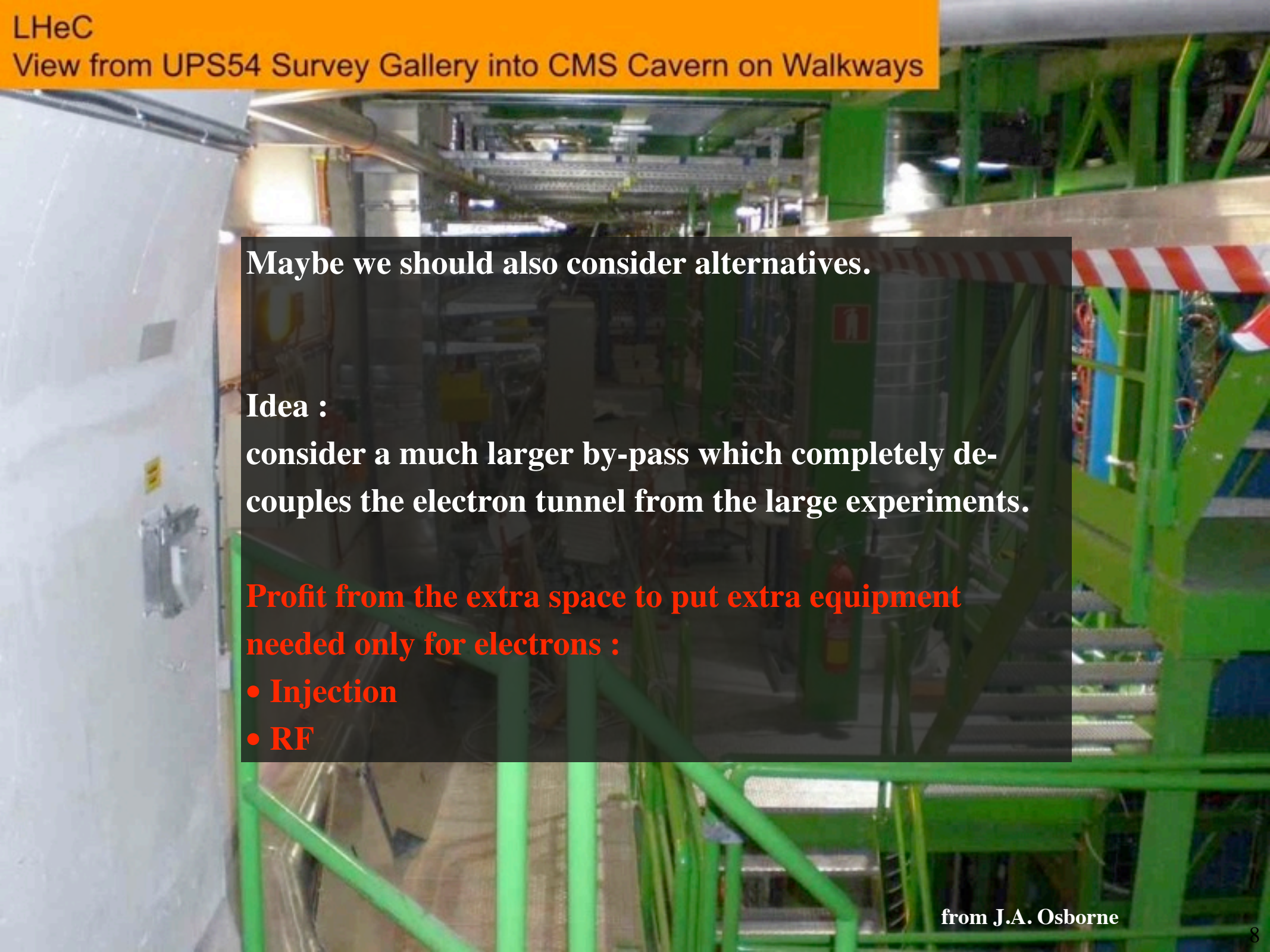
Is that realistic ?


LHeC
UPS 54 Survey Gallery
from J.A. Osborne


LHeC
UPS 54 Survey Gallery
Looks OK
from J.A. Osborne


LHeC
UPS 54 Survey Gallery
Looks OK
Now let us take a look close to CMS
from J.A. Osborne


LHeC
View from UPS54 Survey Gallery into CMS Cavern on Walkways
from J.A. Osborne



Maybe we should also consider alternatives.

Idea :
consider a much larger by-pass which completely de-couples the electron tunnel from the large experiments.

Profit from the extra space to put extra equipment needed only for electrons :

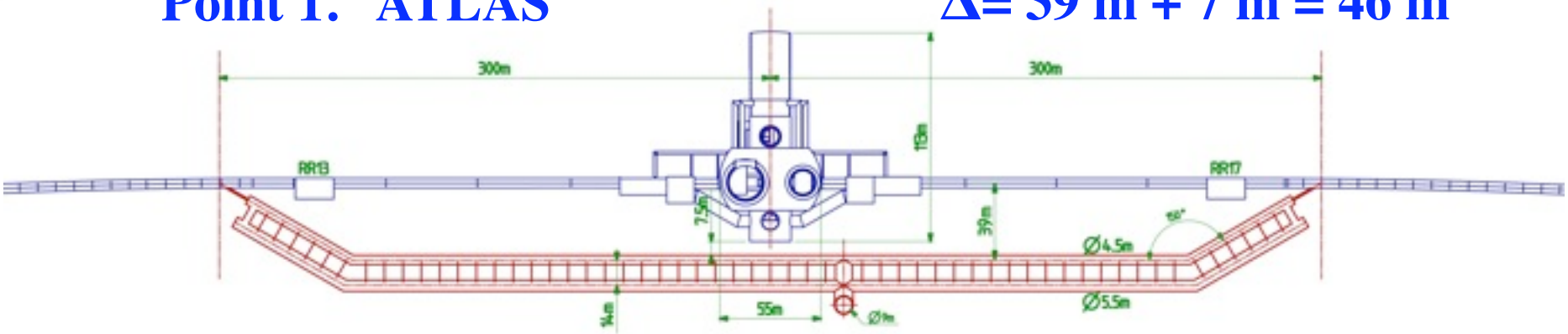
- **Injection**
- **RF**

from J.A. Osborne

Larger “de-coupled” by-passes

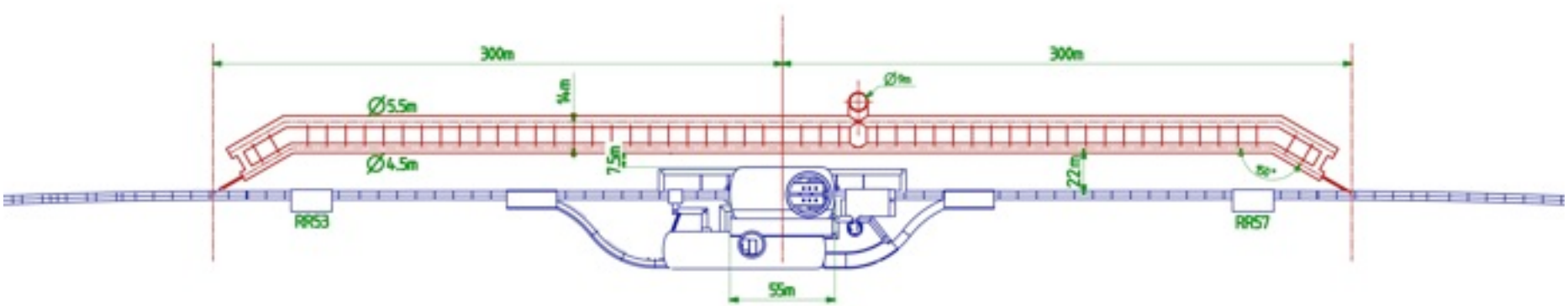
Point 1. ATLAS

Δ= 39 m + 7 m = 46 m



Point 5. CMS

Δ= 22 m + 7 m = 29 m



from J.A. Osborne

Larger by-pass with RF-section

RF requirements for 70 GeV. 1st estimate by Trevor Linnecar 10/2008:

in total about

540 m for klystron gallery

150 m beam-line with RF, spread out over ~ 540 m to match klystron gallery

best : symmetrically distributed in 4 by-pass pieces, or 4 × 135 m RF-sections

Tunnel sizes:

Beam tunnel same size as LHC tunnel.

Klystron gallery of ~ 5 m diameter, separated by 8 m from beam tunnel,

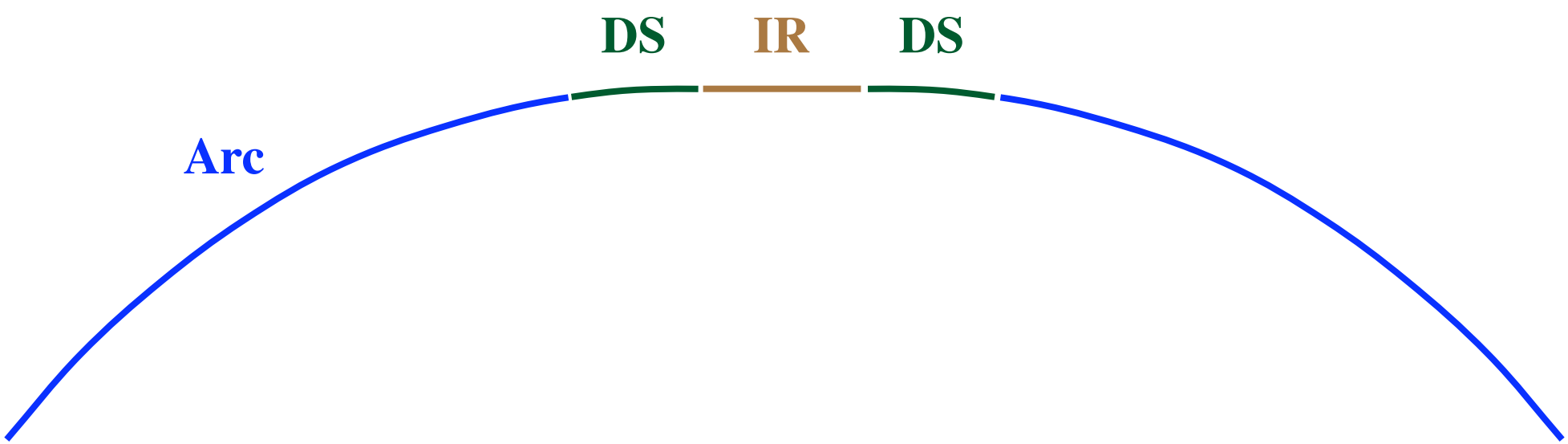
with holes to beam tunnel to take waveguides.

About 100 cavities, group 2 or 4 waveguides : 25 - 50 holes for waveguides

Not enough to reserve the space.

The significant Energy loss requires that the e-ring RF is in stalled in regions with negligible Dispersion !

Normal arc and IR



LEP lengths

79 m long cells ; bending angle of half cell 11.30640 mrad

from 3 × 11.55 m long dipoles

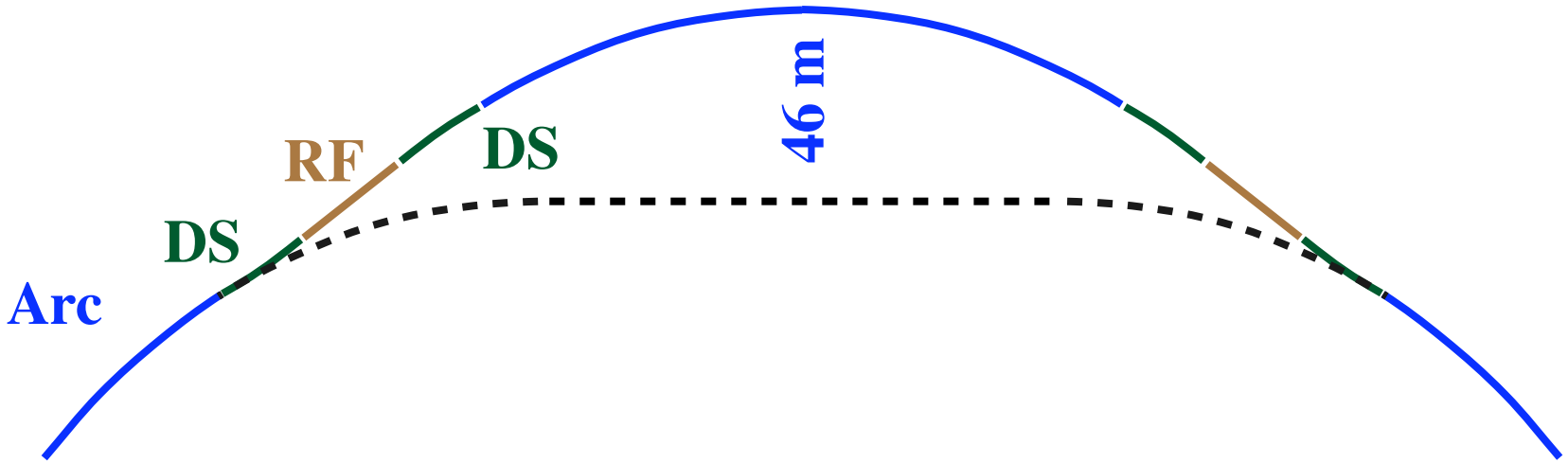
dipole bending radius ϱ = 3096.175 m

31 cells per octant; in total 8 × 31 = 244 cells

LEP DS : from start of QL18 440.8 m from IP to to start of QS11 245.6 m from IP

194.85 m 5 half cells

Design of larger by-passes



No more need for DS at IR.

Instead DS around RF sections

Preliminary length estimates

Arc end at LEP QF29 ~ 875 m from the IP,

~ 300 m for DS + RF + 575 m arc piece to "IP"

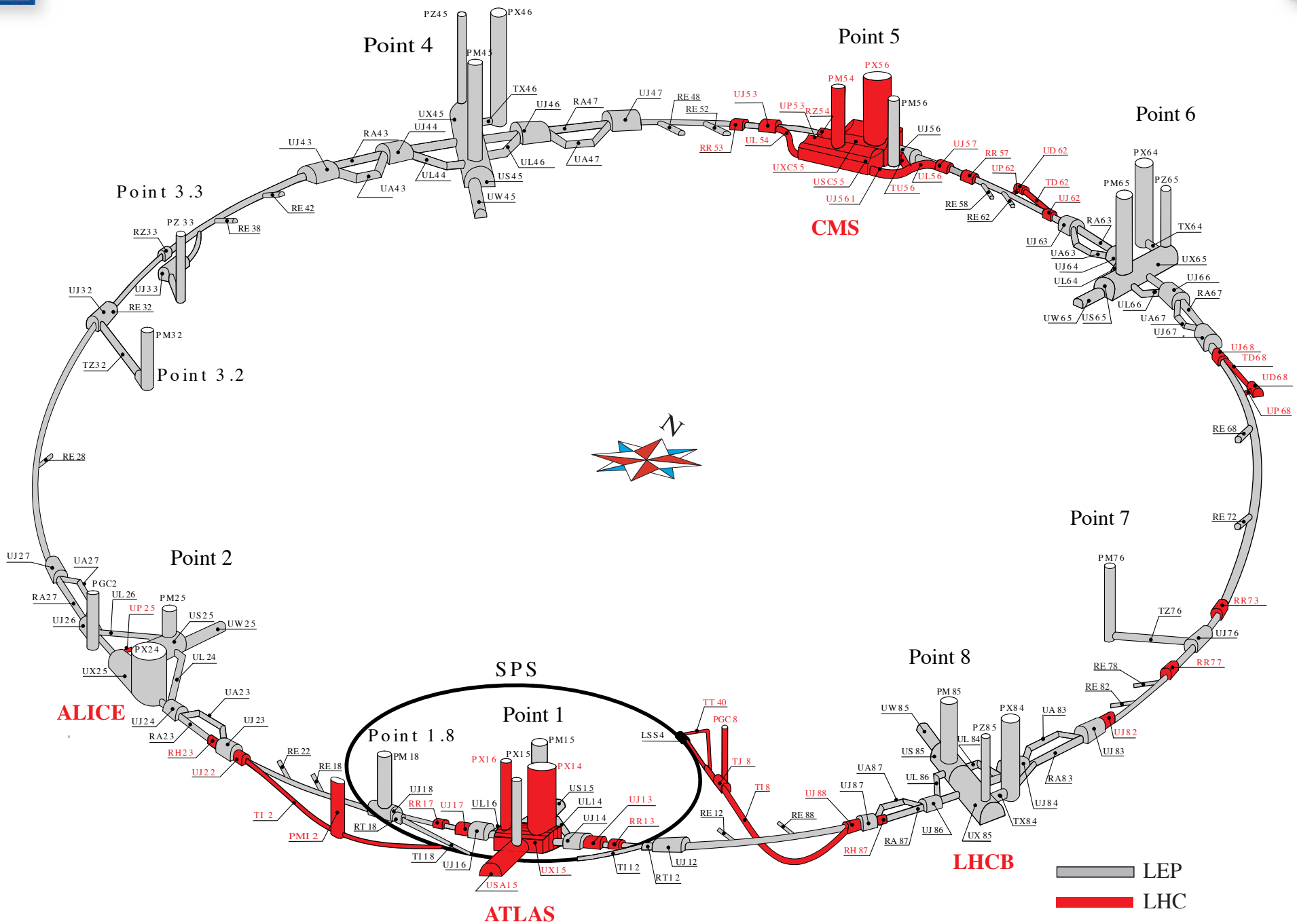
To be confirmed by : full lattice design - part of PhD thesis - starting soon

By-pass length and circumference

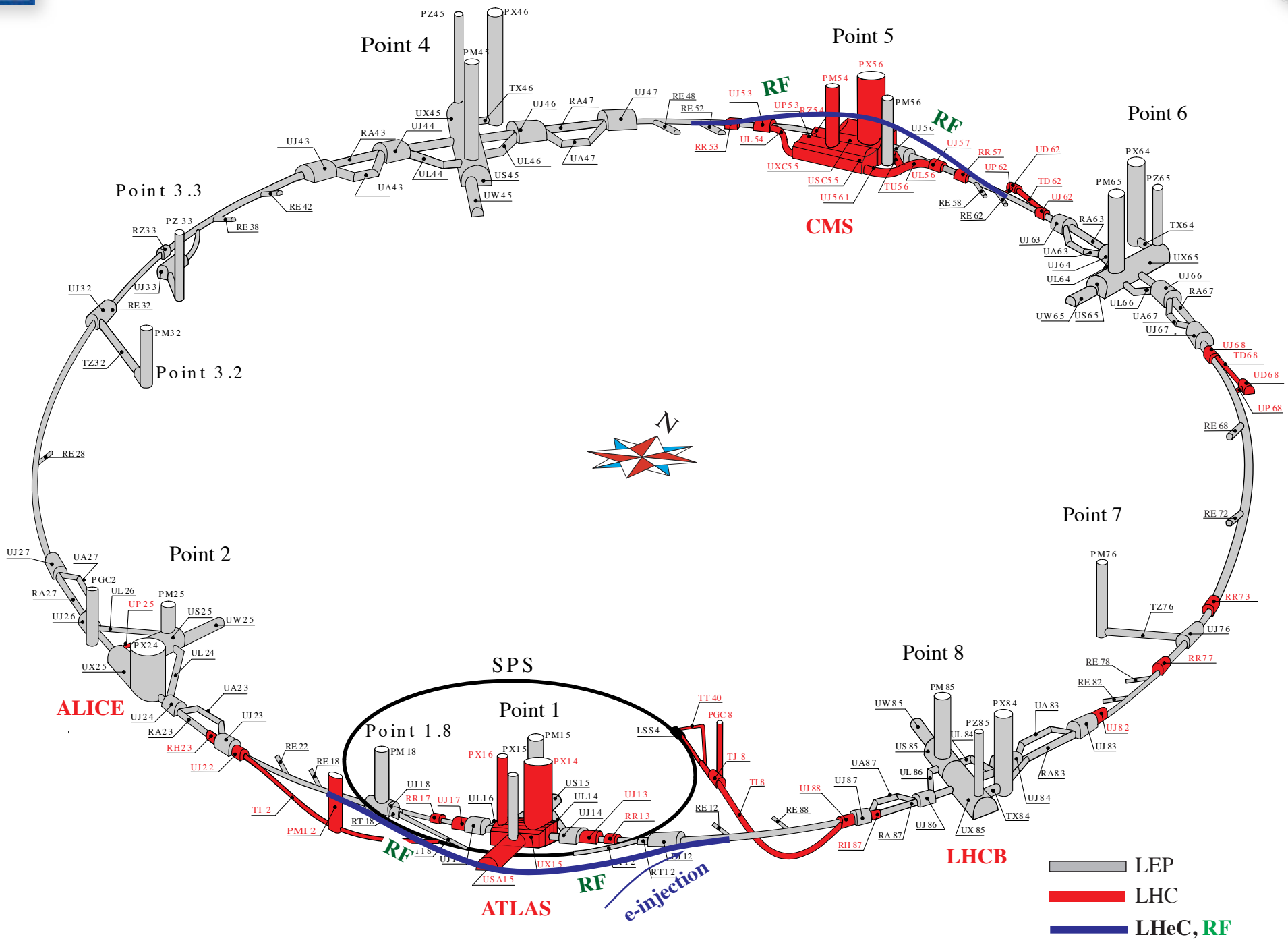
Keep equal circumference for the p and e rings.
Increase of the e-ring length by the by-passes.

By-passes, 46 m separation for ATLAS / IP1 and 29 m for CMS / IP5
Length increase
$2 \times (\sqrt{46m^2 + 875m^2} - 875\ m) +$
$2 \times (\sqrt{29m^2 + 875m^2} - 875\ m)$
$= 2 \times 1.2\ m + 2 \times 0.48\ m = 3.4\ m$
Compensate by a decrease in radius of $3.4\ m / 2\pi = 0.54\ m$
Symmetric case: $2 \times 1.2\ m = 4.8\ m$ $4.8\ m / 2\pi = 0.63\ m$

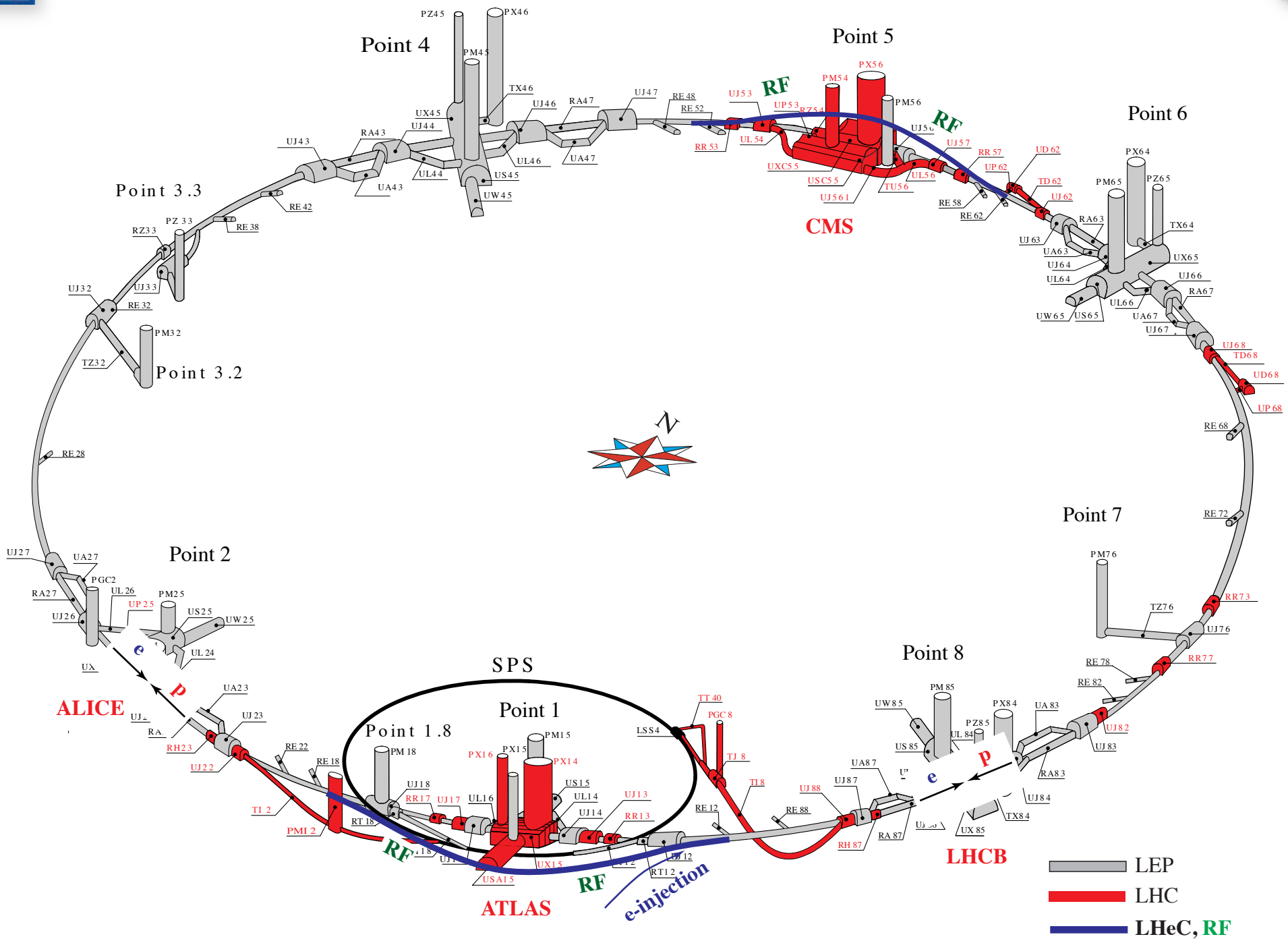
Layout


Point 4
Point 5
Point 6
Point 7
Point 8
Point 1
Point 2
Point 3.3
Point 3.2
Point 1.8
SPS
CMS
ALICE
ATLAS
LHCB
N
LEP
LHC

Layout, with larger, fully de-coupled by-passes



Layout, with larger, fully de-coupled by-passes



Backup Slides

LHeC injection

20 GeV or more like for LEP would be generous

Minimal injection energy : LEP was TMCI limited - here much less of an issue due to 10× reduced bunch intensities. Multi-bunch instab. - feedback.

Careful - make sure bunches no too short at injection and transverse impedance increase be smaller beam pipes than in LEP

Reasonable lower limit ~ 10 GeV (?)

Be able to fill reasonably fast - say within 10 min

low intensity 1.4×10^{10} / bunch – could do without accumulation

many (2800) bunches, 25 ns spacing, total intensity 3.92×10^{13} electrons

injection scheduling :

analog to protons (3 - 4 batches of nominally 72 bunches)

e+ and e– : no principle problem - needs extra e+ source and possibility to change polarities

Beam lifetime from ep collisions

ep cross section, leading to electron loss ~ 0.25 barn, mostly by Bremsstrahlung
lifetime, for single IP at 70 GeV with design parameters
Loss = 3.071e+08 Part/sec coll. lifetimes e =35.55 h p =431.7 h

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Part e+  P=    70 GeV, gamma= 136987,    Ne = 1.4e10 / bunch
Part p   P=     7 TeV, gamma=7460.52,    Np = 1.7e11 / bunch (ultimate intensity)
Lumi =  1.2140e+33 cm**-2 sec**-1
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Ee [GeV]	ξ_{xe}	ξ_{ye}	ξ_{xp}	ξ_{yp}
70 GeV	0.05042	0.05349	0.0005592	0.0002938