Divonne Summary of the Accelerator Working Group

- Two options have been analyzed for the LHeC accelerator installation:

  ➔ A Ring-Ring option featuring an additional lepton beam ring in the LHC tunnel as proposed by E. Keil in 1997 and in the paper by John, Max and Ferdi

  ➔ A Ring-Linac option that avoids the installation of an additional storage ring in the LHC tunnel

- The discussions at this workshop showed that both options can in principle provide collisions at the TeV scale (e.g. collisions between 60 GeV lepton and 7 TeV proton beams) with a luminosity of $L = 10^{33}$ cm^{-2} sec^{-2} in a parasitic mode to the nominal p-p program.

Summary of the Accelerator Working Group

- A wealth of of ideas:

  → We are still in the phase where we discover new ideas and proposals whenever we discuss challenges of the existing proposals.

  → The challenge might be how to focus this creativity into a conceptual design report by the end of 2009

  → We need to find the right balance between a conservative and innovative design

- The devil lies often in the details and insurmountable problems might only become visible during detailed studies.

  → Need to sketch both options for the LHeC in the conceptual design report

Divonne Summary of the Accelerator Working Group

- A Ring-Ring option for LHeC:

  → Based on the experience that a lepton storage ring with 60 GeV lepton beam energy can be build in the old LEP tunnel.

  → Main problems / challenges arise from conflict with the existing infrastructure of the LHC machine.

  → Limited in beam energy (E^4 dependence of SR power)

- A Ring-Linac option for LHeC:

  → Opens the door for lepton beam energies above 60 GeV.

  → Main problems / challenges arise from request for high luminosity at acceptable energy cost .

  → Requires significant amount of R&D.

Ring-Ring Option for the LHeC

→ We have a lot of experience with the design of such a machine (LEP, HERA) and sophisticated tools are at hand for the design and performance analysis of a lepton storage ring (J. Jowett, A. Kling)

→ Polarization might be challenging but is possible (D. Barber) (tools for studying polarization are well developed and at hand).

→ The old LEP lepton injector complex no longer exists and needs to be rebuild

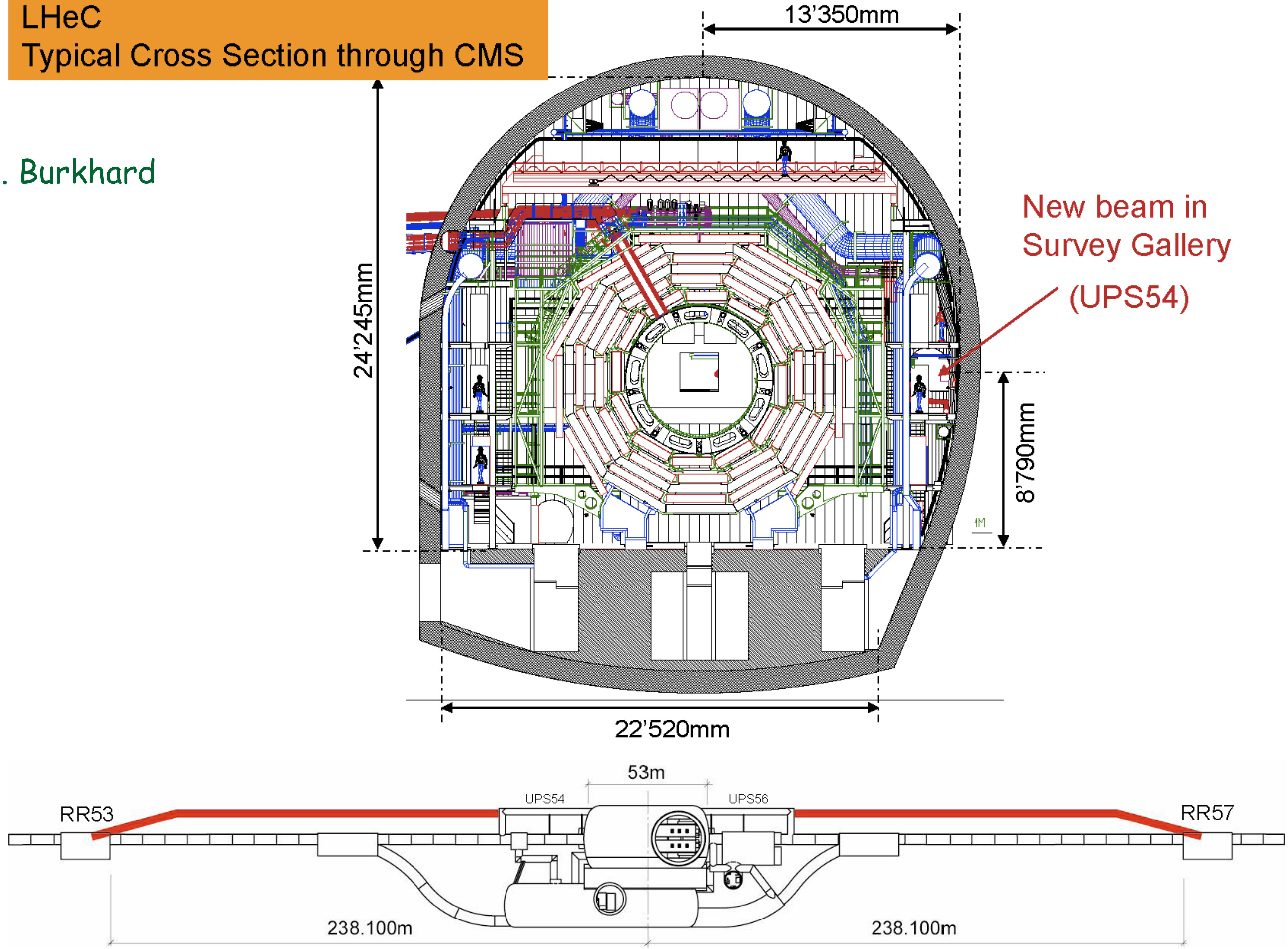
→ a solution might be at hand using the new SPL project.

Ring-Ring Option for the LHeC

- Parasitic operation mode with p-p program;
  - ➔ Need for bypassing the main LHC experiments (H. Burkhard) :
  - ➔ Requires a minimum of 1.5km new tunneling in the LHC (CMS & ATLAS)
  - ➔ 250m tunneling are estimated to be possible within 0.5 years.
  - ➔ Tunneling from within the existing LHC tunnel requires the removal of LHC magnets and the work in a controlled radiation area (K-H Mess)
  - ➔ Implication of radiation on installation work might be significant.
  - ➔ Bypassing other experimental insertions (e.g. IR 3 and IR7 might be impossible all together [water and radiation])

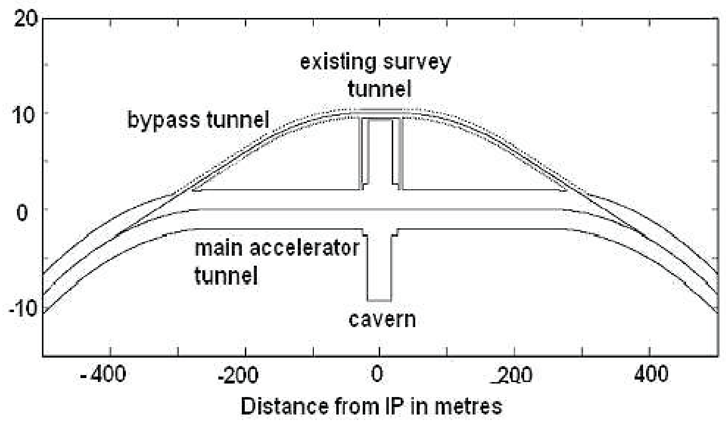
LHeC
Typical Cross Section through CMS

H. Burkhard



Type 1 bypass, no extra bends; Layout

schematic layout
Dainton / Willeke et al.



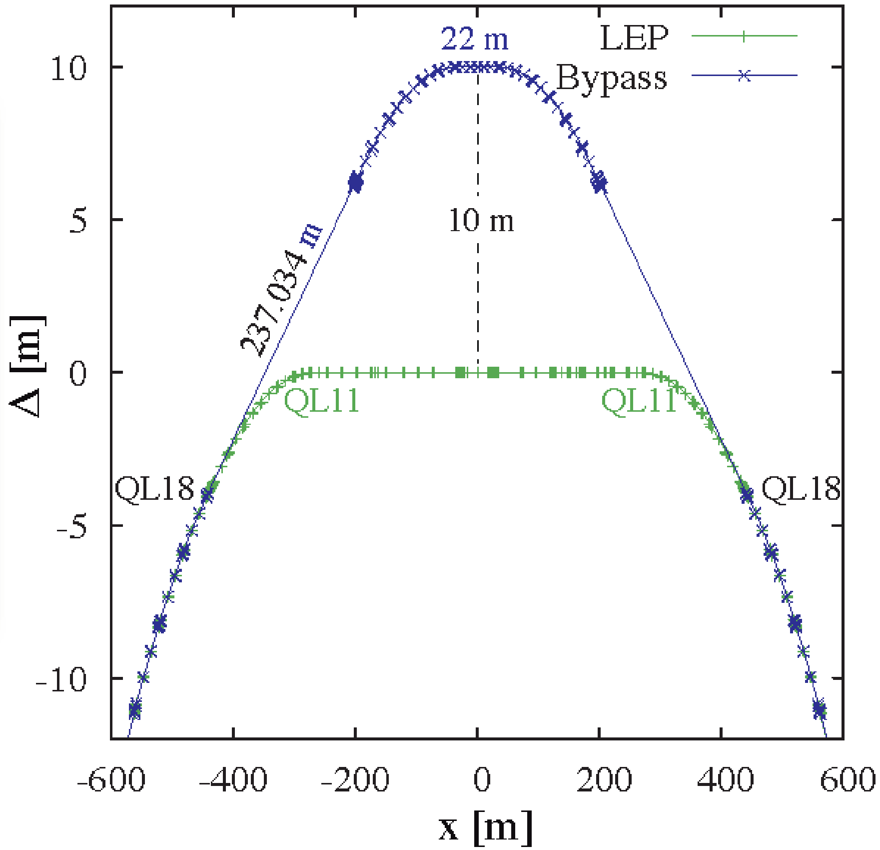
A bit more realistic :

0-th iteration MAD-X lattice layout :

Δ = 10 m bypass. As previously shown at DIS2008 and EPAC 2008

Advantage : no extra power / radiation,

but rather long, about a 1 km !



Ring-Ring Option for the LHeC

- The old underground space for the LEP RF system is no longer available (T. Linnecar):

  → Requires space for ca. 100 cavities (ca. 150m beam line)

  → requires 100 Klystrons (ca. 400m shielded space underground). (more bypasses?)

  → installation can be distributed over 2 or 4 insertions

  → space for Klystrons requires additional civil engineering unless the space in the old Klystron galleries can be liberated (cryo link development for the LHC power converters: R&D!)

  → Finding space for powering of the new lepton ring magnets is another issue (analyzing all this requires detailed layout plans!)

The accelerator has to be emptied up to at least 700m (LHC cell 14) on both sides.

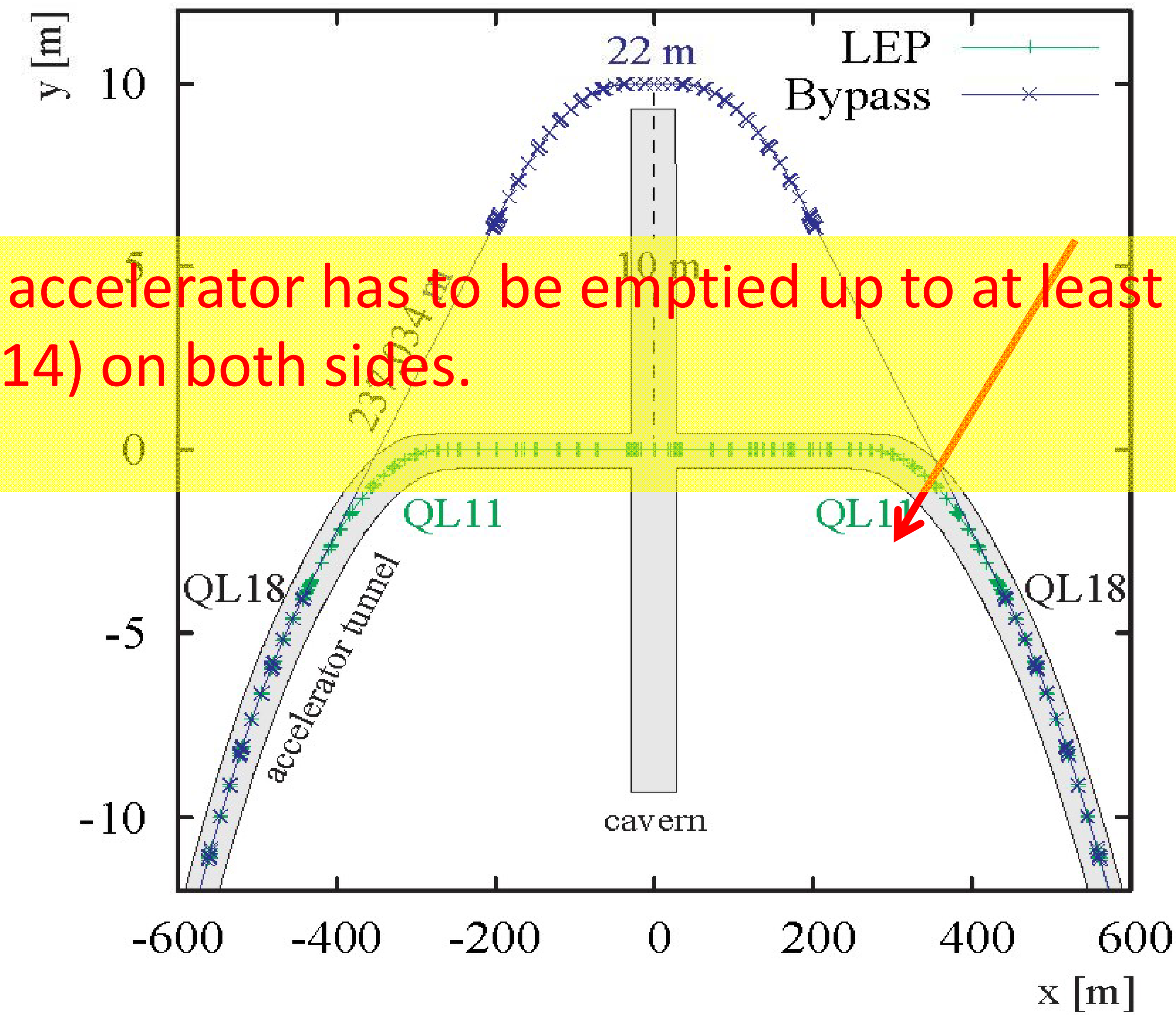


Figure 2: By-pass layout study, derived from the LEP lattice without addition of bending magnets. The y-scale is stretched by a factor of 50.

Ring-Ring Option for the LHeC

- Discussions after the workshop showed that civil engineering problems might be overcome by additional access tunnels.
  Quantifying this corresponding cost requires more detailed studies!

- Operation with large crossing angles (0.5mrad to 3 mrad) implies a significant loss in luminosity unless it can be corrected with CRAB cavities
  ➔ requires R&D (not yet used in hadron accelerators!)
  ➔ impact on p-p experiments!?
  ➔ synergy with R&D for the LHC upgrade program
  ➔ but who is doing the R&D?

Linac-Ring Option for the LHeC

- ➔ new concept and not much experience (we need a 60+GeV linac, probably with CW operation and with energy recovery)

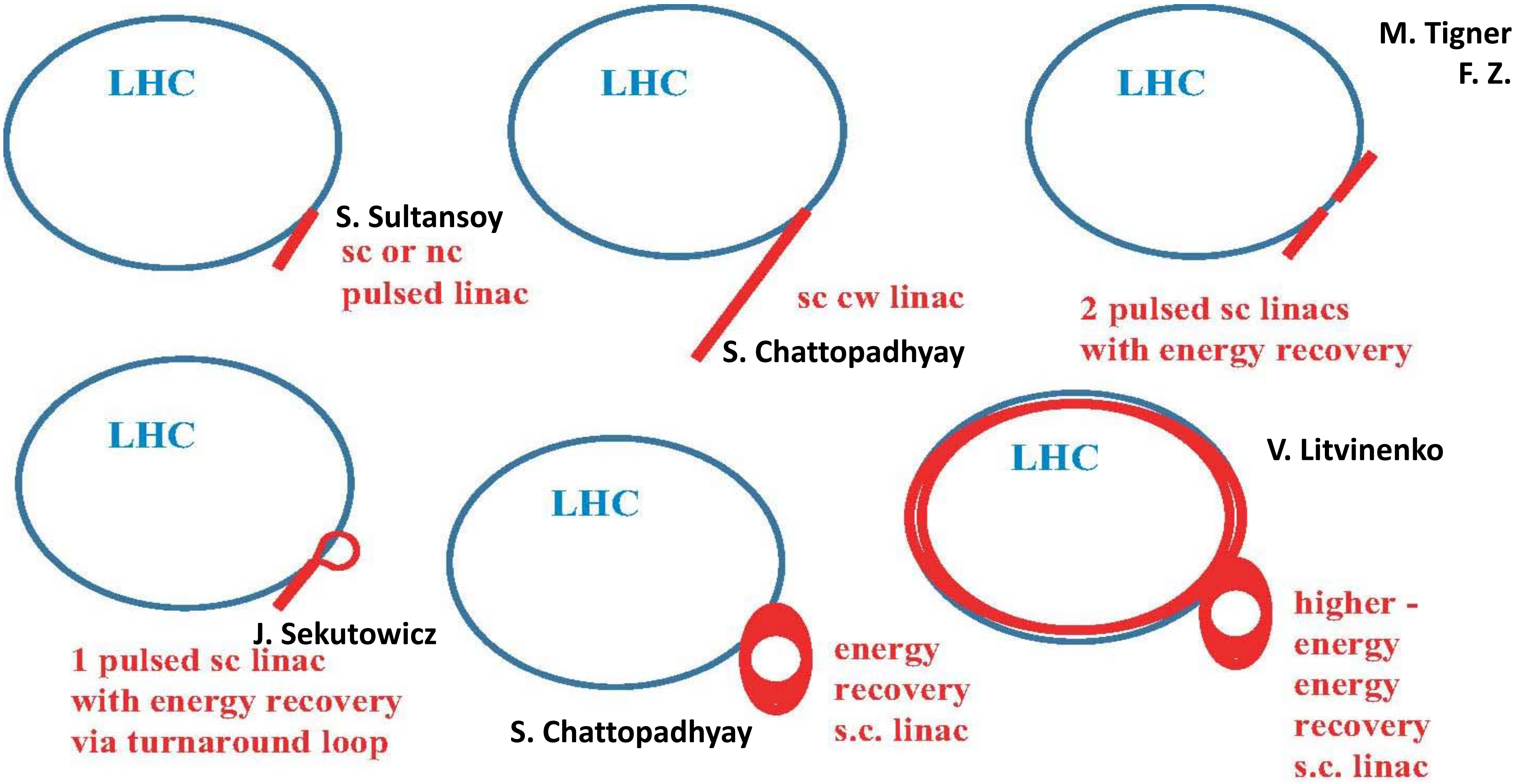
- ➔ this implies a lot of R&D and development of new tools / studies

- ➔ has the big advantage that it can largely decouple the construction from the LHC operation (not a strong argument anymore)

- ➔ compatibility of positron operation with energy recovery?

- ➔ might get by without the use of CRAB cavities

LR scenarios



Linac-Ring Option for the LHeC

- → There is still a wealth of proposals and ideas
- → we need to identify the most promising proposal and develop a detailed layout (pre-requisite for a conceptual design report and comparison with Ring-Ring option!)
- → agree on basic boundary conditions and parameters:

  100MW wall power consumption

  $L = 10^{33}$ cm^{-2} sec^{-1} luminosity

  Beam energy of 60 GeV or more

  10 degrees detector acceptance

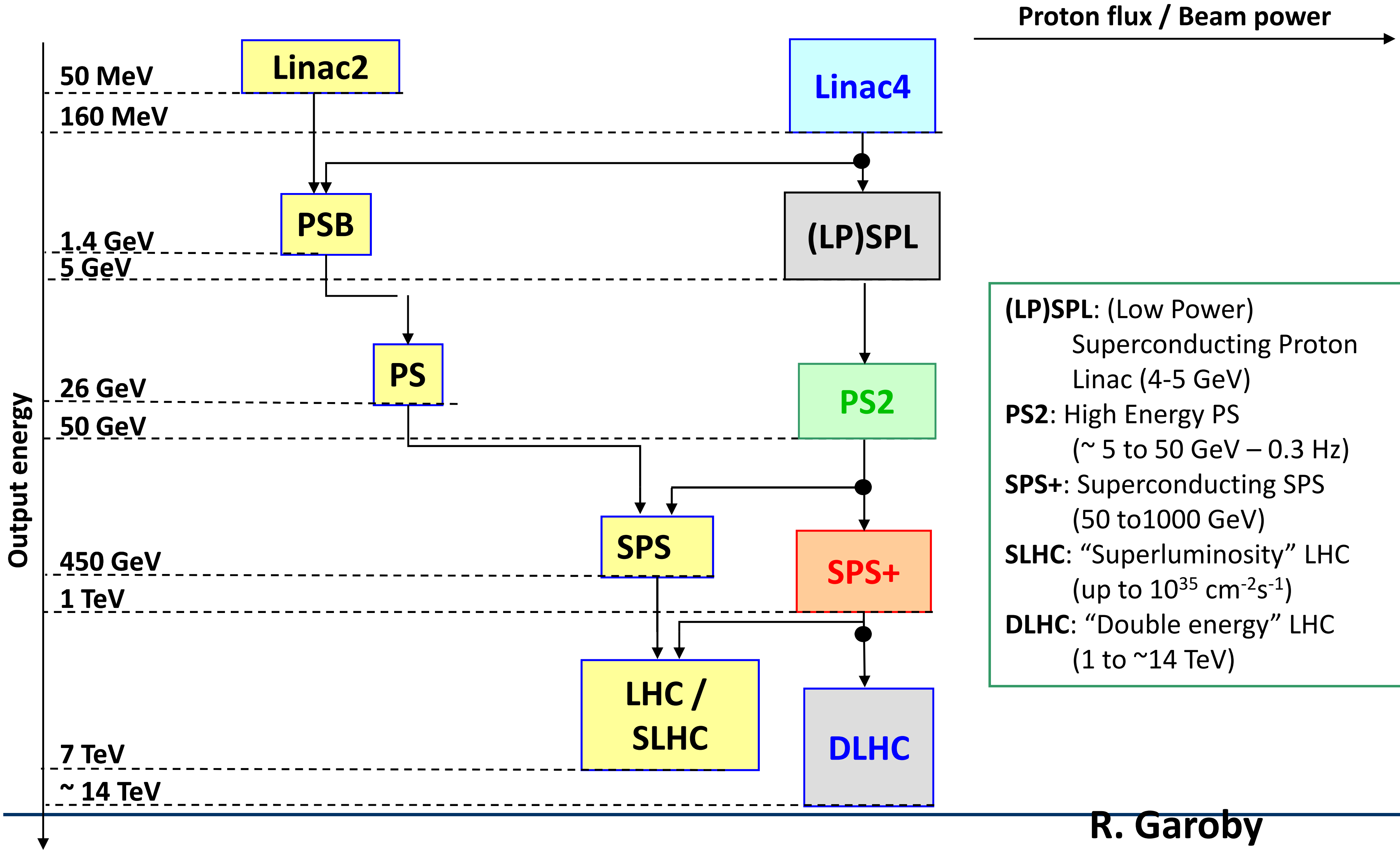
  L* = 2m (→ integrated magnets inside the detector)

  proton beam parameters as defined in the LHC upgrade program

e- energy [GeV]	5	15	20	20	60	60	140
comment	SPL*	SPL*	SPL*	SPL*	new	new	new
#passes	1	3	4	4	3	3	2
wall plug power RF+Cryo **[MW]**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
energy recovery efficiency [%]	**0**	**0**	**0**	**66**	**0**	**98**	**98**
bunch population [10^9]	**64**	**21**	**16**	**50**	**0.25**	**12**	**3.8**
duty factor [%]	5	5	5	5	100	100	100
average e- current [mA]	**10**	**4**	**3**	**8**	**0.8**	**38**	**12**
emittance $\gamma\varepsilon$ [μm]	20	40	50	50	50	50	50
RF gradient [MV/m]	25	25	25	25	10	10	10
total linac length β=1 [m]	350	350	350	350	3300	3300	11700
minimum return arc radius [m]	-	6	22	22	377	377	1520
beam power at IP [MW]	50	50	50	160	50	2300	1700
e- IP beta function [m]	**0.025**	**0.035**	**0.04**	**0.04**	**0.1**	**0.1**	**0.3**
ep hourglass reduction factor	0.5	0.6	0.6	0.6	0.8	0.8	0.9
disruption parameter D	336	112	84	84	28	28	12

, σ_z=11.8 cm

CERN p accelerator upgrade



(LP)SPL: (Low Power)
Superconducting Proton
Linac (4-5 GeV)
PS2: High Energy PS
(~ 5 to 50 GeV – 0.3 Hz)
SPS+: Superconducting SPS
(50 to1000 GeV)
SLHC: “Superluminosity” LHC
(up to 10^{35} $cm^{-2}s^{-1}$)
DLHC: “Double energy” LHC
(1 to ~14 TeV)

R. Garoby

F. Zimmermann

Linac-Ring Potential

100 MW wall plug power

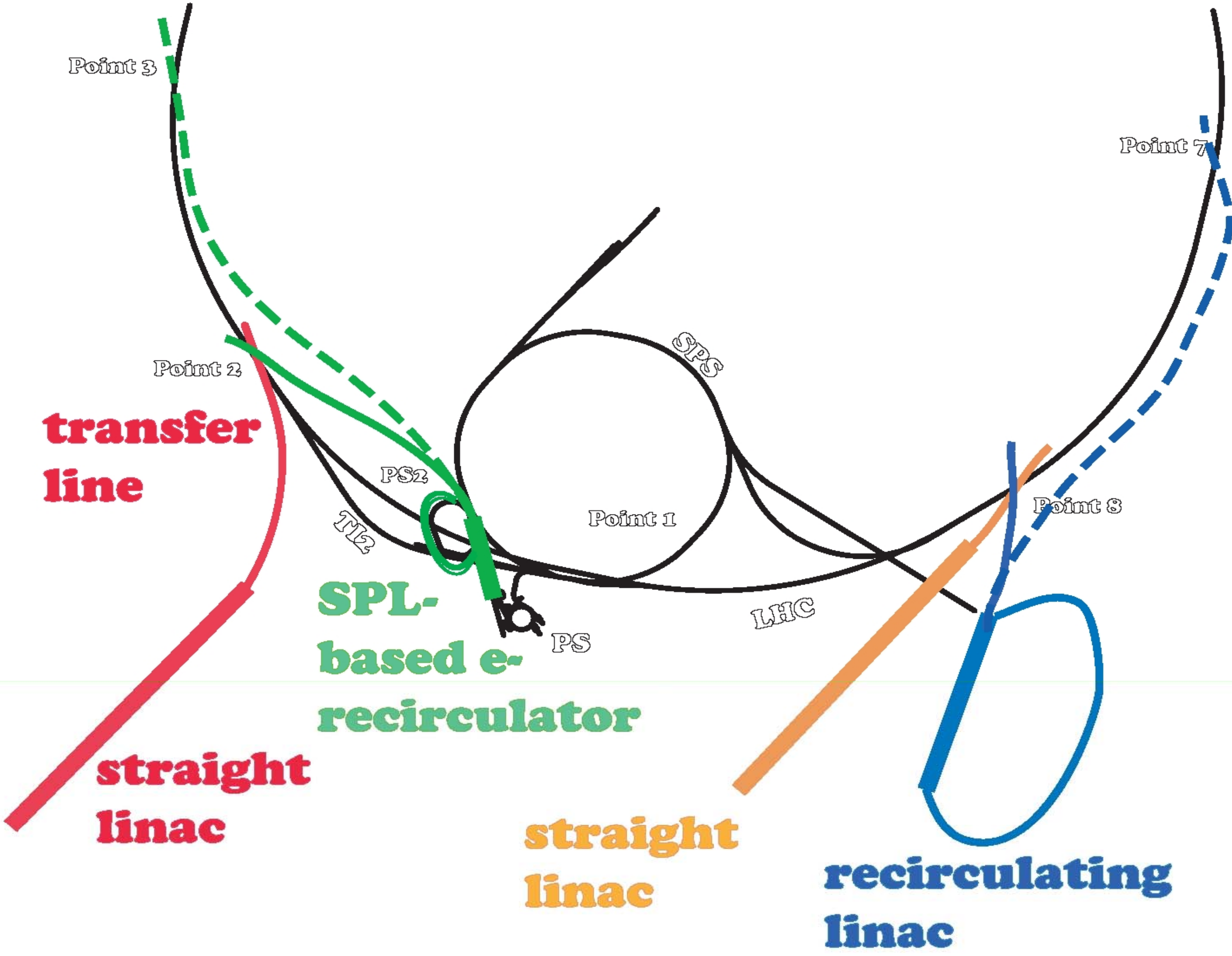
20 GeV 98% energy recovery	**60 GeV w/o energy recovery**	**60 GeV 98% energy recovery**	140 GeV 98% energy recovery
5×10^{34} $cm^{-2}s^{-1}$	**5×10^{32} $cm^{-2}s^{-1}$**	**1×10^{34} $cm^{-2}s^{-1}$**	4×10^{33} $cm^{-2}s^{-1}$

proton parameters from LHC "phase-2" upgrade

N_b=5×10^{11}, 50 ns spacing, $\gamma\varepsilon$=3.75 μm, β^*=0.1 m

example linac layouts at CERN

J. Osborne, F. Z.



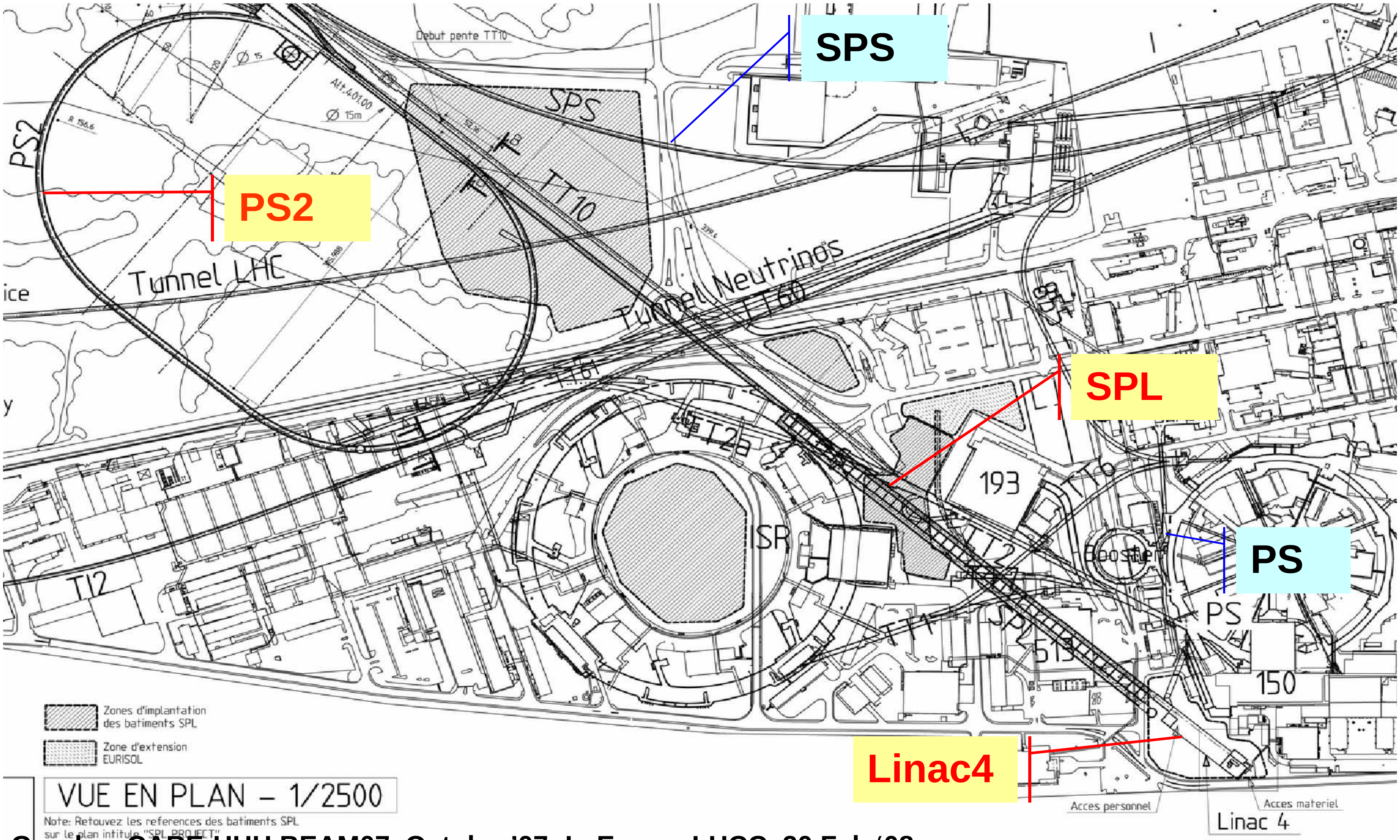
Linac-Ring Option for the LHeC

- ➔ we need more detailed layout plans for each proposed case in order to select a good solution for the conceptual design report
  ➔ CERN needs more help from other laboratories!

- ➔ there are many synergies with other projects (e.g. ILC, LHC upgrade, eRHIC, HIE-Isolde, SPL etc)
  ➔ help and expertise from other laboratories is much welcomed!

- ➔ option of a re-circulating electron linac based on the new SPL
  ➔ interesting option for a new lepton injector complex (RR option)
  ➔ interesting? option for a low cost first stage of the LHeC with collisions between 20 GeV electrons and 7 TeV protons

layout of the new injectors



R. Garoby, CARE-HHH BEAM07, October'07; L. Evans, LHCC, 20 Feb '08

Conceptual Design Report Preparation

- The workshop showed that both options (RR and LR) can provide the requested performance for the LHeC

- We should prepare conceptual design proposals for both options
  ➔ (this was also done for eRHIC)
  ➔ this implies more work!!! But we do not know yet the hard limits!

- The workshop identified a large ‘to do’ list. We have to well organize the follow-up work in order to meet the 2009 deadline for the conceptual design report

What have we Done Since Divonne?

- Discussion on civil engineering work for Ring-Ring option bypasses
  - ➔ should be possible to decouple LHC operation from bypass construction
- Recirculation Linac options for the SPL:
  - ➔ launched studies with a new student
  - ➔ more results within one year
- Discussed in more detail possible synergies between Ring-Linac option and ILC at CERN
  - ➔ synergies are not obvious
- Discussion on parameters sets for both LHC Phase II upgrade options

Recent Linac-Ring Scenarios

- SPL with ERL + TI2 with single-pass
- 6 km pulsed, continuous
- highest gradient, 120 GeV

(Frank Zimmermann)

QuickTime™ and a
decompressor
are needed to see this picture.

e- energy [GeV]	30	100	100	120
comment	SPL* (20)+TI2	new	new	new
#passes	4+1	2	2	2
wall plug power RF+Cryo **[MW]**	**100 (1 cr.)**	**100 (3 cr.)**	**100 (35 cr.)**	**100 (50 cr.)**
energy recovery efficiency [%]	**0**	**0**	**0**	**0**
bunch population [10^9]	**10**	**3.0**	**0.1**	**0.06**
duty factor [%]	**5**	**5**	**100**	**100**
average e- current [mA]	**1.6**	**0.5**	**0.3**	**0.2**
emittance $\gamma\varepsilon$ [μm]	50	50	50	50
RF gradient [MV/m]	25	25	13.9	16.7
total linac length $\beta=1$ [m]	350+333	3300	6000	6000
minimum return arc radius [m]	240 (final bends)	1100	1100	1900
beam power at IP [MW]	48	48	30	22
e- IP beta function [m]	**0.06**	**0.2**	**0.2**	**0.23**
ep hourglass reduction factor	0.62	0.86	0.86	0.86
disruption parameter D	56	17	17	14
luminosity [10^{32} cm^{-2} s^{-1}]	**5**	**2.2**	**1.3**	**0.8**

QuickTime™ and a decompressor are needed to see this picture.

, σ_z=11.8 cm

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What have we Done Since Divonne?

- The workshop identified a large 'to do' list. We have to well organize the follow-up work in order to meet the 2009 deadline for the conceptual design report:
  - ➔ Tried creation or 'work packages' for some collaborators
    - ➔ unfortunately no commitment yet!
  - ➔ Desperately need more detailed studies on integration issues for Ring-Ring option: magnet and vacuum system design and powering
  - ➔ Need design effort for 1 degree acceptance option

LHeC Collaboration

Main Study areas for the LHeC that need to be addressed in time for the 2008 September workshop in Divonne:

Ring-Ring option:

1.1) Lattice design for a ring-ring option: CERN contact: **Oliver Br□ning**

Work packages:

i. Lattice design of the main arcs including specifications for the required vacuum chamber dimensions -> **John Jowett** (CERN)
ii. Synchrotron radiation calculations and Layout design of the bypasses **-> Helmut Burkhardt** (CERN)
iii. LHeC IR optics design **-> Bernhard Holzer** (DESY)

1.2) RF design for the ring-ring option: CERN contact: **Trevor Linnecar**

Work packages:

i. RF design (total length, required cavities and RF power)
ii. Space estimate for the alcoves / bypasses for cavities and klystrons

1.3) Injector complex design: CERN contact: **Helmut Burkhardt**

Work packages:

i. Electron and positron source design
ii. Injector ring design

1.4) Injection areas and beam dump aspects: CERN contact: **Brennan Goddard**

Work packages:

i. Interaction region design for a ring-ring option
ii. Transfer line design
iii. Beam dump line and beam dump design

1.5) Beam-Beam effects CERN contact: **Werner Herr**

Work packages:

i. Head-on beam-beam limit
ii. Long range beam-beam effects and required crossing angle
iii. Multi bunch beam-beam effects
iv. Coupling between p-p and p-e collisions

2.6) Vacuum aspects CERN contact: **Migule Jimmenez**

Work packages:

1) Specification of vacuum requirements
2) Layout vacuum design
3) Vacuum Engineering: can be a work package (bellows, plug in modules, magnet chambers...)
4) Vacuum studies
5) Vacuum Instrumentation & Interlocks

2.7) Integration and machine protection issues CERN contact: **K-H. Mess**

Work packages:

i. Space requirements in the electron injection and ejection areas
ii. Space requirements for the power converters and other electronics
iii. Space requirements for the electron dump
iv. Space requirements for the electronics in the LINAC
v. Impact of the synchrotron radiation on the electronics in both tunnels
vi. Machine Protection System for the LINAC
vii. Compatibility with the proton beam loss system
viii. Protection of the p-machine against heavy electron losses

2.8) IR Layout for linac-ring scenarios CERN contact: **D. Schulte**

Work packages:

1) Magnet and detector layout, β^*, three-beam orbits & separation
2) IR optics, β^*, crab waist

2.9) Magnet issues CERN contact: **D. Tommasini**

Work packages:

i. Magnet coil design (main dipole and quadrupole and corrector magnets)
ii. Magnet infrastructure specification (cooling, ventilation etc...)
iii. Specification of space and support requirements

2.10) Powering issues CERN contact: **F. Bordry**

Work packages:

i. Specification of space and infrastructure requirements