Upgrade scenario for the LHC complex

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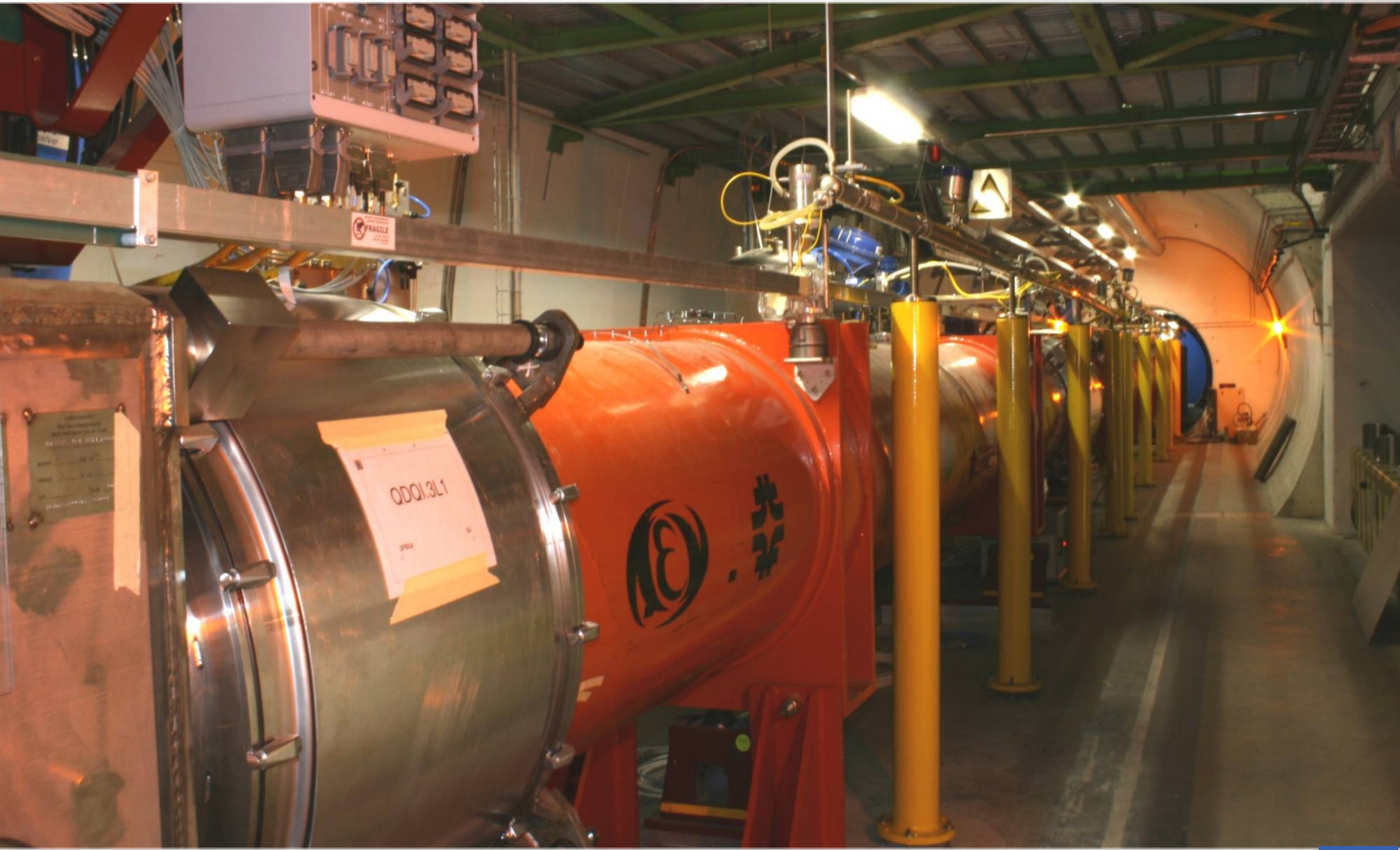
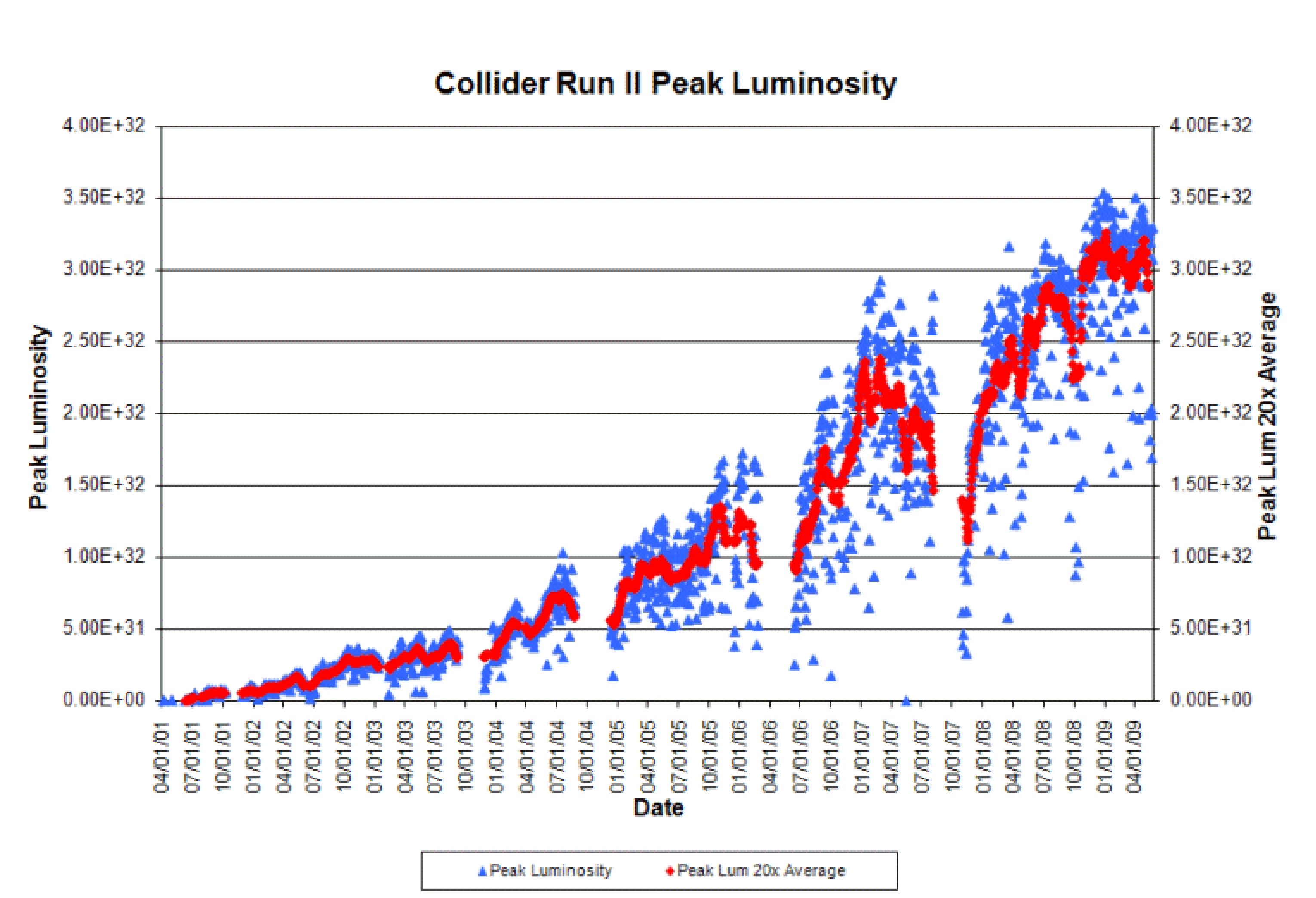


sLHC Seminar, CERN 8th June 2009

Tevatron luminosity evolution



Peak Luminosity

$$L = \frac{N_b^2 n_b f_r \gamma}{4\pi\varepsilon_n \beta^*} F$$

N_b number of particles per bunch

n_b number of bunches

f_r revolution frequency

ε_n normalised emittance

β^* beta value at Ip

F reduction factor due to crossing angle

N_b, ε_n → injector chain

β^* → LHC insertion

F → beam separation schemes

n_b → electron cloud effect

LHC Upgrade-Phase I

Goal of "Phase I" upgrade:

Enable focusing of the beams to $\beta^*=0.25$ m in IP1 and IP5, and reliable operation of the LHC at double the operating luminosity on the horizon of the physics run in 2013.

Scope of "Phase I" upgrade:

1. Upgrade of ATLAS and CMS experimental insertions. The interfaces between the LHC and the experiments remain unchanged at $\pm$ 19 m.
2. Replace the present triplets with wide aperture quadrupoles based on the LHC dipole cables (Nb-Ti) cooled at 1.9 K.
3. Upgrade the D1 separation dipole, TAS and collimation system so as to be compatible with the inner triplet aperture.
4. The cooling capacity of the cryogenic system and other main infrastructure elements remain unchanged.
5. Modifications of other insertion magnets (e.g. D2-Q4) and introduction of other equipment in the insertions to the extent of available resources.

Participants and Milestones

Several departments are involved in the “Phase I” project:

TE Department: low-beta quadrupoles and correctors, D1 separation dipoles, magnet testing, magnet protection and cold powering, vacuum equipment, QRL modifications.

BE Department: optics and performance, power converters, instrumentation, TAS and other beam-line absorbers, …

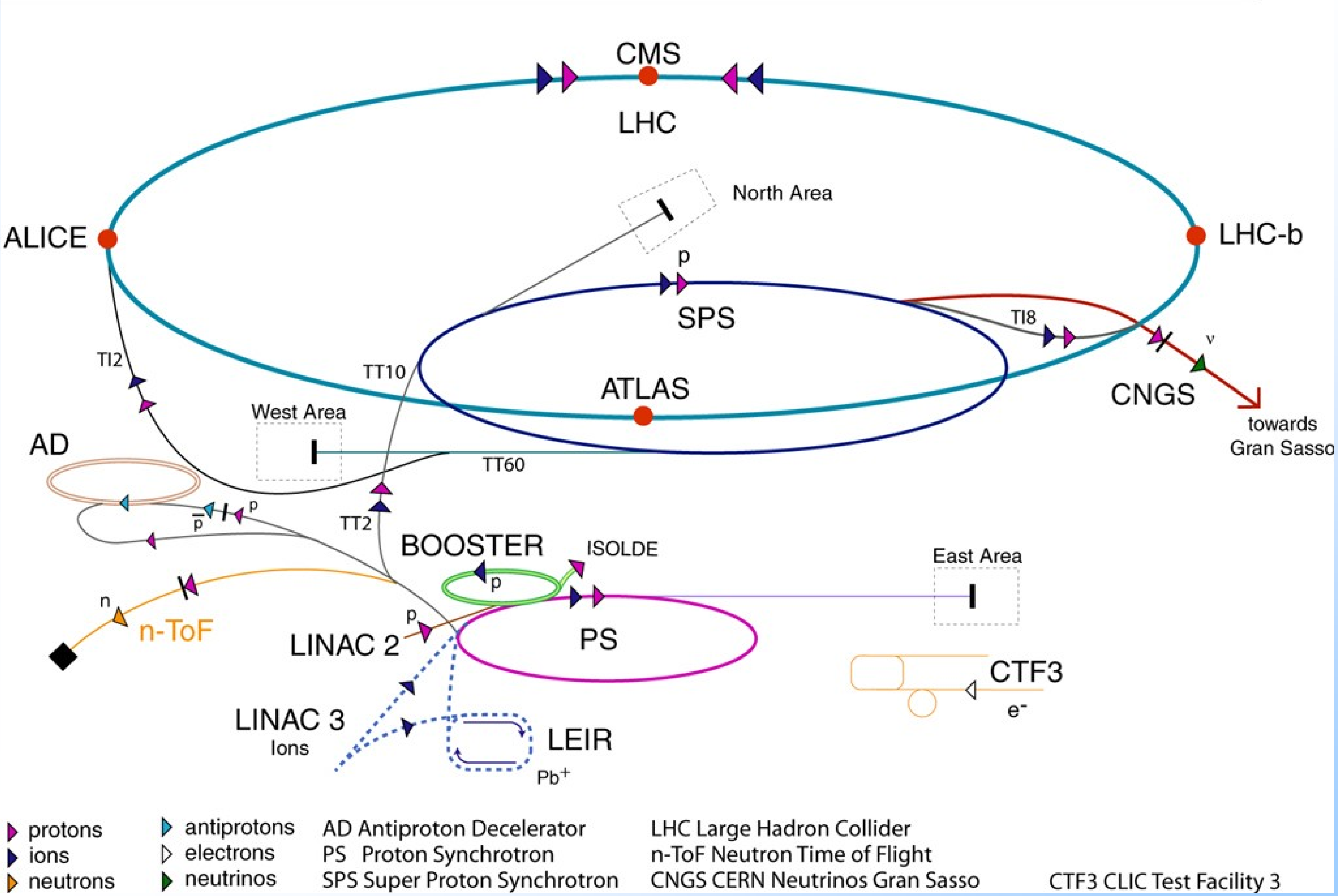
EN Department: cryostat support and alignment equipment, interfaces with the experiments, installation, design effort, …

SLHC-PP collaborators.

Milestones:

Conceptual Design Report	mid 2008
Technical Design Report	mid 2009
Model quadrupole	end 2009
Pre-series quadrupole	2010
String test	2012
Installation	shutdown 2013

CERN accelerator complex



Present limitations

1. Lack of reliability:

Ageing accelerators (PS is 48 years old !) operating far beyond initial parameters

➡ need for new accelerators designed for the needs of SLHC

2. Main performance limitation:

Excessive incoherent space charge tune spreads DQSC at injection in the PSB (50 MeV) and PS (1.4 GeV) because of the high required beam brightness N/e*.

$$\Delta Q_{SC} \propto \frac{N_b}{\varepsilon_{X,Y}} \cdot \frac{R}{\beta\gamma^2}$$

with N_b : number of protons/bunch

$\varepsilon_{X,Y}$: normalized transverse emittances

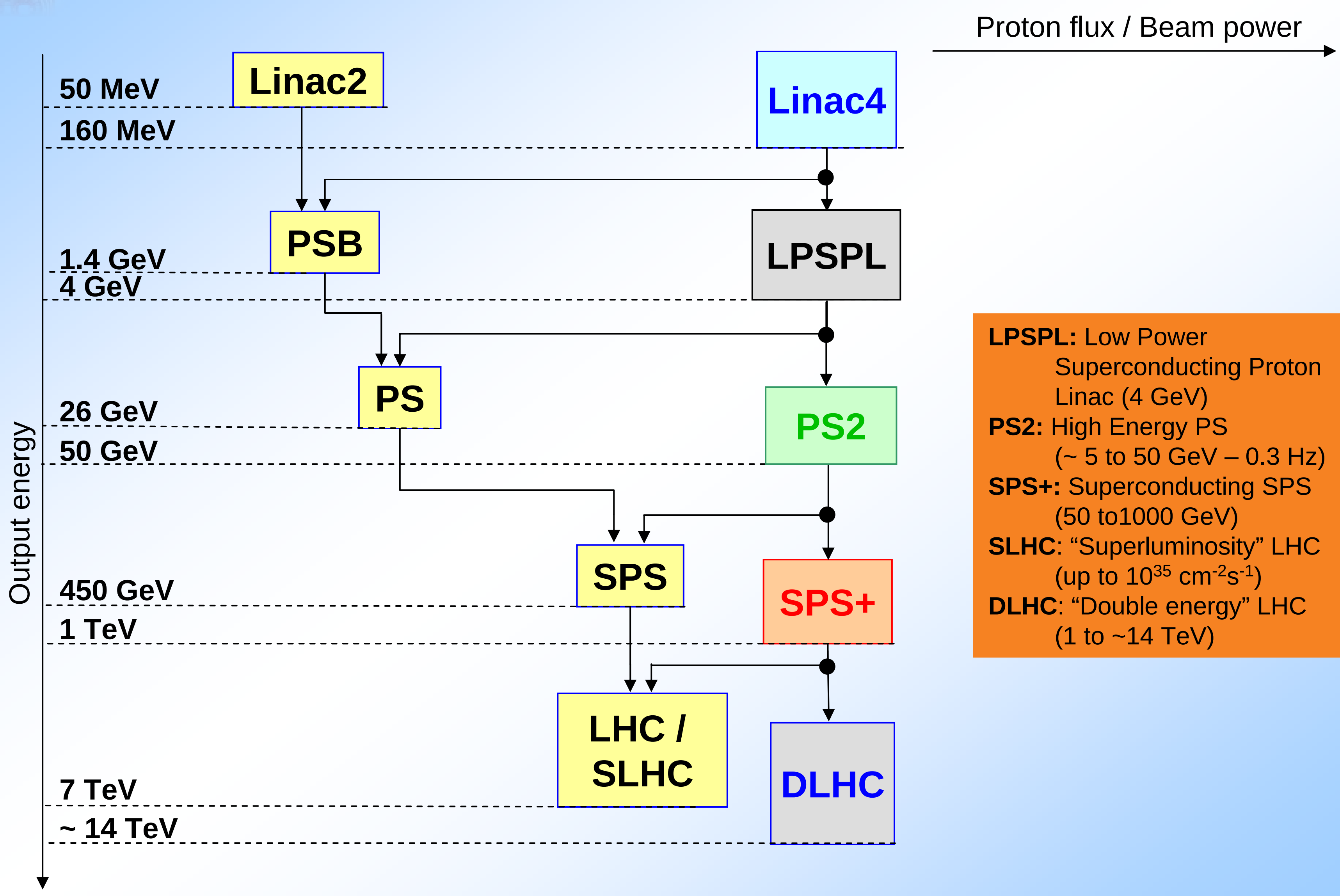
R : mean radius of the accelerator

$\beta\gamma$: classical relativistic parameters

➡ need to increase the injection energy in the synchrotrons

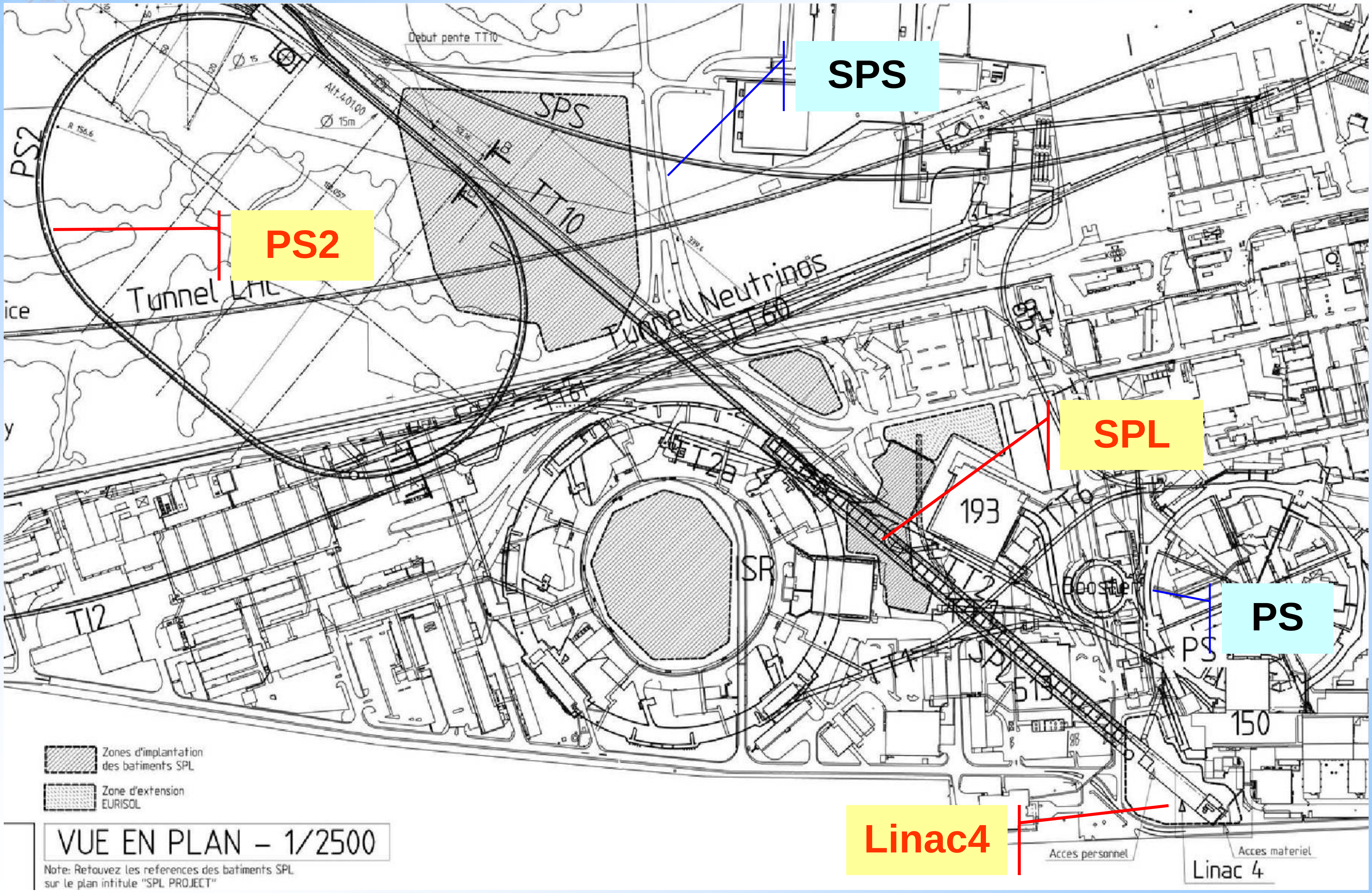
- Increase injection energy in the PSB from 50 to 160 MeV kinetic
- Increase injection energy in the SPS from 25 to 50 GeV kinetic
- Design the PS successor (PS2) with an acceptable space charge effect for the maximum beam envisaged for SLHC: => injection energy of 4 GeV

Upgrade components



LPSPL: Low Power Superconducting Proton Linac (4 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)

Layout of the new injectors



Stage 1: Linac4

- **Direct benefits of the new linac**

  Stop of Linac2:
  - End of recurrent problems with Linac2 (vacuum leaks, etc.)
  - End of use of obsolete RF triodes (hard to get + expensive)

  Higher performance:
  - Space charge decreased by a factor of 2 in the PSB

    => potential to double the beam brightness and fill the PS with the LHC beam in a single pulse,

    => easier handling of high intensity. Potential to double the intensity per pulse.
  - Low loss injection process (Charge exchange instead of betatron stacking)
  - High flexibility for painting in the transverse and longitudinal planes (high speed chopper at 3 MeV in Linac4)

  First step towards the SPL:
  - Linac4 will provide beam for commissioning LPSPL + PS2 without disturbing physics.

- **Benefits for users of the PSB**

  Good match between space charge limits at injection in the PSB and PS

  => for LHC, no more long flat bottom at PS injection + shorter flat bottom at SPS injection: easier/ more reliable operation / potential for ultimate beam from the PS

  More intensity per pulse available for PSB beam users (ISOLDE) – up to 2´

  More PSB cycles available for other uses than LHC

Stage 2: LPSPL + PS2

- **Direct benefits of the LPSPL + PS2**

  Stop of PSB and PS:
  - End of recurrent problems (damaged magnets in the PS, etc.)
  - End of maintenance of equipment with multiple layers of modifications
  - End of operation of old accelerators at their maximum capability
  - Safer operation at higher proton flux (adequate shielding and collimation)

  Higher performance:
  - Capability to deliver 2.2´ the ultimate beam for LHC to the SPS

    => potential to prepare the SPS for supplying the beam required for the SLHC,
  - Higher injection energy in the SPS + higher intensity and brightness

    => easier handling of high intensity. Potential to increase the intensity per pulse.

  First step towards the SPL:
  - Linac4 will provide beam for commissioning LPSPL + PS2 without disturbing physics.

- **Benefits for users of the LPSPL and PS2**

  More than 50 % of the LPSPL pulses will be available (not needed by PS2)

  => New nuclear physics experiments – extension of ISOLDE (if no EURISOL)…

  Upgraded characteristics of the PS2 beam wrt the PS (energy and flux)

  Potential for a higher proton flux from the SPS

Stage 2': SPL

Upgrade the LPSPL into an SPL (multi- MW beam power at 2-5 GeV):

- 50 Hz rate with upgraded infrastructure (electricity, water, cryo-plants, …)
- 40 mA beam current by doubling the number of klystrons in the superconducting part

Possible users

- **EURISOL (2nd generation ISOL-type RIB facility)**

  => special deflection system(s) out of the SPL into a transfer line

  => new experimental facility with capability to receive 5 MW beam power

  => potential of supplying b-unstable isotopes to a b-beam facility…
- **Neutrino factory**

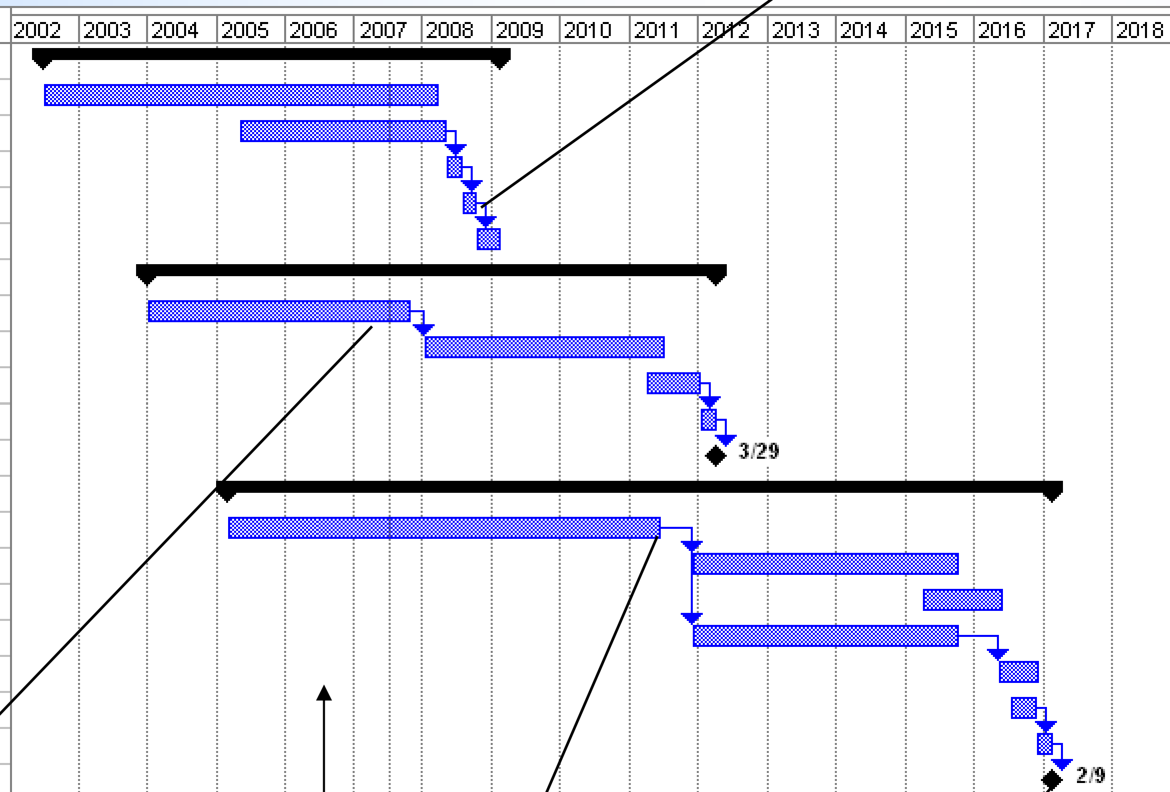
  => energy upgrade to 5 GeV (+70 m of sc accelerating structures)

  => 2 fixed energy rings for protons (accumulator & compressor)

  => accelerator complex with target, m capture-cooling-acceleration (20-50 GeV) and storage

Planning …

ID	Task Name
1	**3 MeV Front End**
2	Design and construction
3	CERN Installation
4	Commissioning w/o beam
5	IPHI RFQ Installation
6	Commissioning and operation
7	**LINAC4**
8	Design refinement
9	Construction
10	Linac commissioning
11	Linac + PSB commissioning
12	Start for physics
13	**SPL + PS2**
14	Design refinement
15	SPL Construction
16	SPL beam commissioning
17	PS2 construction
18	PS2 beam commissioning
19	SPS modification
20	SPS beam commissioning
21	Start operation for physics



3 MeV test place ready

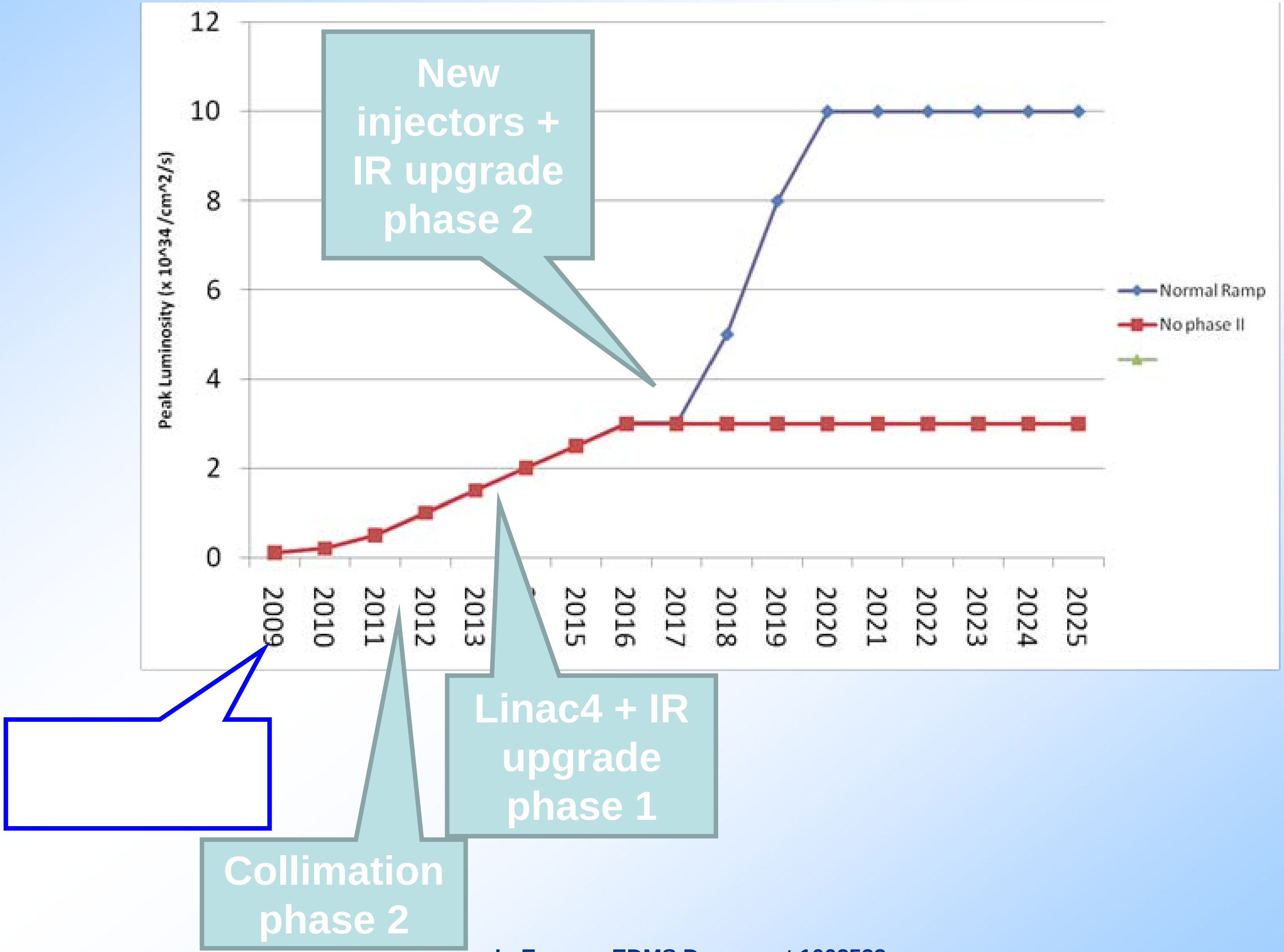
Linac4 approval

CDR 2

SPL & PS2 approval

Start for Physics

Peak luminosity…



Integrated luminosity…