The future of LHC and boosted objects

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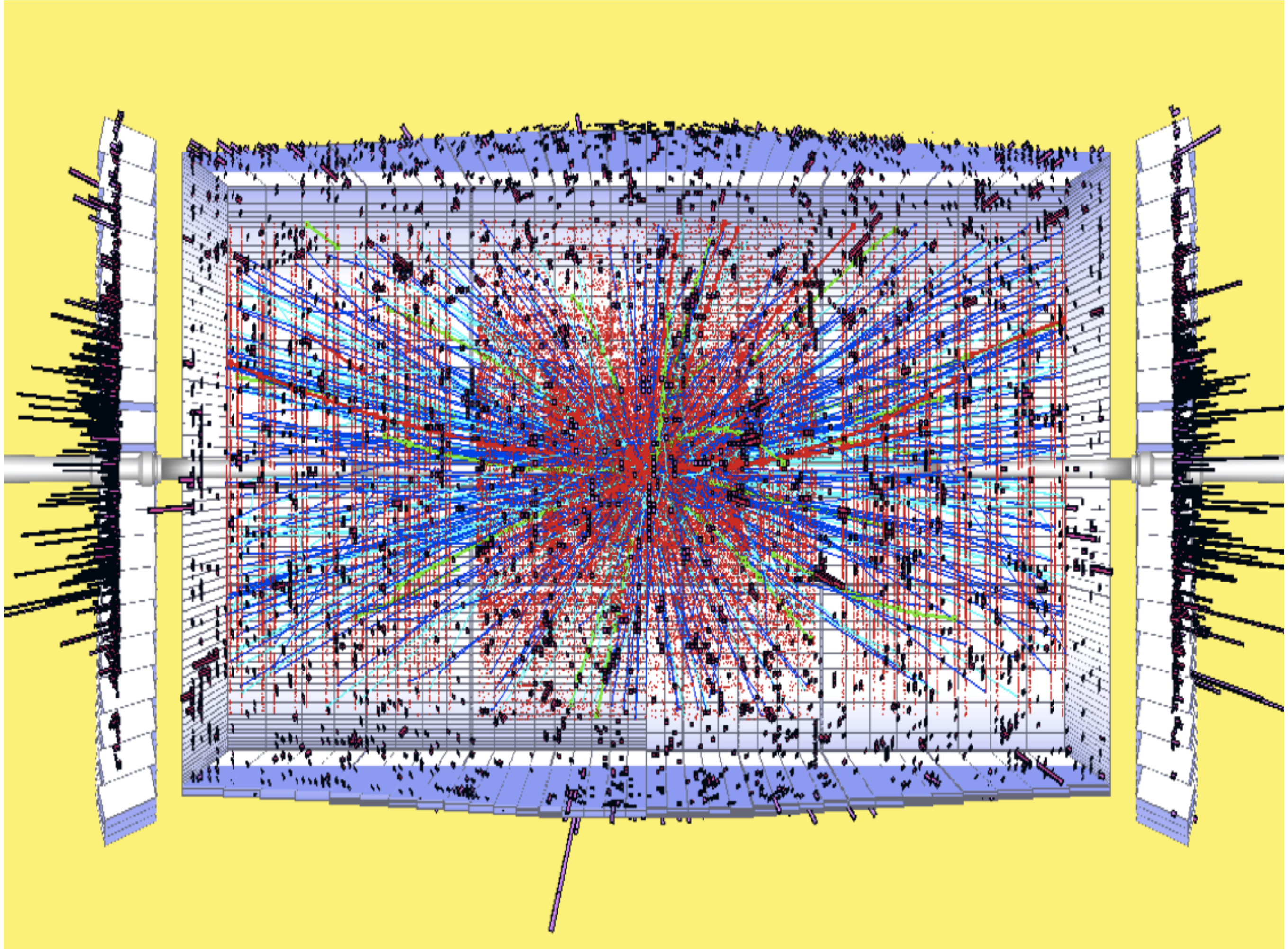
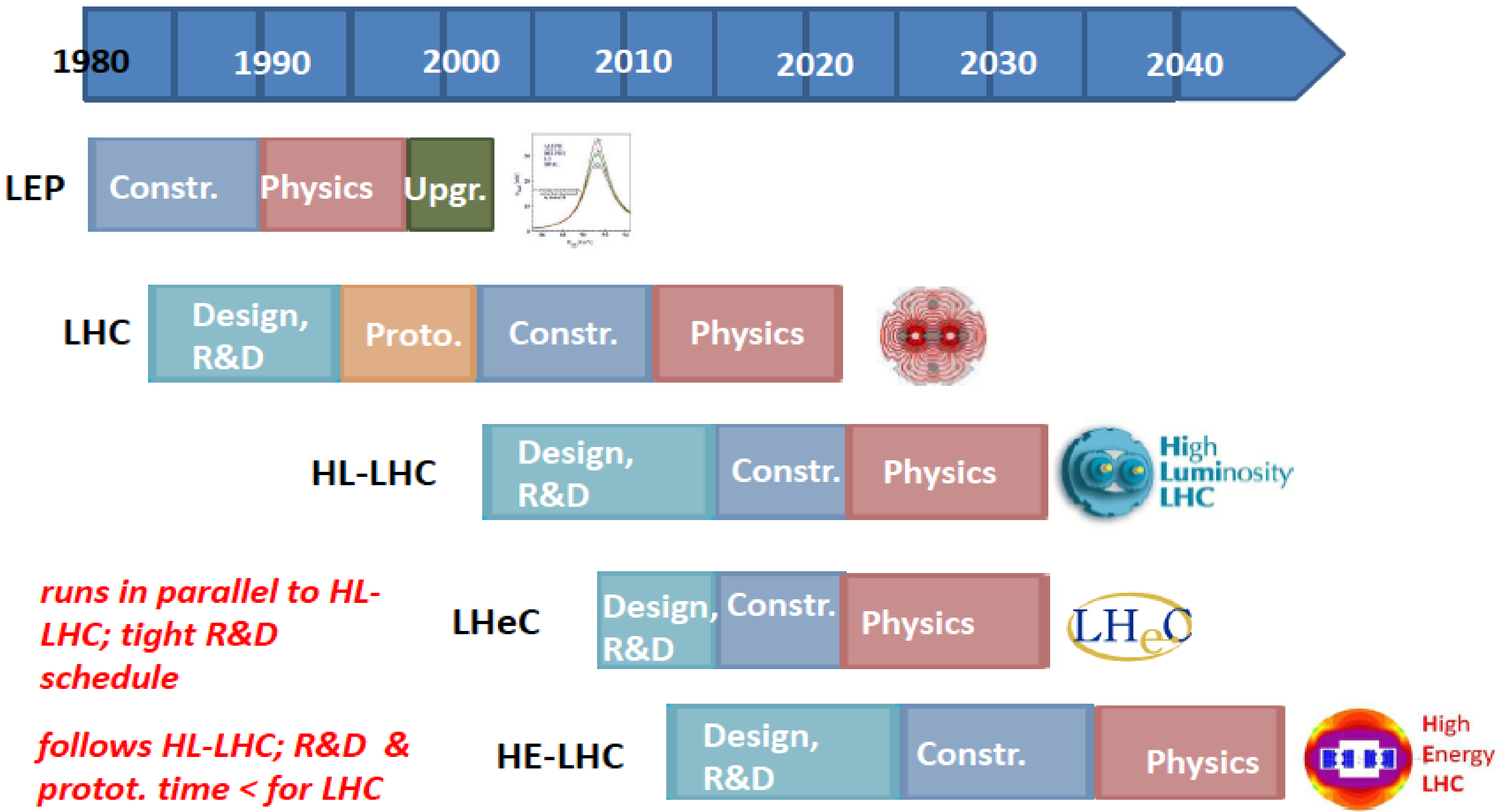


LHC timeline
The 14 TeV run
Phase-2 upgrades and European Strategy
Some intermediate results and work proposal

time line of CERN HEP projects



Source: L. Rossi. LMC 2011 (modified)

First high-energy run

The 14 TeV run will have a slightly smaller energy, and real physics will only start in 2015 (we may have some pilot MD runs end of 2014)

Aim is to reach design luminosity of 10E34 cm2s-1 with 25 ns bunch separation. This corresponds to about 40-50/fb of integrated luminosity per year, reaching about 300/fb by 2012.

Pileup conditions may be similar to current ones (μ~25) in the beginning: higher luminosity achieved with more bunches, same bunch density.

Later in the run, we could expect a value of μ twice this value due to improvements in the accelerator performances and injection chain

after LS1 (2015-2017)

	Beta* [cm]	Ib SPS	Emit SPS [um]	Peak Lumi [$cm^{-2}s^{-1}$]	~Pile-up	Int. Lumi [fb^{-1}]
25 ns	50	1.2e11	2.8	1.2e34	27	32
25 ns low emit	50	1.2e11	1.4	2.1e34	46	54
50 ns level	50	1.7e11	2.1	1.7e34 level 0.9e34	75 level 40	~50

- 150 days proton physics
- 5% beam loss, 10% emittance blow-up in LHC
- 10 sigma separation
- 70 mb visible cross-section

All numbers approximate!

Mike Lamont (CERN BE-OP) 21.5.2012 at CMS Upgrade week

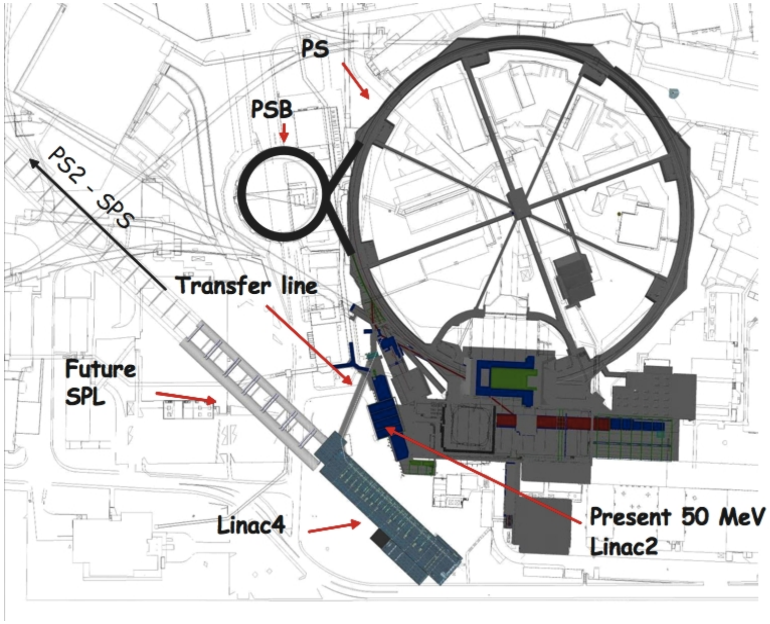
Linac 4

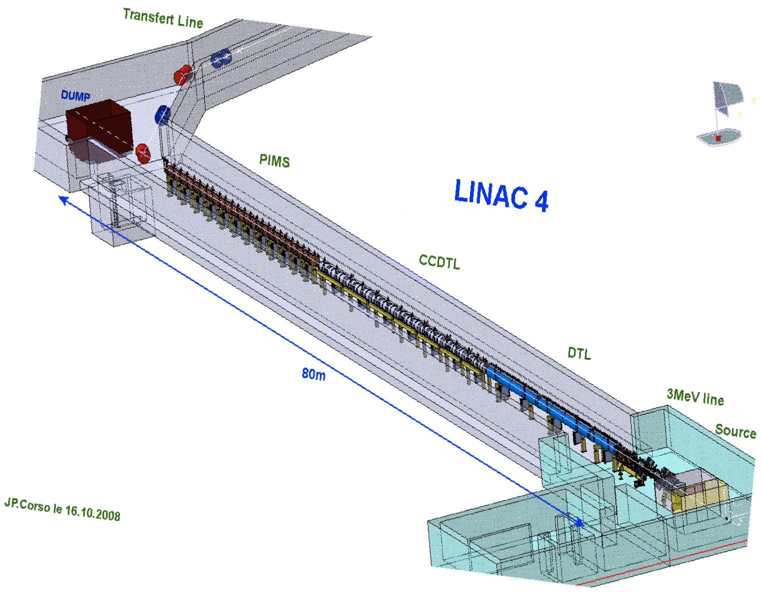
Main bottleneck to LHC brightness (beam current/emittance) are space charge effects in injection from Linac2 to PSB.
This limitation will be overcome by a new Linac currently under construction, that will:

- double the injection energy inside the booster
- Accelerate H- instead of protons, stripping the electrons at the entrance of PSB

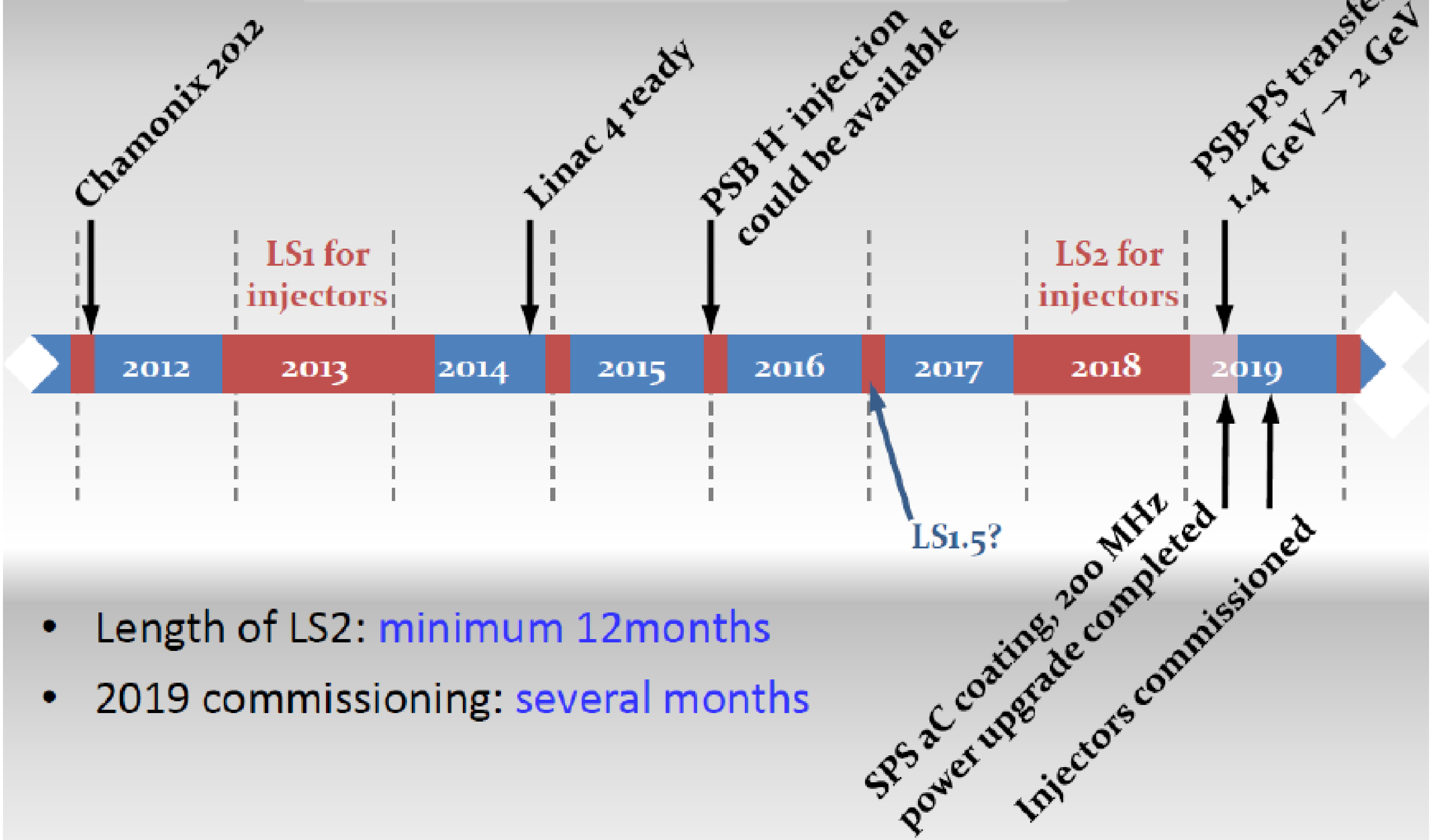
Currently under construction, expected to go into commissioning mode in 2014

Essential for higher luminosities, fits well in a framework of global updates of the LHC injection, as well as for possible SPL and high-intensity neutrino beams.





Injector upgrades



- Length of LS2: minimum 12months
- 2019 commissioning: several months

- 2 GeV upgrade of PSB + increase of PS injection energy excluded for LS1

Mike Lamont (CERN BE-OP) 21.5.2012 at CMS Upgrade week

after LS2 (2019-2021)

- 7 TeV,
- 150 days of proton physics
- HF = 0.2 for 25 ns

	Beta* [cm]	Ib (SPS)	Emit (SPS) um	Peak Lumi [$cm^{-2}s^{-1}$]	Pile-up	Int. Lumi [fb^{-1}]
25 ns	50	1.6e11	2.3	2.5e34	56	~65
50 ns	50	2.7e11	2.7	2.8e34 level 0.9e34	125 level 40	~61

Neglecting low emittance option
All numbers approximate!

Mike Lamont (CERN BE-OP) 21.5.2012 at CMS Upgrade week

High-Luminosity LHC

By ~ 2020 and an accumulated luminosity of 300/fb, we will reach a plateau of diminished return: without upgrades it will take O(5 years) to double luminosity

The LHC program is currently funded only up to this point!

HL-LHC is the project aiming at increasing LHC luminosity by a factor ~10, to reach 3000/fb by 2030 (by comparison, Tevatron collected 10/fb)

Limitations of LHC luminosity:

HL-LHC: LHC Machine

LHC: Total beam current

Bunch Intensity

$$L \approx \frac{6.24 \cdot 10^{18} (\mathrm{As})^{-1} \cdot i_{beam} \cdot N_p}{4\pi \cdot \beta^* \cdot \varepsilon_n}$$

LIU: INJECTORS

LHC: beta*
(optics, collimation, MP)

Normalized Emittance

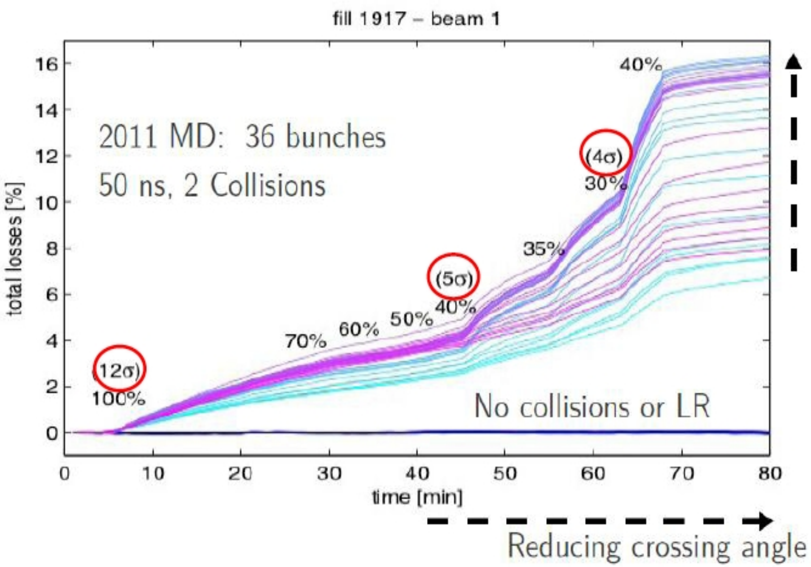
Some current HL-LHC accelerator R&D

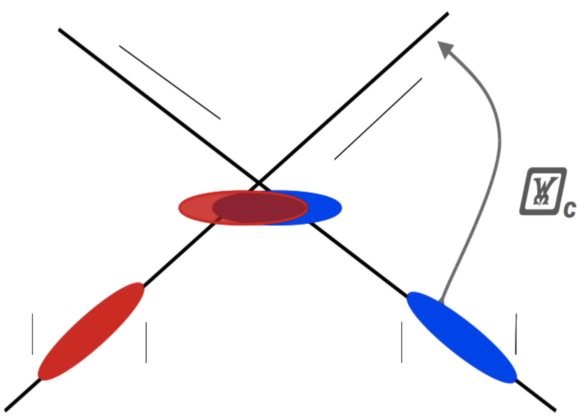
New Interaction-Region (low-β*) magnets:

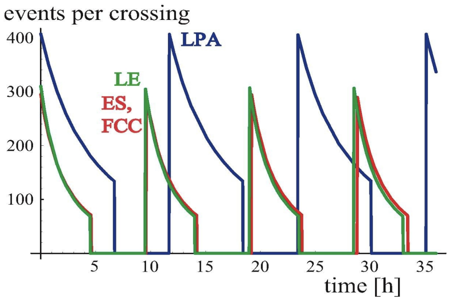
New superconductor (Nb3Sn) tested to stand 11T; Required field gradients already achieved for many magnet configurations, at HL-LHC operational level

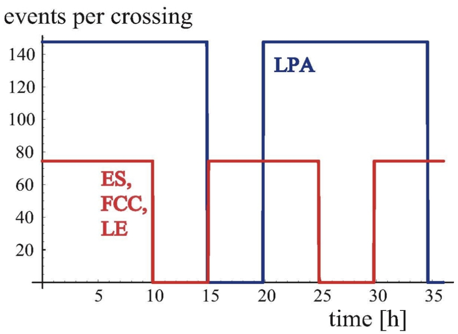
Crab cavities:

Losses increase with crossing angle, separations around 10σ inevitable. Crab cavities spatially rotate bunches, and allow full overlap; they also allow luminosity leveling

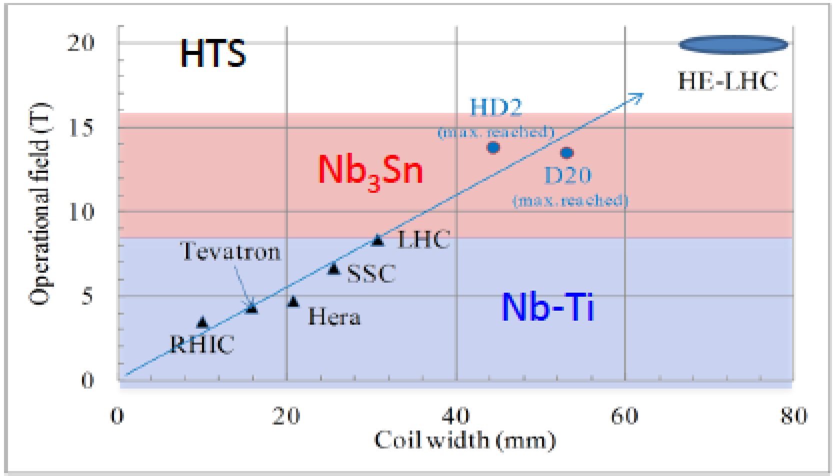


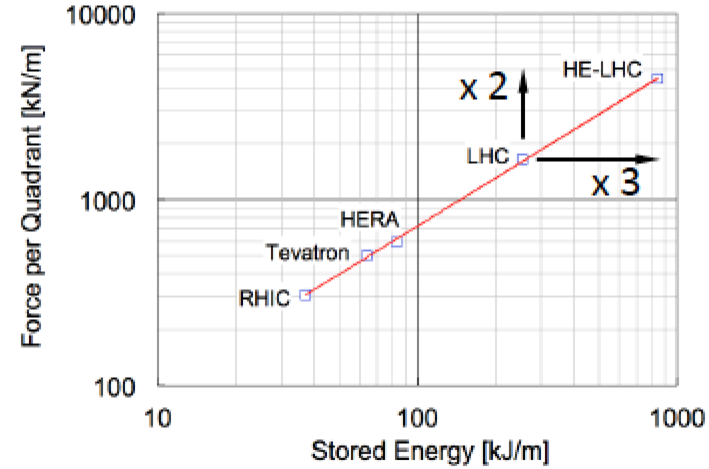




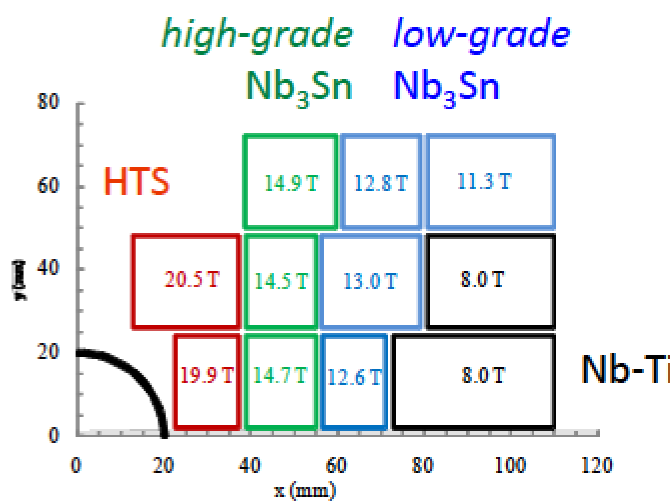


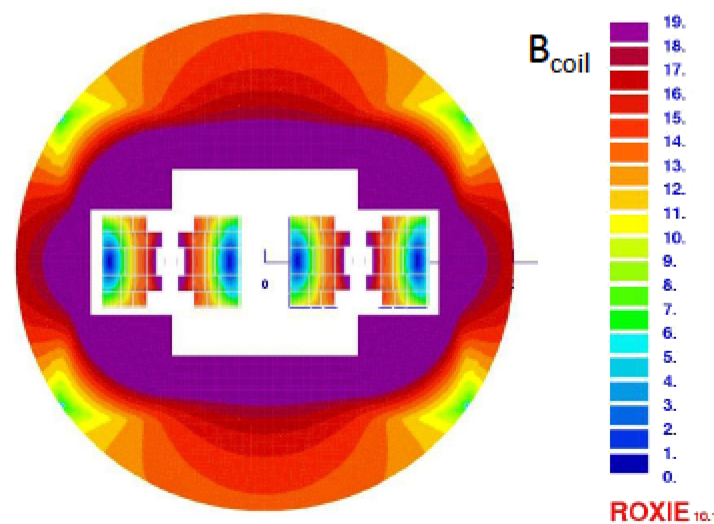
A *really high field* dipole





HTS/Nb_3Sn/Nb-Ti nested coil magnet



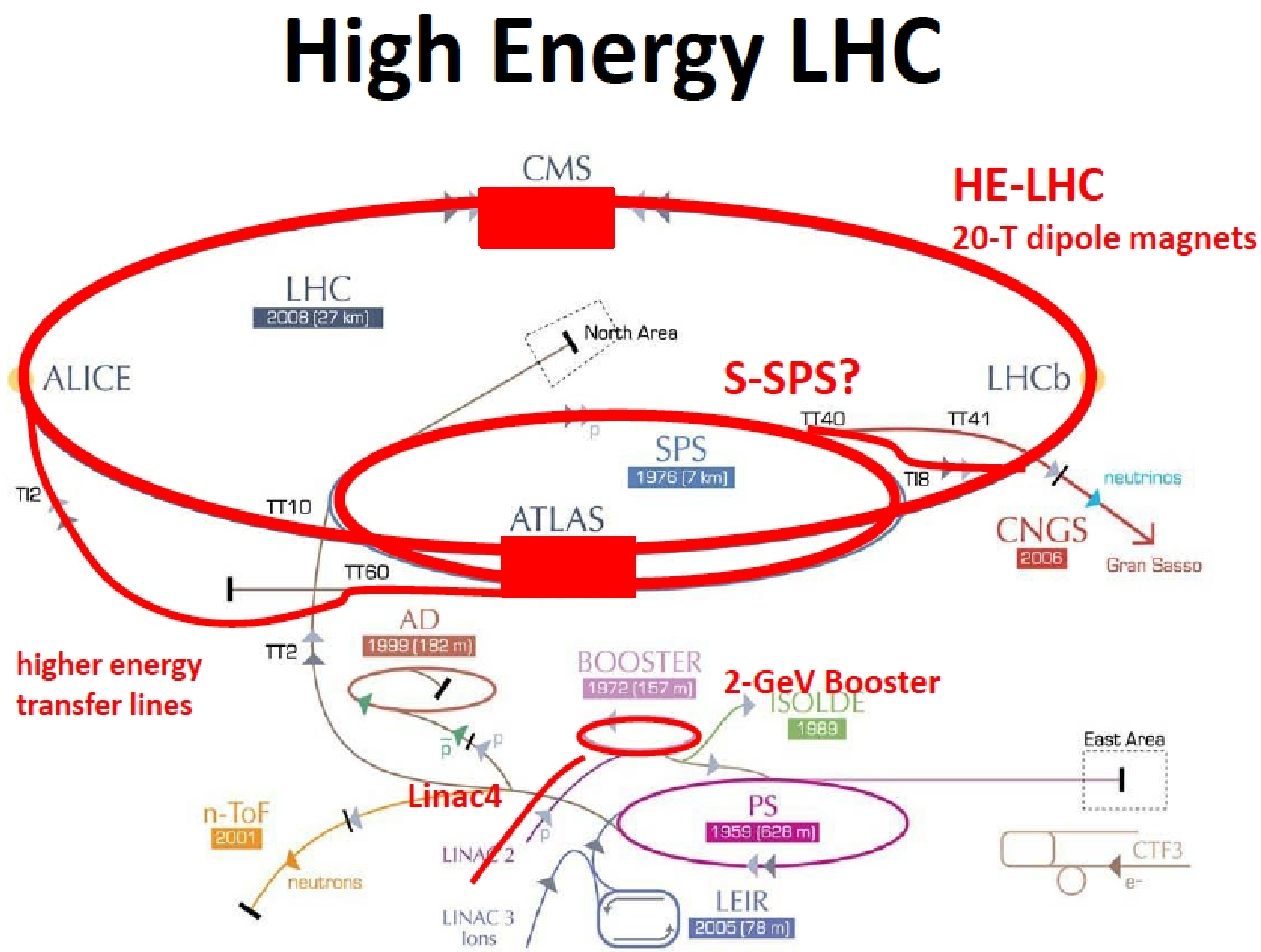


By courtesy of E. Todesco

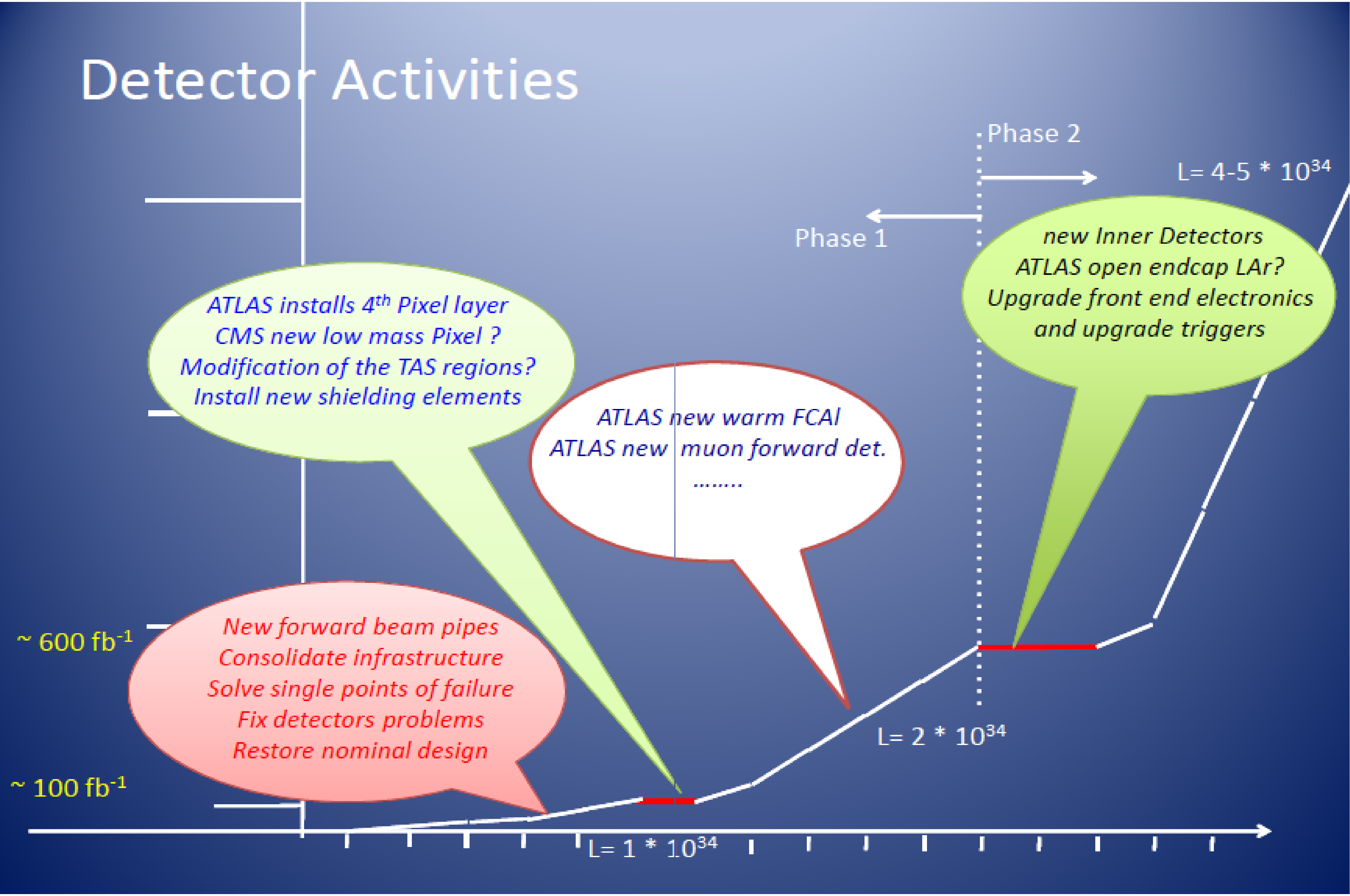
Aim is to double the B-field using High-critical Temperature Superconductors to allow twice the beam energy. It is in practice a new accelerator

Talking about a first phase collecting 300/fb and a second one up to 3000/fb (2050?)

A new (but familiar) accelerator complex?



Foreseen High-Lumi upgrades for the experiments



It is not clear if current detectors/collaborations/interaction points are suited for HE-LHC

Triggering at High Luminosity

A 10 times larger instantaneous luminosity means:

- 10 times larger event size
- 10 times larger rates for events of a given kind (ex. Electrons with Pt > 20 GeV)

Even if rate of events written to tape can be increased to O(kHz) over the next years due to faster links and trigger processors, trigger outputs expected to be back to O(200 Hz) for HL-LHC.

L1 is going to be an issue: we already expect single-object L1 triggers to be widely prescaled during the 14 TeV run, so many analysis-specific combined items will be present from L1

To do that, latency will be increased, higher calorimeter granularity will be read out and more trigger chambers will be included in the muon reading system.

Jet triggering will be particularly affected, given the low rate reduction provided by HLT

The case for the upgrade: the European Strategy group study

No LHC running beyond 300/fb is approved so far. The CERN council called a working group, with representatives from each country, to define the future of particle physics in Europe. ATLAS and CMS will both present a case for HL-LHC, perhaps also for HE-LHC. Submission deadline is next week (but can be amended by Krakow), so no official results yet!

CERN Council

Update of the European Strategy for Particle Physics

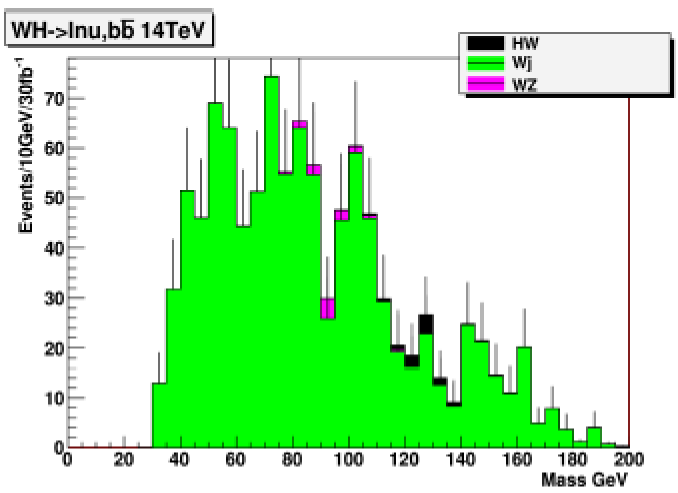
www.europeanstrategygroup.web.cern.ch

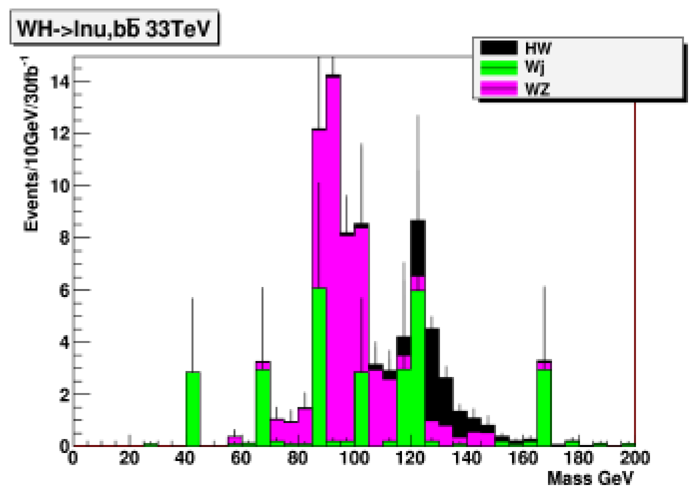
Timeline for Update of European Strategy

Open for Submissions on scientific issues	1 February 2012
Submissions closed for the Open Symposium	**31 July 2012**
All submissions will be made available to the speakers and the session-chairs of the Open Symposium.	
Open Symposium (Krakow, Poland) - website	10-12 September 2012
Submissions closed for being included in the Briefing Book to the Strategy Group	**15 October 2012**
Strategy Group meeting to draft Update of Strategy (Erice, Italy)	21-26 January 2013
Finalizing Update of Strategy by CERN Council	March 2013
Special Council Session to adopt Update of European Strategy in Brussels	May/June 2013

The case for the upgrade

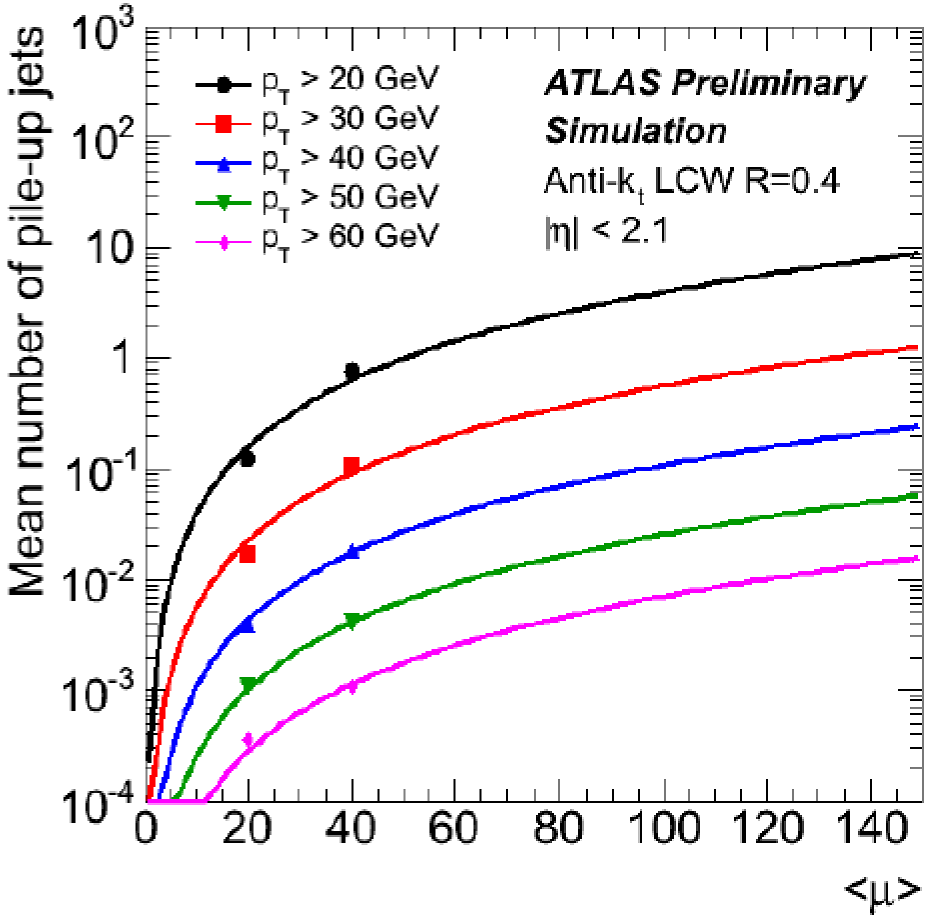
Mainly focusing on Higgs confirmation, SUSY and exotic searches. Boosted objects mainly relevant for H->bb and VV-scattering final states. The HE-LHC scenario clearly offers a lot of boost, but will we be swamped by pileup in the High-Luminosity scenario?

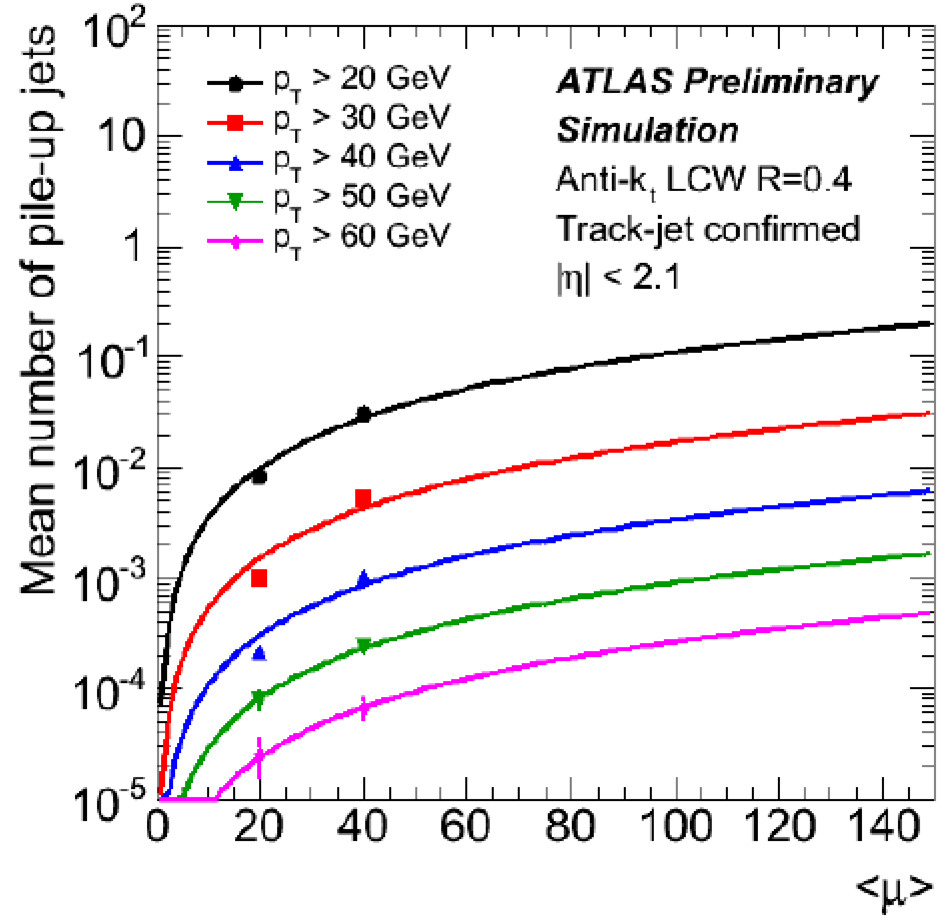




S.Baker, very preliminary:
Application of the BDRS HW search to the 33 TeV scenario; smeared 4-vectors, no pileup

Number of reconstructed pileup jets vs μ

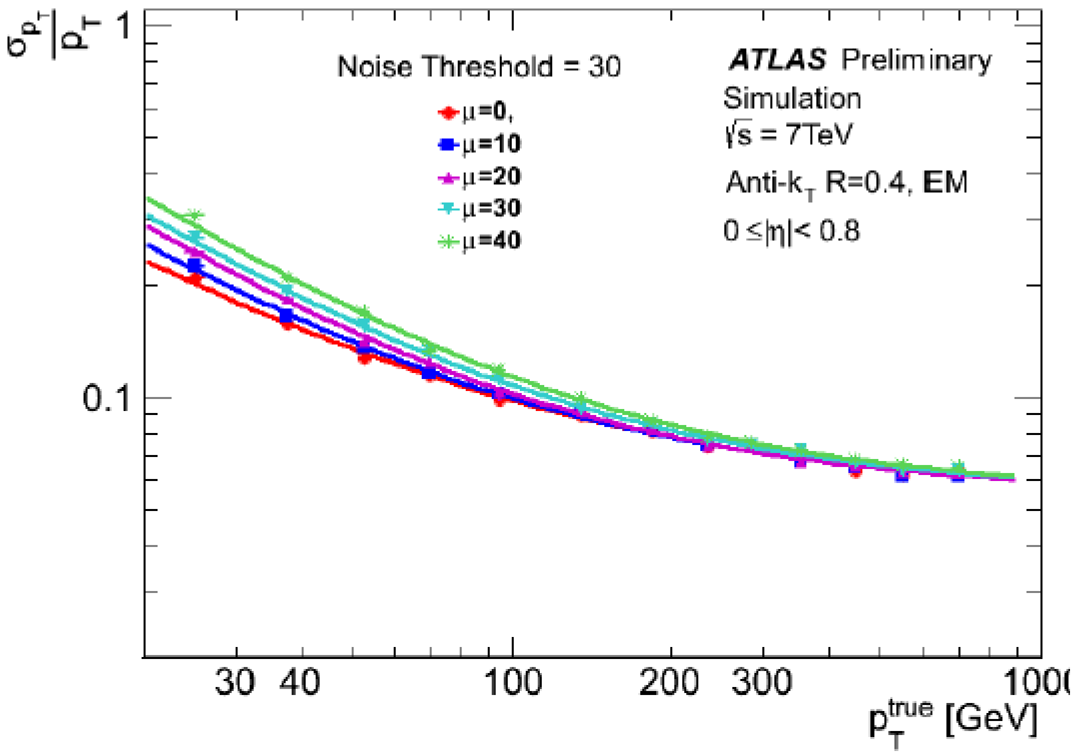


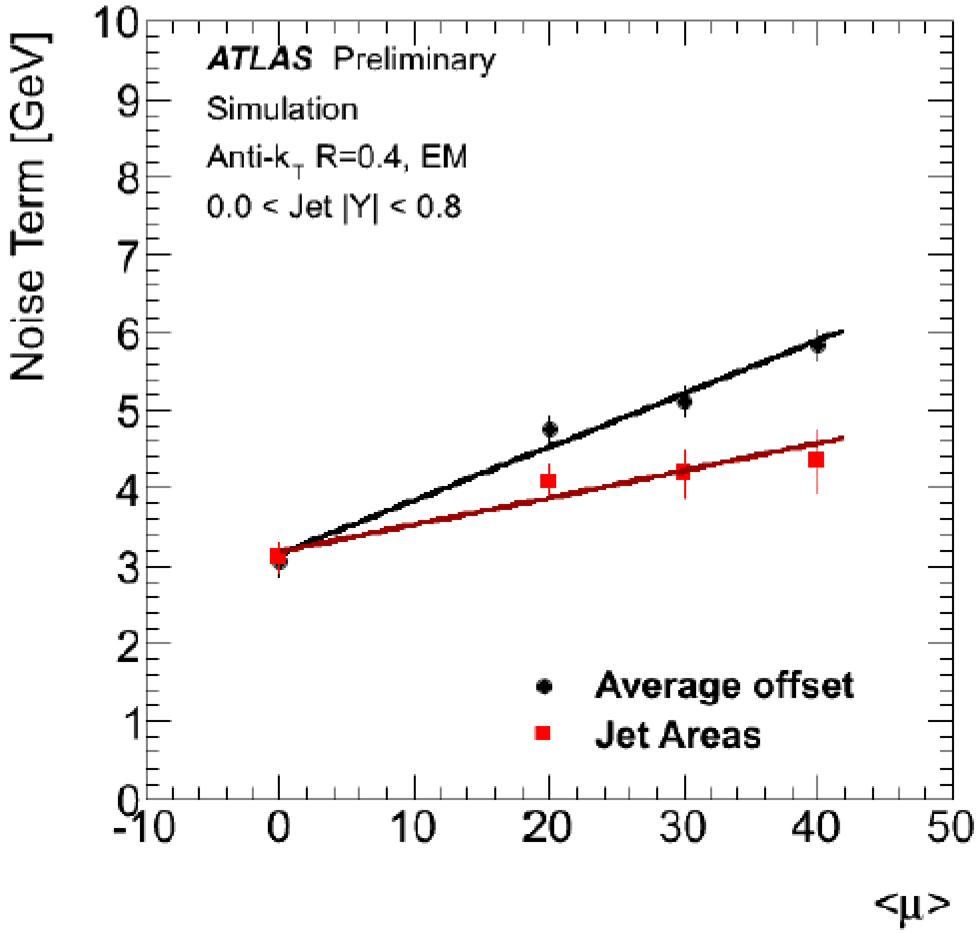


Pileup dependence is quadratic, so a few points can be extrapolated to large μ values. About 10 pileup jets at 20 GeV for μ > 100 in the central region only, despite average offset corrections based on reconstructed NVTX has been applied.

Tracks are not used in momentum determination in Atlas; however, the requirement that jets match a hard-scattering track jet with pT>5 GeV reduces pileup jets by about a factor 50

Effect of pileup on jet resolution





Resolution parametrised by $\sqrt{N^2/(p_T^2) + S^2/p_T + C^2}$

Pileup only affects the noise term N, as also shown by fit
Jet area correction can reduce it by a significant fraction
For instance, extrapolation to μ=150 gives S = 14 GeV for average offset and 8 GeV using jet area method

More ongoing work (not yet approved), and next steps

Similar work ongoing for jet mass resolution under pileup conditions

Optimisation of substructure grooming techniques with high pileup using expertise gained in recent years and realistic experimental techniques has started, in the context of H->bb and VV scattering studies

The spirit of BOOST is that of a real workshop, where proceedings should contain all the work done during after the conference

Showing that high pileup conditions would be a welcome outcome of this workshop, and would strengthen the HL-LHC case and the future of these techniques

To be realistic, work has to be done using techniques from the two experiments, but ideas can be exchanged and performances compared

Approval from the collaborations will be needed before proceeding publication

Conclusions

The LHC is not resting on its laurels, a very diversified upgrade program can keep us (and our children) busy for the first half of the century

We are learning to fight pileup in standard jet reconstructions, and these ideas seem to work under conditions comparable to HL-LHC (with luminosity leveling). Memory-hungry and time-consuming simulations needed to confirm extrapolations.

A similar work is going on for jet mass and substructure measurements; manpower is still limited, and could benefit from help from this workshop

Organisation and milestones could be common, but to be realistic, the work has to be carried out in the framework of the two experiments, with results approved and compared on a regular basis.

Volounteers needed!