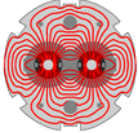




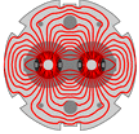
LHC Operations 2009/2010

Mike Lamont



LMC 25 - 5th August

- Energy extraction times (K.H. Mess)
- RRR and recommended values for simulation (A. Siemko)
- Beam induced quenches in magnets, interconnects and connection cryostats (J Wenninger)
- Simulation results for MB and MQ circuits (A. Verweij)
- FRESCA measurements status (L. Bottura)
- Splice resistance measurements and worst case estimate (A. Siemko)
- Recommendation for safe energy for operation in 2009/2010



Initial operating energy of the LHC

- Operating at 7 TeV com with a dipole energy extraction time of 50s
 - Simulations show that resistances of 120 micro-ohm are safe from thermal runaway under conservative assumed conditions of worst case conditions for the copper quality (RRR) and no cooling to the copper stabilizer from the gaseous helium
- Operating at 10 TeV com with a dipole energy extraction time of 68s
 - Simulations show that resistances of 67 micro-ohm are safe from thermal runaway under conservative assumed conditions of worst case conditions for the copper quality (RRR), and with estimated cooling to the stabilizer from the gaseous helium
- **Decision:**
 - Operation initially at 7 TeV com (energy extraction time of 50s) with a safety factor or more than 2 for the worst stabilizers. During this time monitor carefully all quenches to gain additional information.
- Then operate at 9 – 10 TeV com.

Steve Myers

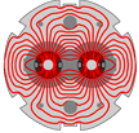


3.5 TeV running – prelim.

Acknowledgements:

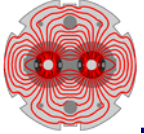
Ralph Assmann

Werner Herr

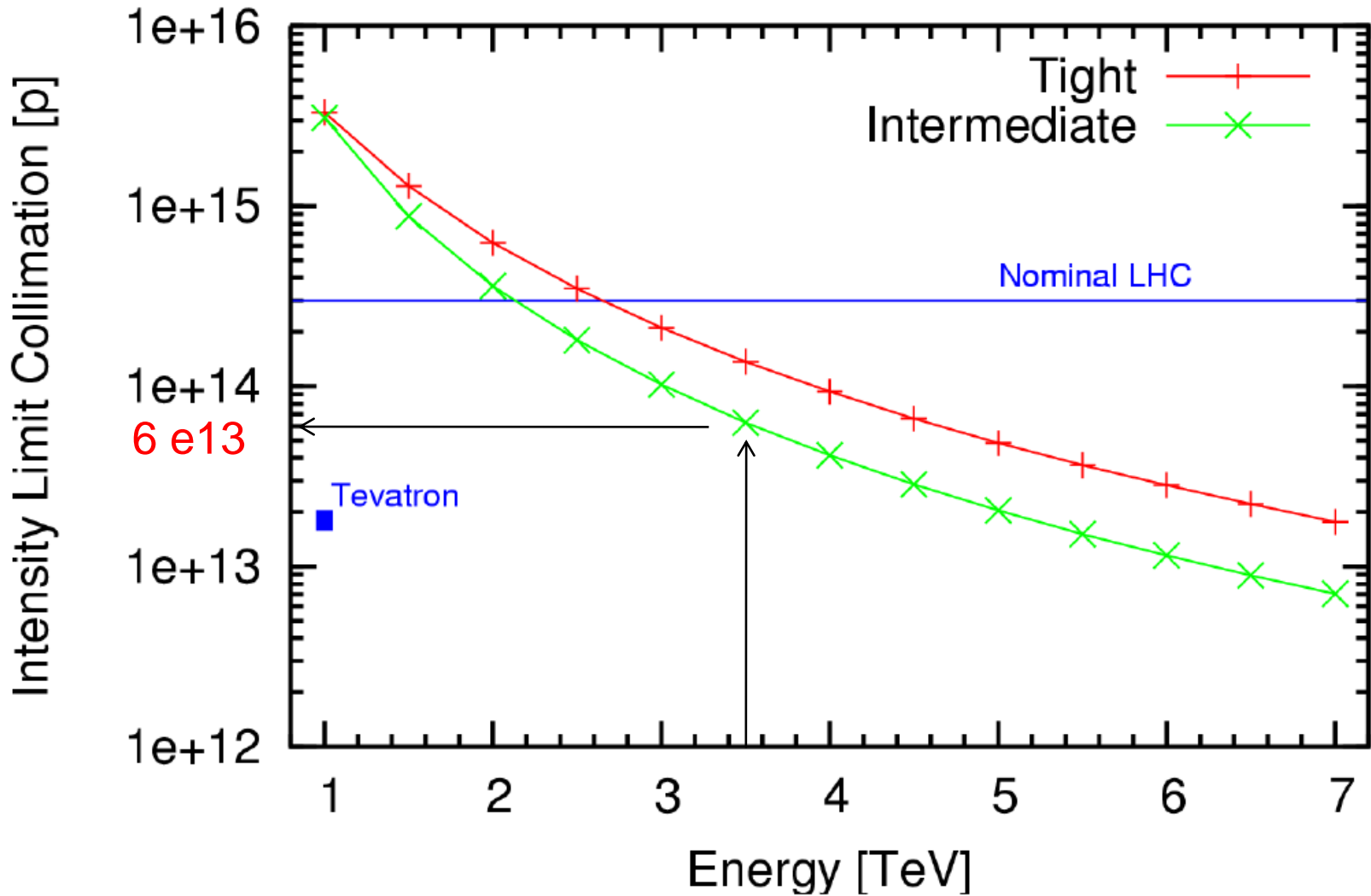


Recall

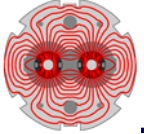
- Emittance goes down with increasing γ : $\varepsilon_N = \beta\gamma\varepsilon$
- And thus luminosity increases with increasing γ **IF** we can hold other parameters constant: $L \propto \gamma$
- However, because beam size goes as: $\frac{1}{\sqrt{\gamma}}$
 - lower energy:
 - \rightarrow increased beam size – less aperture \rightarrow higher β^*
 - \rightarrow separation of beams in interaction regions drops



Intensity limit - collimation

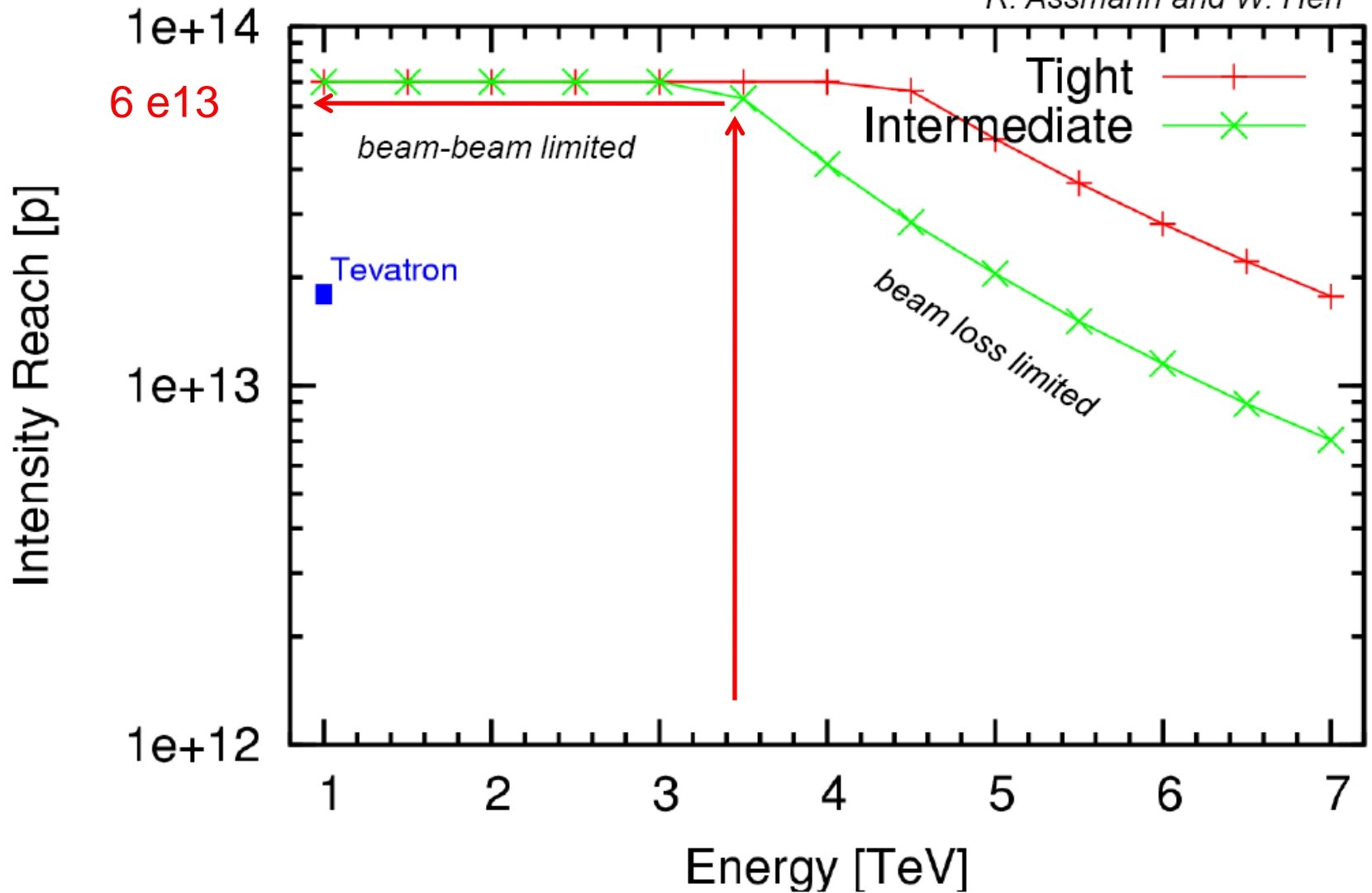


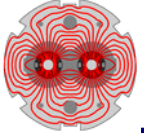
Ralph Assmann



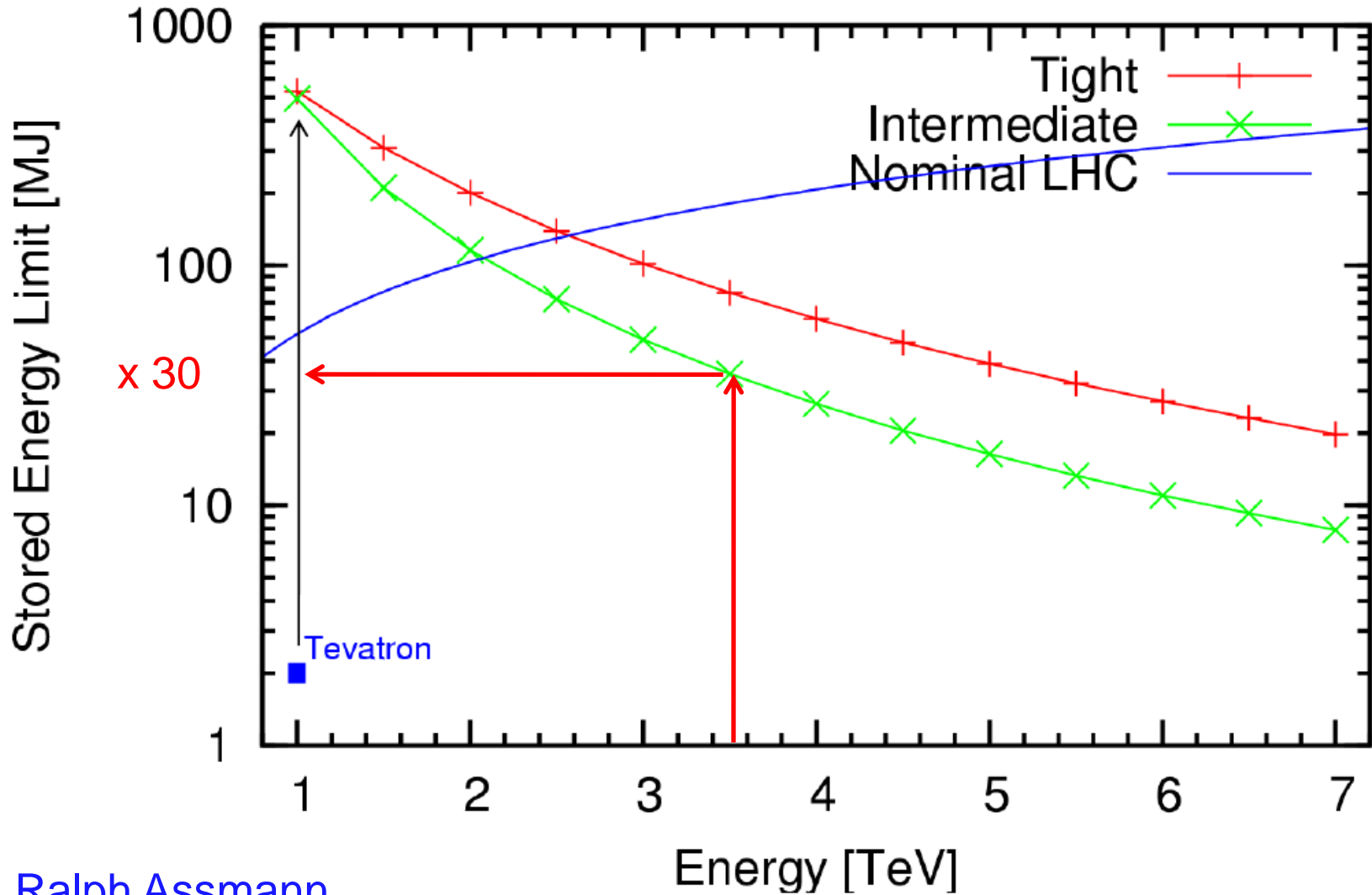
Intensity – collimators and beam-beam

R. Assmann and W. Herr

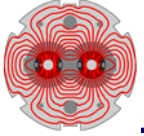




Limit stored energy versus beam energy

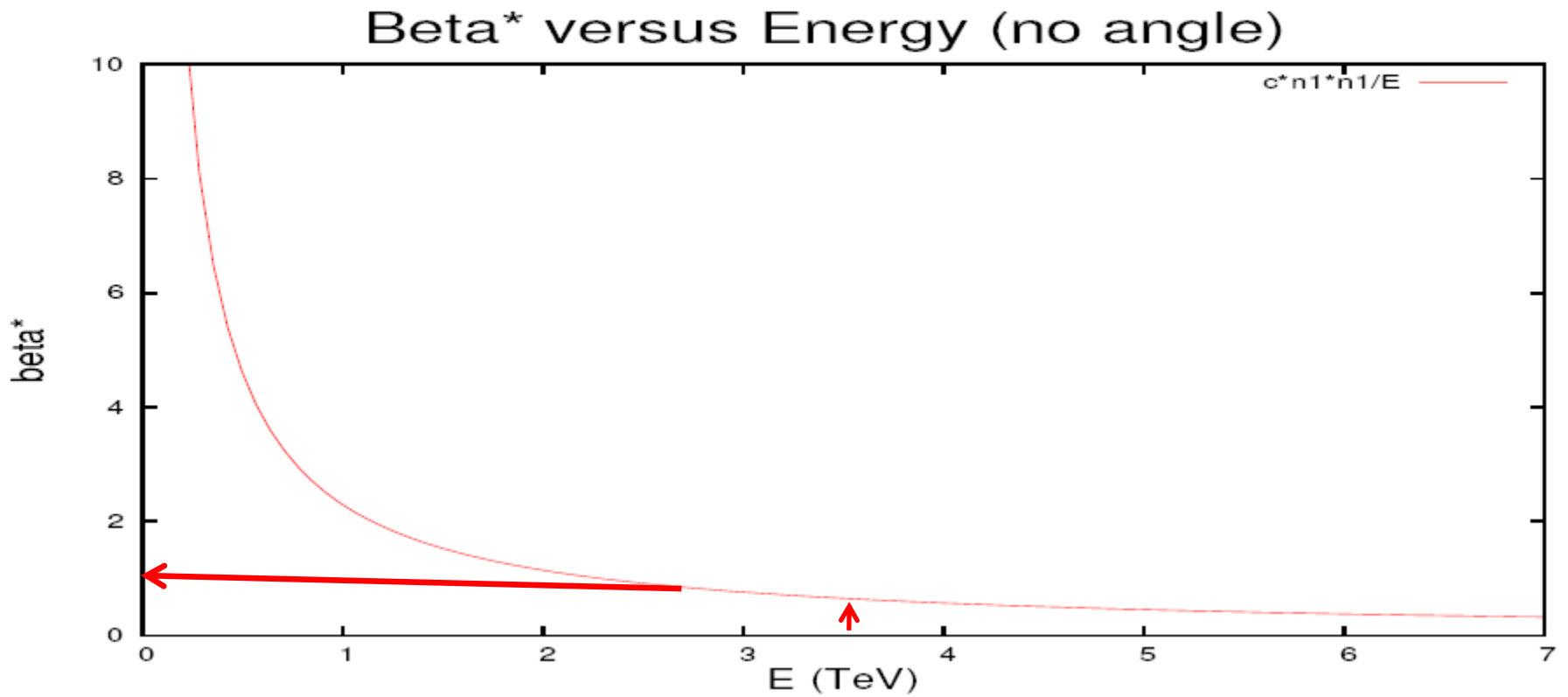


Ralph Assmann

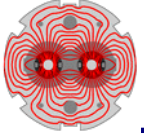


Beta* - no angle

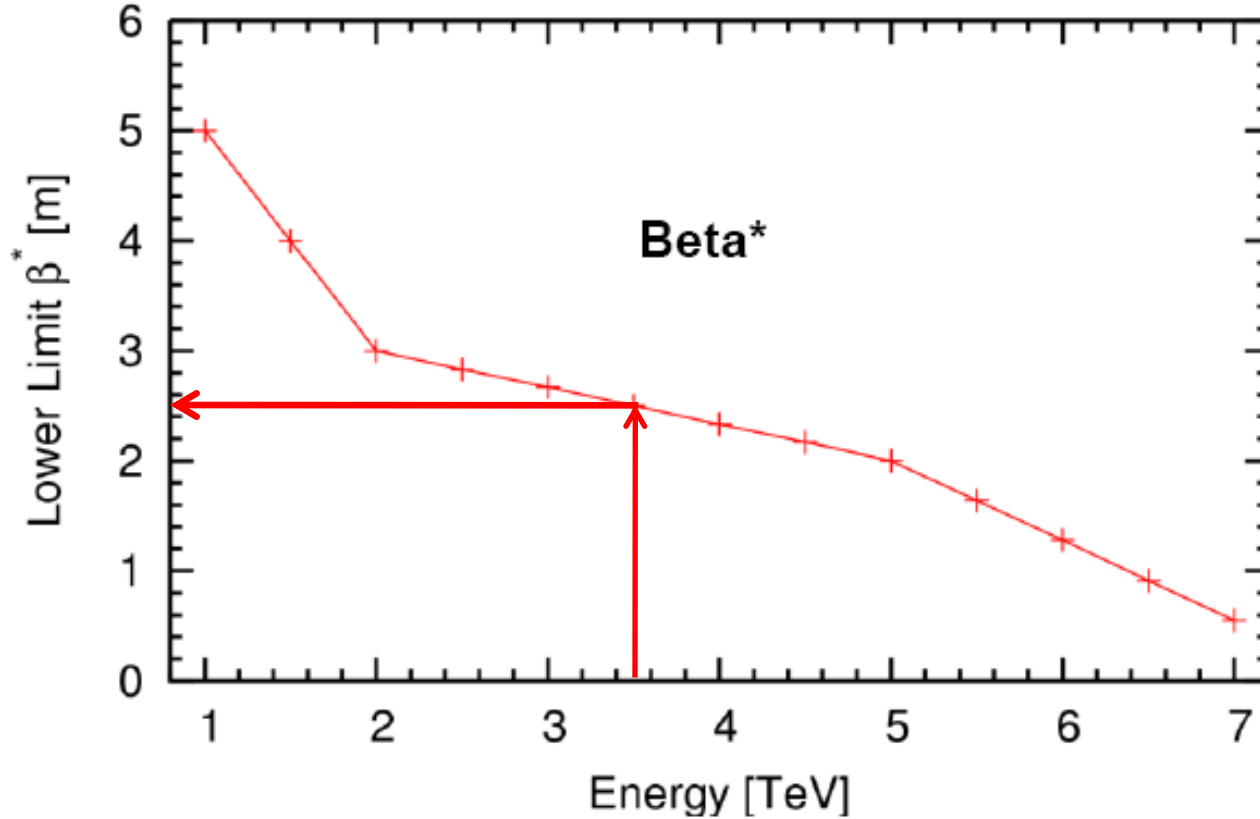
➤ Requiring minimum n_1 of 7.0



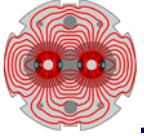
Werner Herr



Beta* - with crossing angle

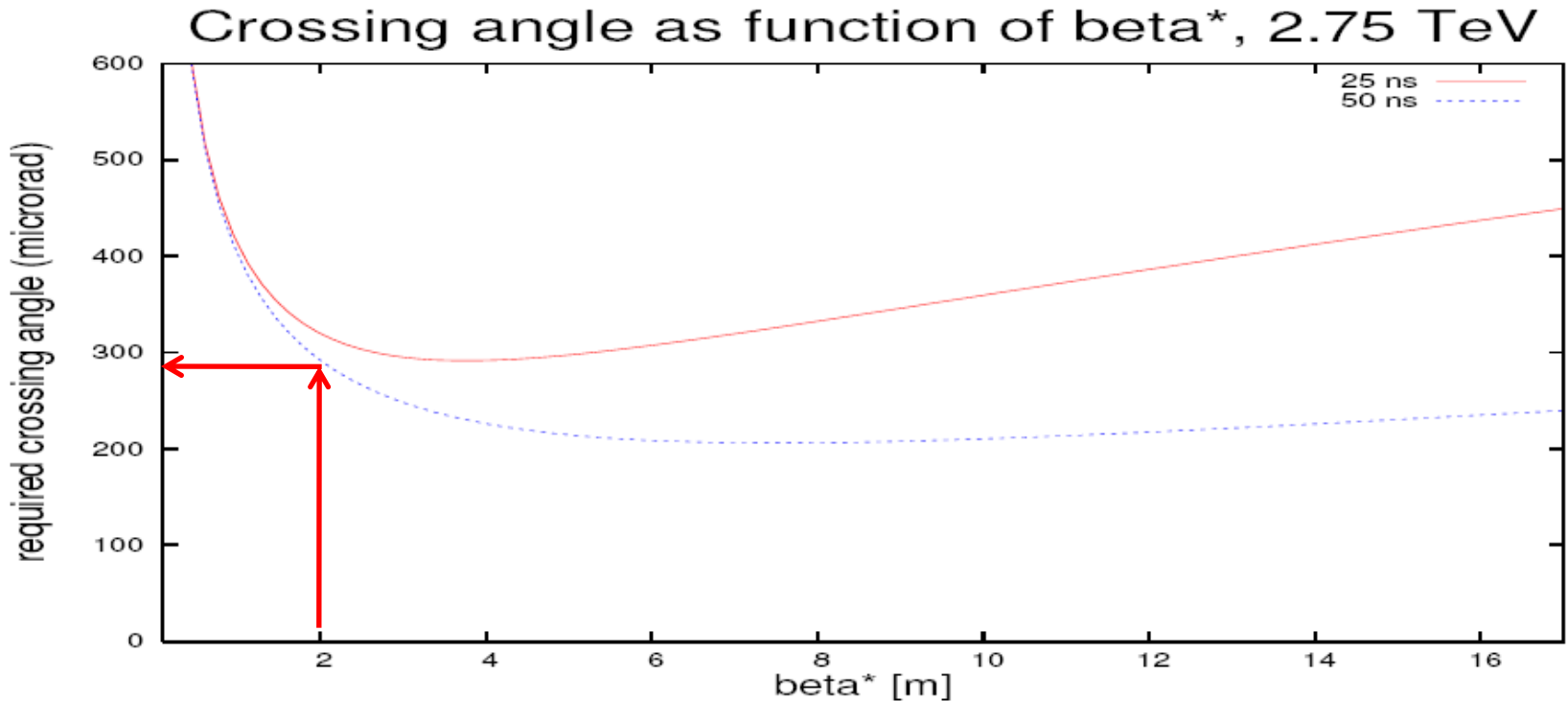


Werner Herr

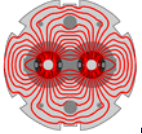


Crossing angle versus beta*

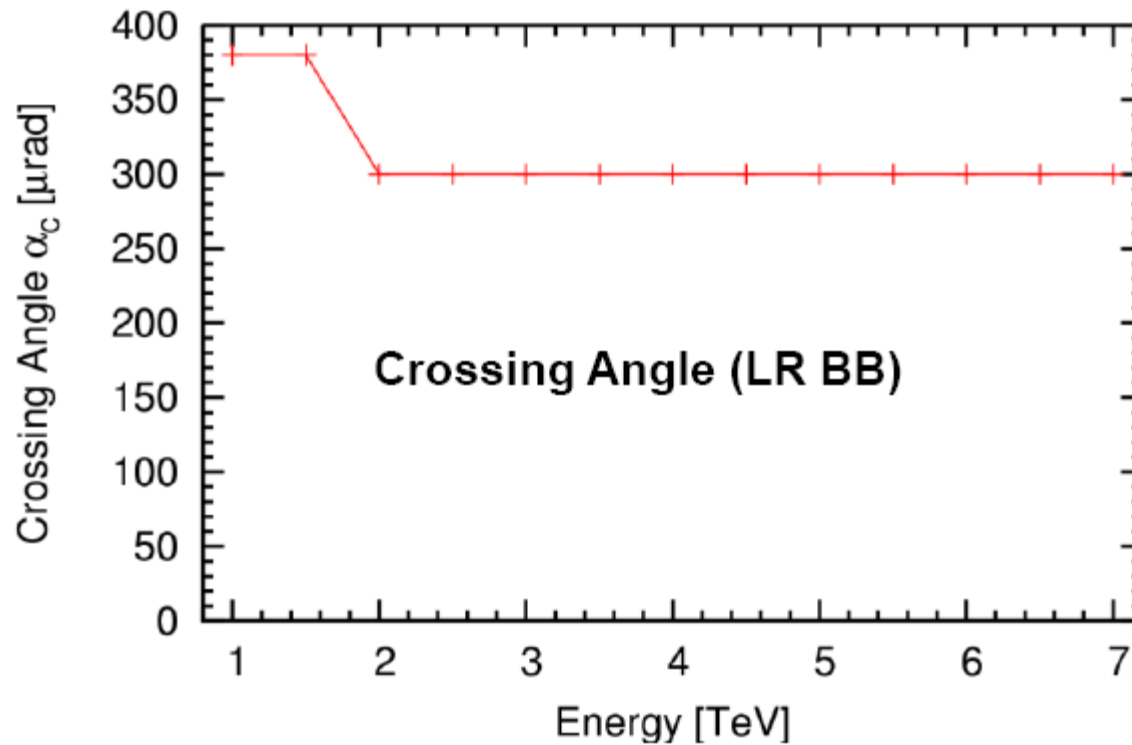
- Required crossing angle for 2.75 TeV for minimum 10σ separation (scales $\approx 1/\sqrt{\gamma}$)

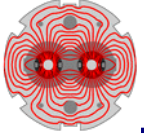


Werner Herr



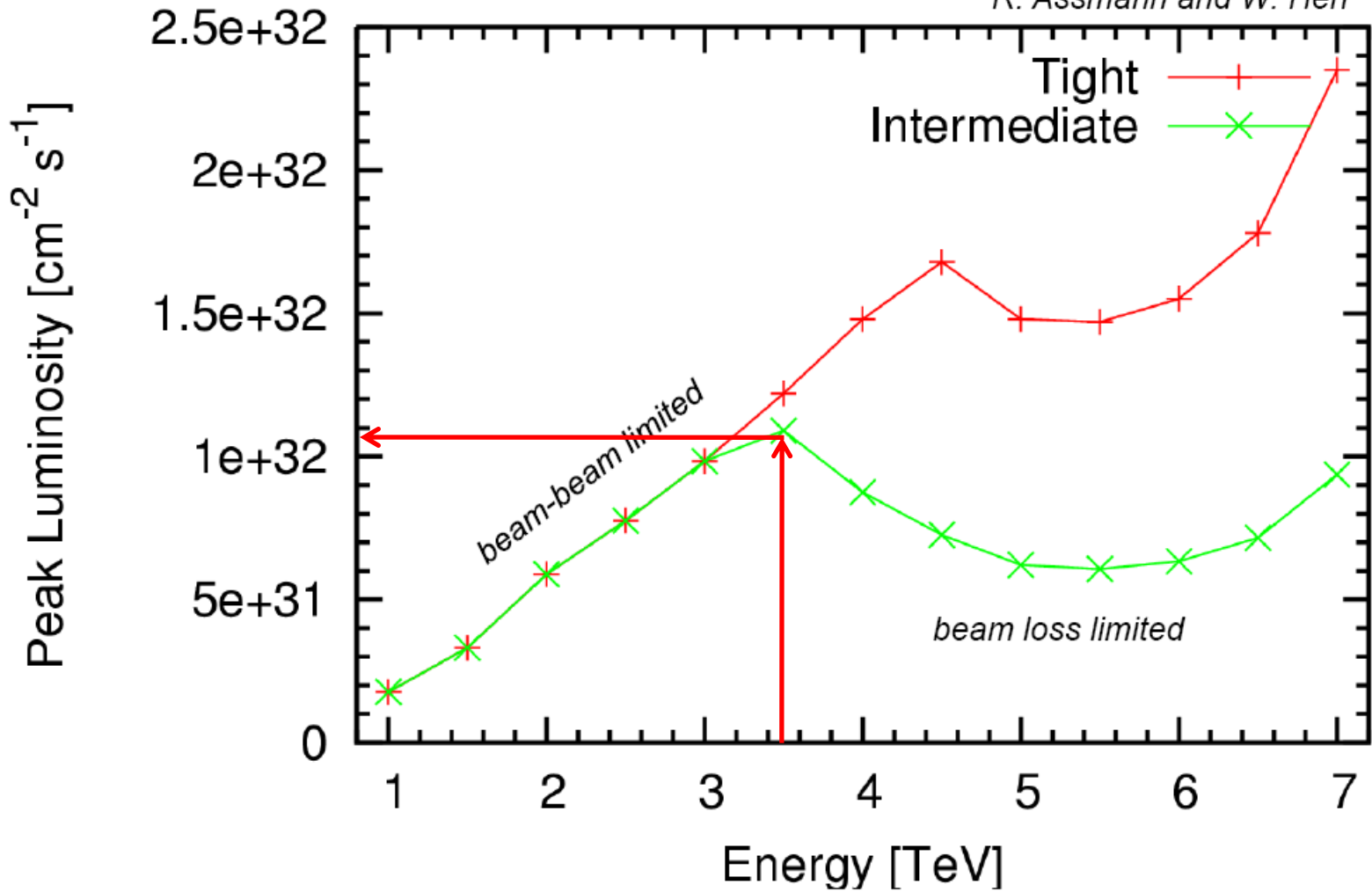
Crossing angle – LRBB v. energy

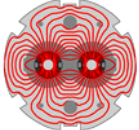




Peak luminosity

R. Assmann and W. Herr

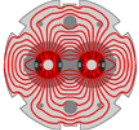




Operation - assumptions

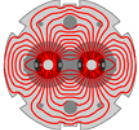
- Fill length: 8 hours
- Turnaround time: 5 hours
- 20 hours luminosity lifetime
- 30 day months.
- 40% machine availability
- Nominal crossing angle assumed for 50 ns.
- Total intensity limited to around 12% of nominal
- No squeeze beyond 2 m. with 156 bunches, crossing angle off - conservative

NB: BIG ERROR BARS – BALL PARK FIGURES ONLY



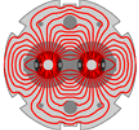
Plugging in the numbers – 3.5 TeV

Month	OP scenario	Max number bunch	Protons per bunch	Min beta*	Peak Lumi	Integrated	% nominal	events/X
1	Beam commissioning							
2	Pilot physics combined with commissioning	43	3×10^{10}	4	8.6×10^{29}	$\sim 200 \text{ nb}^{-1}$		
3		43	5×10^{10}	4	2.4×10^{30}	$\sim 1 \text{ pb}^{-1}$		
4		156	5×10^{10}	2	1.7×10^{31}	$\sim 9 \text{ pb}^{-1}$	2.5	
5a	No crossing angle	156	7×10^{10}	2	3.4×10^{31}	$\sim 18 \text{ pb}^{-1}$	3.4	
5b	No crossing angle – pushing bunch intensity	156	1×10^{11}	2	6.9×10^{31}	$\sim 36 \text{ pb}^{-1}$	4.8	1.6
6	partial 50 ns – nominal crossing angle	144	7×10^{10}	2-3	3.1×10^{31}	$\sim 16 \text{ pb}^{-1}$	3.1	0.8
7		288	7×10^{10}	2-3	8.6×10^{31}	$\sim 32 \text{ pb}^{-1}$	6.2	
8		432	7×10^{10}	2-3	9.2×10^{31}	$\sim 48 \text{ pb}^{-1}$	9.4	
9		432	9×10^{10}	2-3	1.5×10^{32}	$\sim 80 \text{ pb}^{-1}$	12	
10		432	9×10^{10}	2-3	1.5×10^{32}	$\sim 80 \text{ pb}^{-1}$	12	
11		432	9×10^{10}	2-3	1.5×10^{32}	$\sim 80 \text{ pb}^{-1}$	12	



Plugging in the numbers with a step in energy

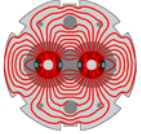
Month	OP scenario	Max number bunch	Protons per bunch	Min beta*	Peak Lumi	Integrated	% nominal	events/X
1	Beam commissioning							
2	Pilot physics combined with commissioning	43	3×10^{10}	4	8.6×10^{29}	$\sim 200 \text{ nb}^{-1}$		
3		43	5×10^{10}	4	2.4×10^{30}	$\sim 1 \text{ pb}^{-1}$		
4		156	5×10^{10}	2	1.7×10^{31}	$\sim 9 \text{ pb}^{-1}$	2.5	
5a	No crossing angle	156	7×10^{10}	2	3.4×10^{31}	$\sim 18 \text{ pb}^{-1}$	3.4	0.8
5b	No crossing angle – pushing bunch intensity	156	1×10^{11}	2	6.9×10^{31}	$\sim 36 \text{ pb}^{-1}$	4.8	1.6
6	Shift to higher energy: approx 4 weeks	Would aim for physics without crossing angle in the first instance with a gentle ramp back up in intensity						
7	4 – 5 TeV (5 TeV luminosity numbers quoted)	156	7×10^{10}	2	4.9×10^{31}	$\sim 26 \text{ pb}^{-1}$	3.4	
8	50 ns – nominal crossing angle	144	7×10^{10}	2	4.4×10^{31}	$\sim 23 \text{ pb}^{-1}$	3.1	1.1
9	50 ns	288	7×10^{10}	2	8.8×10^{31}	$\sim 46 \text{ pb}^{-1}$	6.2	
10	50 ns	432	7×10^{10}	2	1.3×10^{32}	$\sim 69 \text{ pb}^{-1}$	9.4	
11	50 ns	432	9×10^{10}	2	2.1×10^{32}	$\sim 110 \text{ pb}^{-1}$	12	



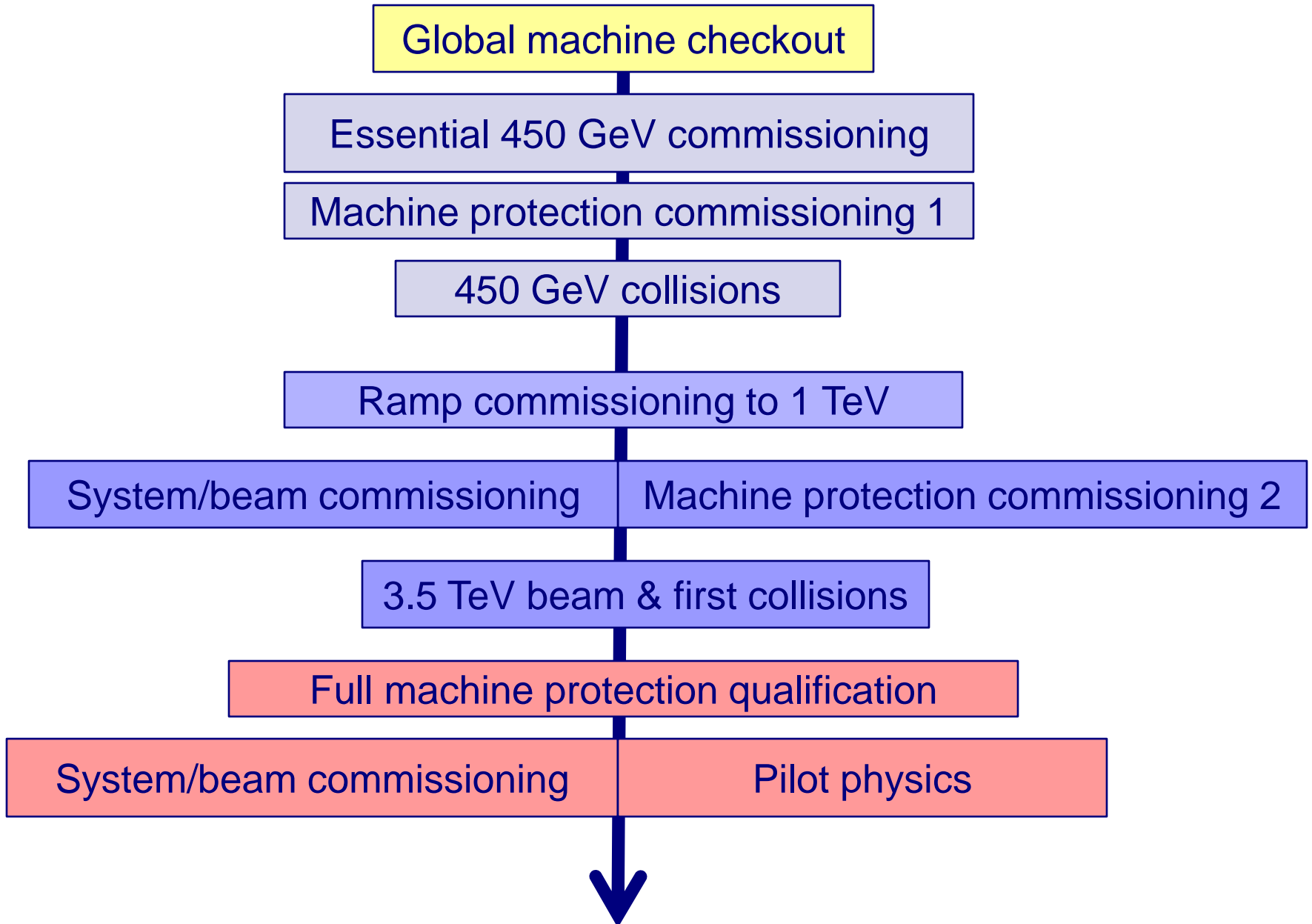
Step up in energy

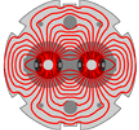
Task	Comment	Time
Hardware commissioning of main circuits	<ul style="list-style-type: none">• Modification and testing of dump resistors• Installation of snubbing capacitors• Calorimetry and QPS measurements	~ 2 weeks
Qualification of machine protection without beam	FMCMs, PIC, Collimators, TCDQ, BLMs, BPM interlocks, SMPs, RF, LBDS	In parallel with HWC
Operation dry runs of re-qualified sectors		After hand over from HWC
Re-commissioning of ramp and associated machine protection	Safe beam: LBDS, BLMs, RF	~ 1 week
Re-commissioning of squeeze	Could possibly ramp-squeeze-ramp (avoiding the need to re-com the 3.5 TeV squeeze)	
Optics and operations' checks at high energy		~ 2 days
Collimator re-optimization		~4 days

Estimate: 4 weeks to re-establish physics



Beam commissioning

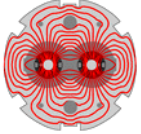




450 GeV collisions

- Time limited: 3-4 shifts
- No squeeze
- Low intensity – machine protection commissioning unlikely to be very advanced.
- ~1 week after first beam

No of bunches	1	4	12
Particles/bunch 10^{10}	4	4	4
Beam Intensity	$4 \cdot 10^{10}$	$16 \cdot 10^{10}$	$4.8 \cdot 10^{11}$
fraction of nominal beam intensity	0.0001	0.0005	0.0015
beta* [m]	11	11	11
Luminosity [$\text{cm}^{-2} \text{s}^{-1}$]	$1.7 \cdot 10^{27}$	$6.6 \cdot 10^{27}$	$2 \cdot 10^{28}$
Integrated Lumi 24 hours [nb^{-1}]*	0.06	0.24	0.7
Beam size at IP [microns]	293	293	293
inelastic event rate [kHz]**	0.07	0.27	0.8



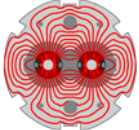
Possible evolution

Physics at 3.5 TeV
beta* = 2m.
no crossing angle, 156 bunches

Step up

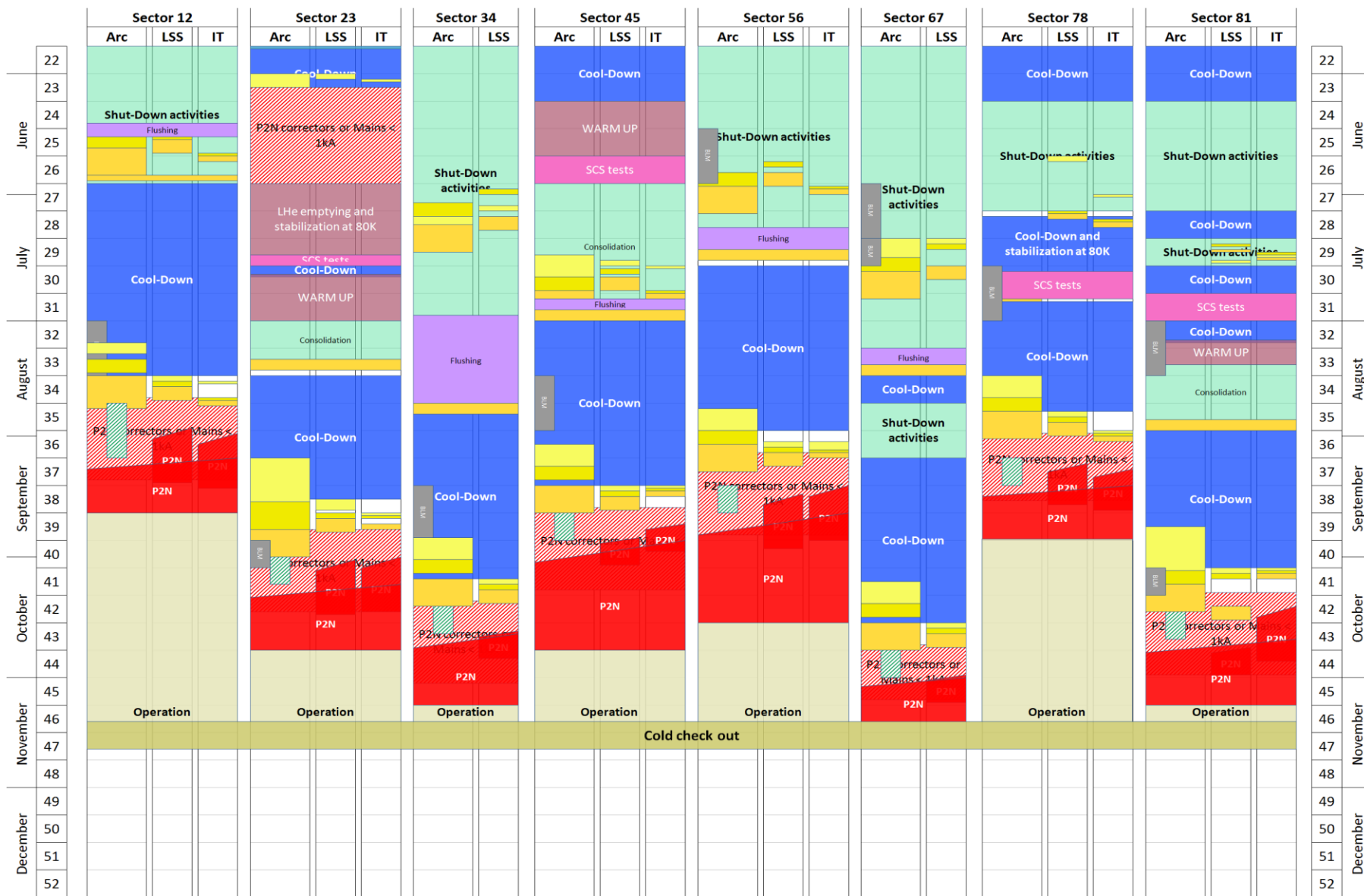
Ramp, squeeze, ramp to 4-5 TeV
beta* = 2m.
no crossing angle, 156 bunches

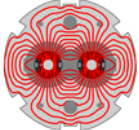
Ramp, squeeze at 4.5 TeV
beta* = 2 m
crossing angle, 50 ns



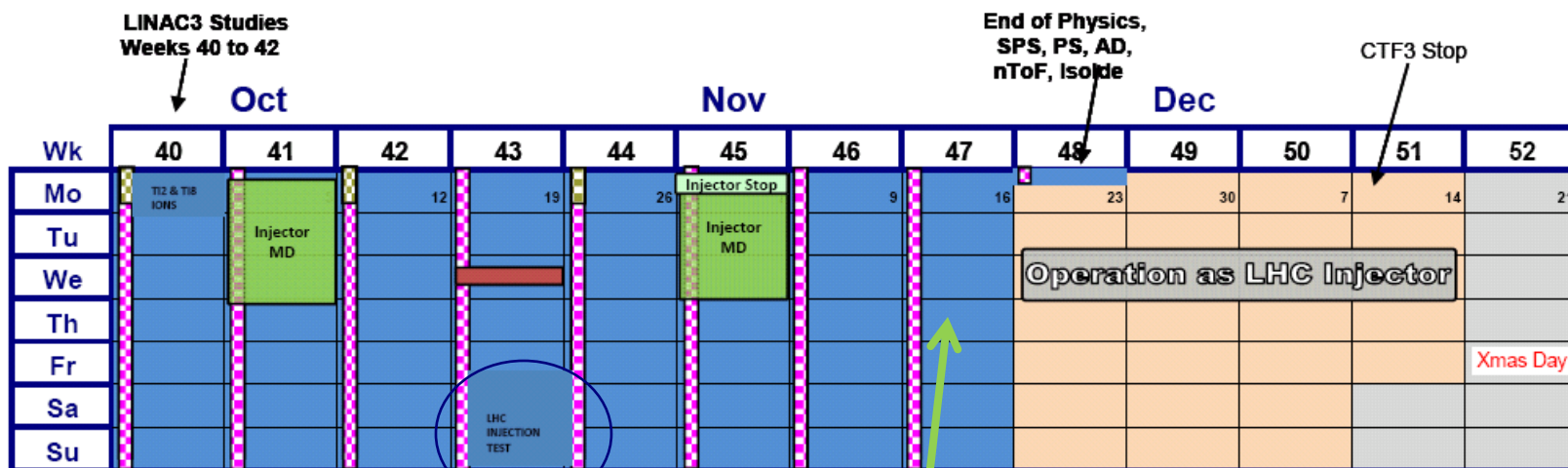
Latest Schedule

Katy Foraz





Injectors

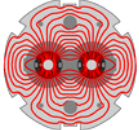


- Injector Complex MD Block
- 8-hour Wednesday MD
- Injector Stop Technical Stop for the injector Chain

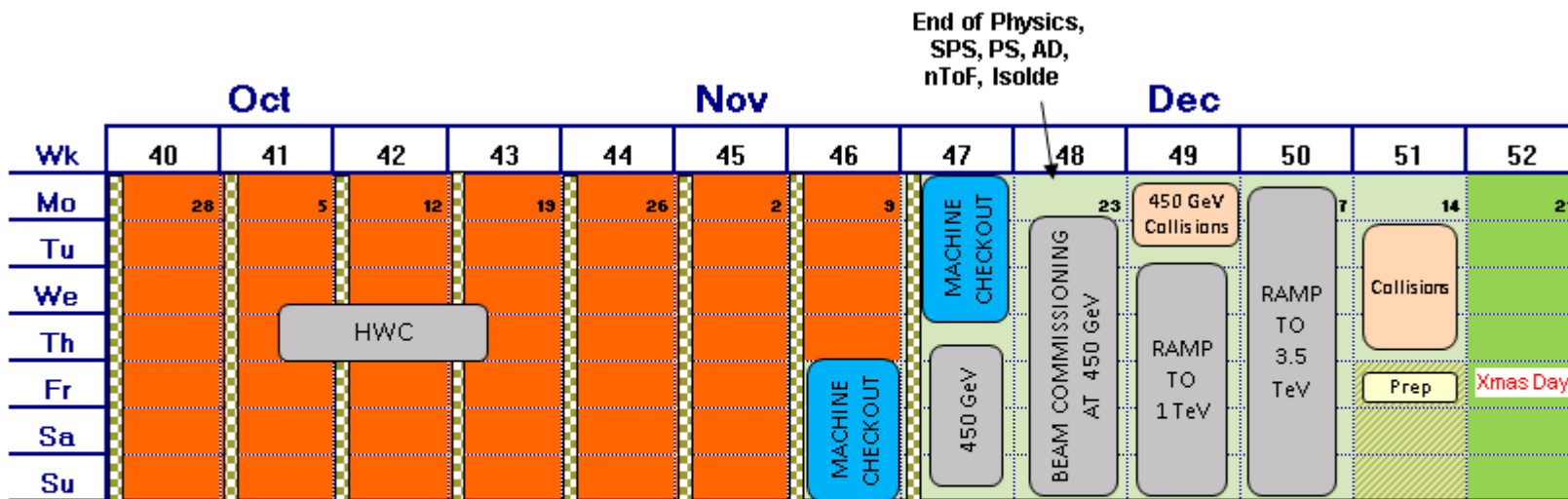
- AD Physics
- AD Setting-up & Studies

Injection test

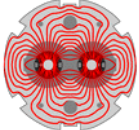
± first LHC beam



LHC 2009



- Technical Stop
- Beam commissioning
- SPS et al physics

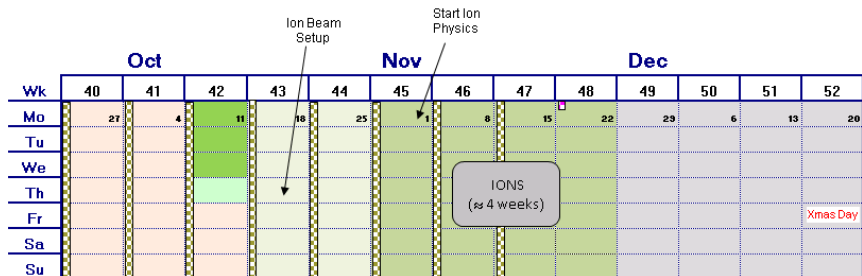
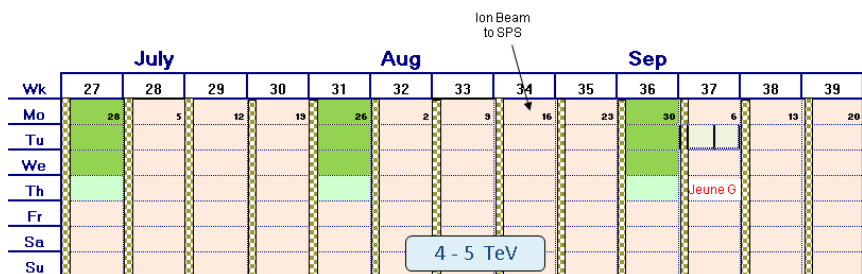
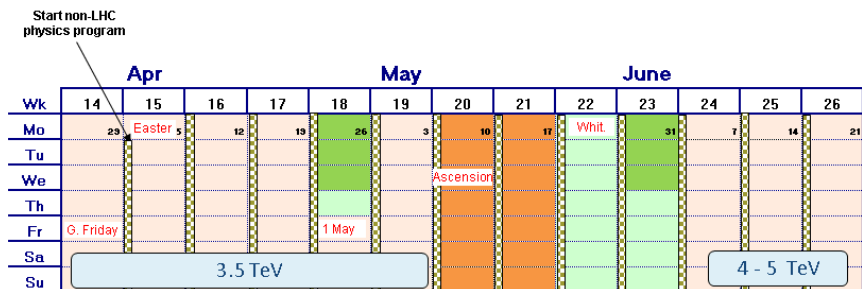
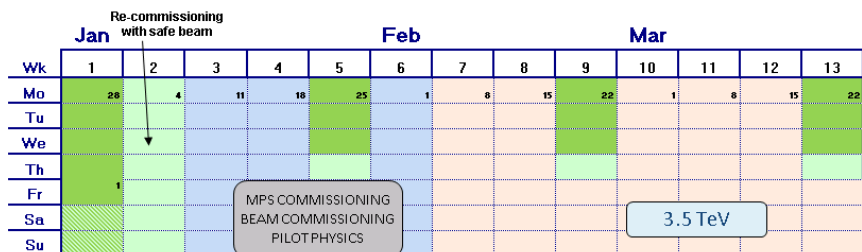


LHC 2010 – very draft

ml

29/4/2009
V1.0

2010 LHC Schedule Very draft

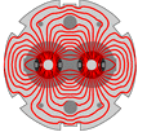


• 2009:

- 1 month commissioning

• 2010:

- 1 month pilot & commissioning
- 3 month 3.5 TeV
- 1 month step-up
- 5 month 4 - 5 TeV
- 1 month ions



Conclusions

- Constraints of 3.5 TeV enumerated
- Potential performance shown
 - NB: ball park figures only
- Step up in energy would take ~4 weeks
- Would start with a flat machine at the higher energy...
- before bringing on crossing angle and exploiting 50 ns.
- Potential performance shown
- As always, we note:
 - importance of collimator system commissioning in allowing any increases in intensity
 - Full and thorough commissioning of machine protection system as an essential pre-requisite