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 c0m (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

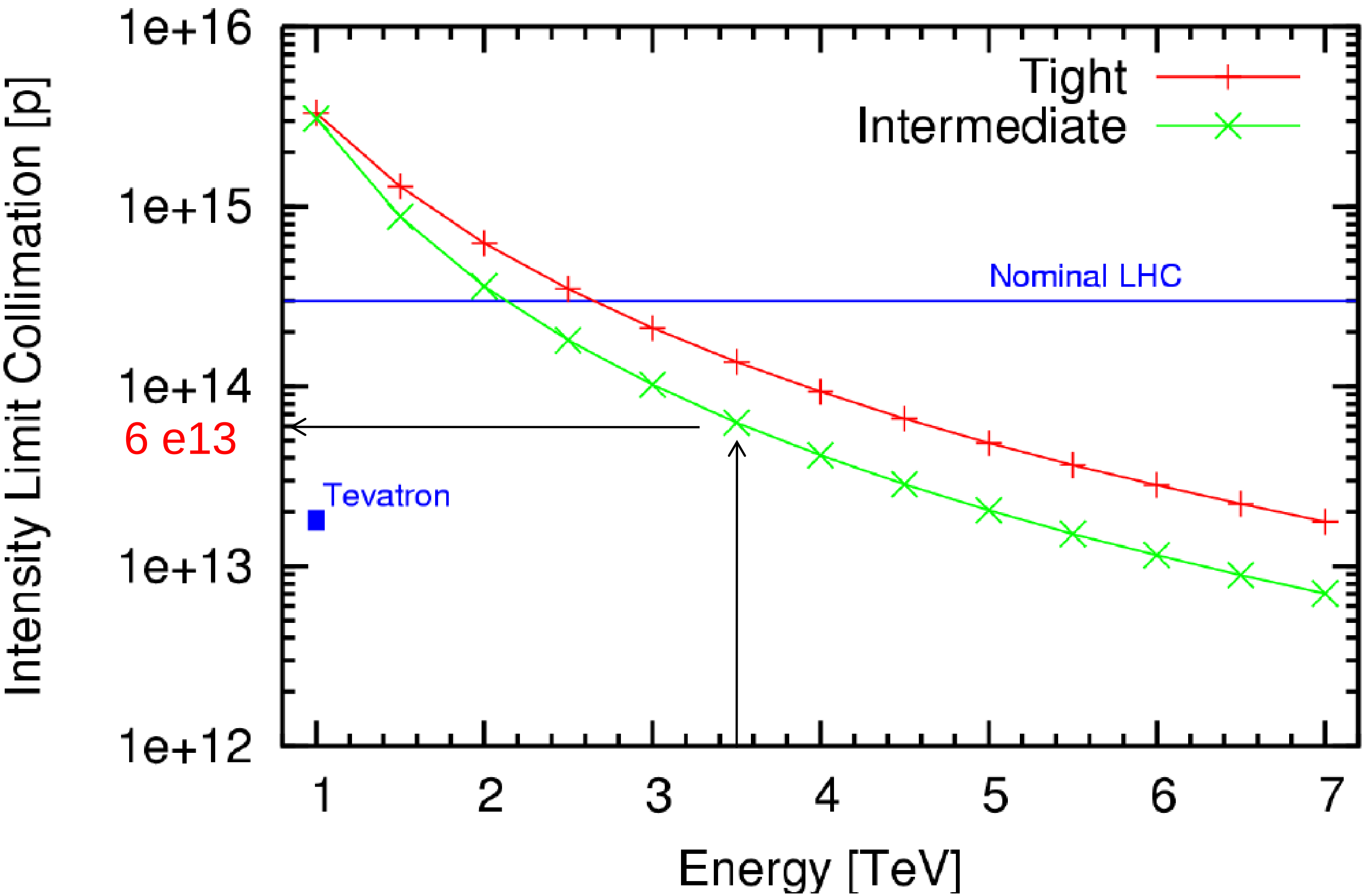
Recall

- 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: $L \propto \gamma$

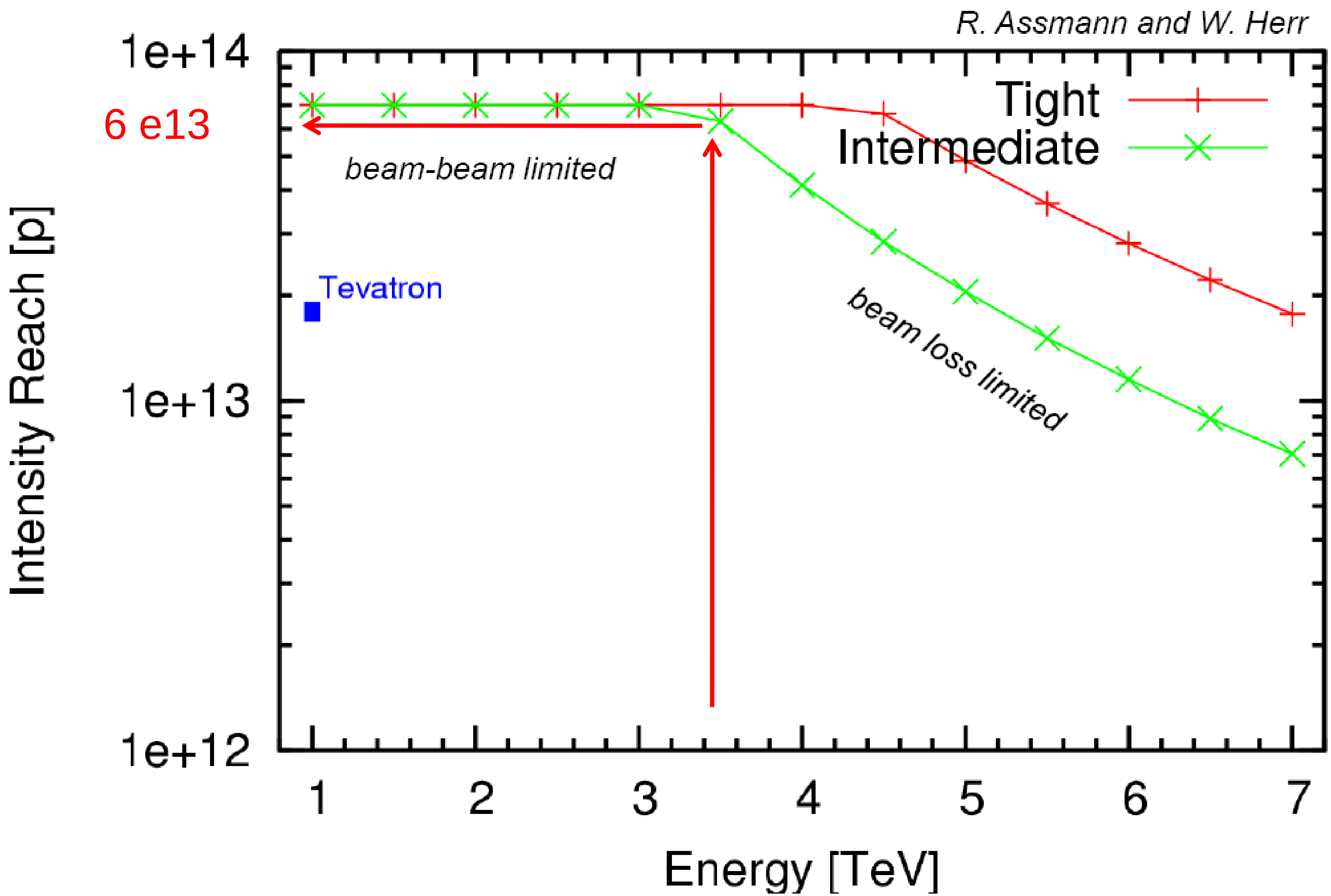
- However, because beam size goes as: $\frac{1}{\sqrt{\gamma}}$
  - lower energy:
    - $\rightarrow$ increased beam size – less aperture $\rightarrow$ higher β^*
    - $\rightarrow$ separation of beams in interaction regions drops

Intensity limit - collimation

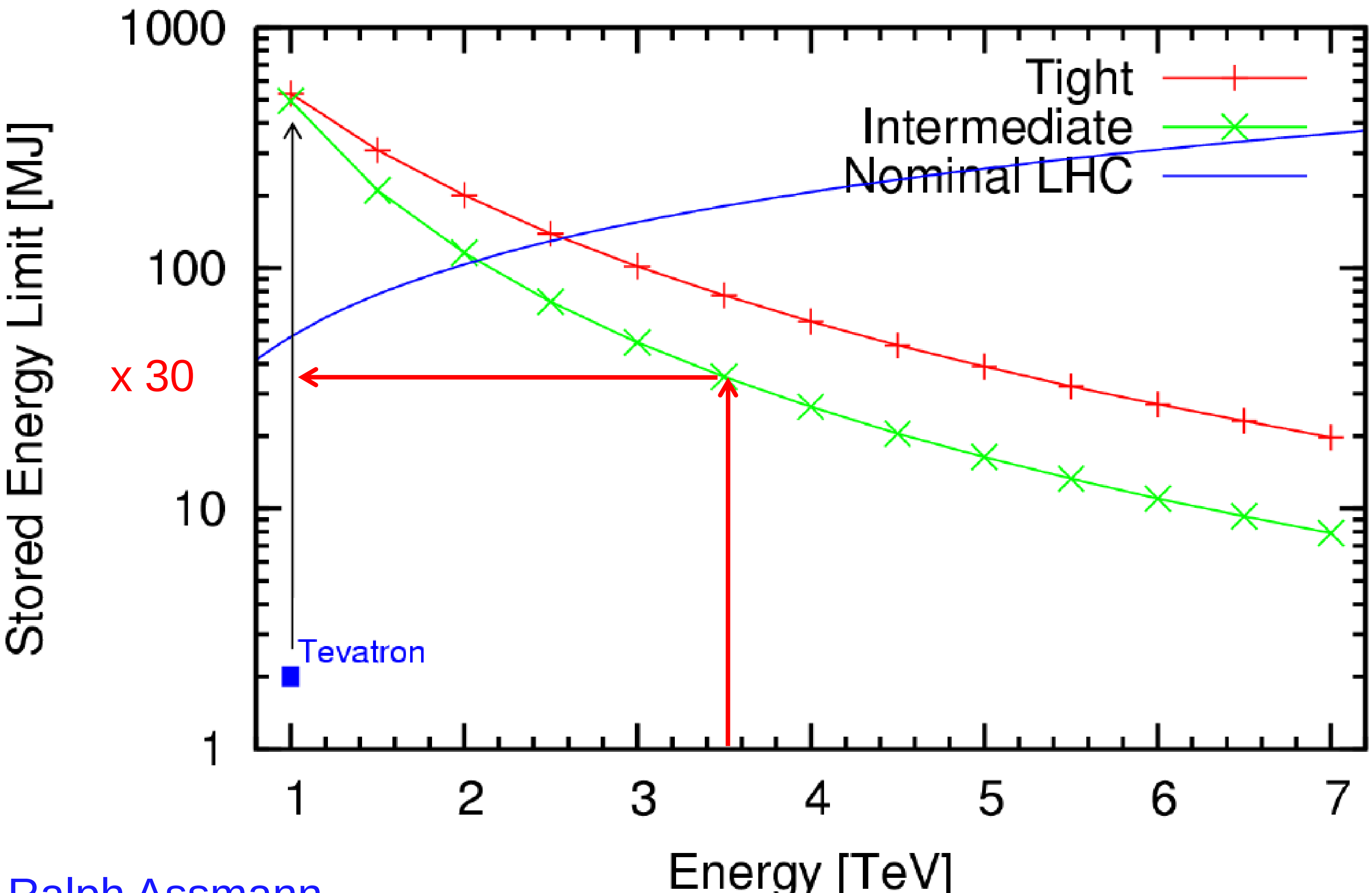


Ralph Assmann

Intensity – collimators and beam-beam



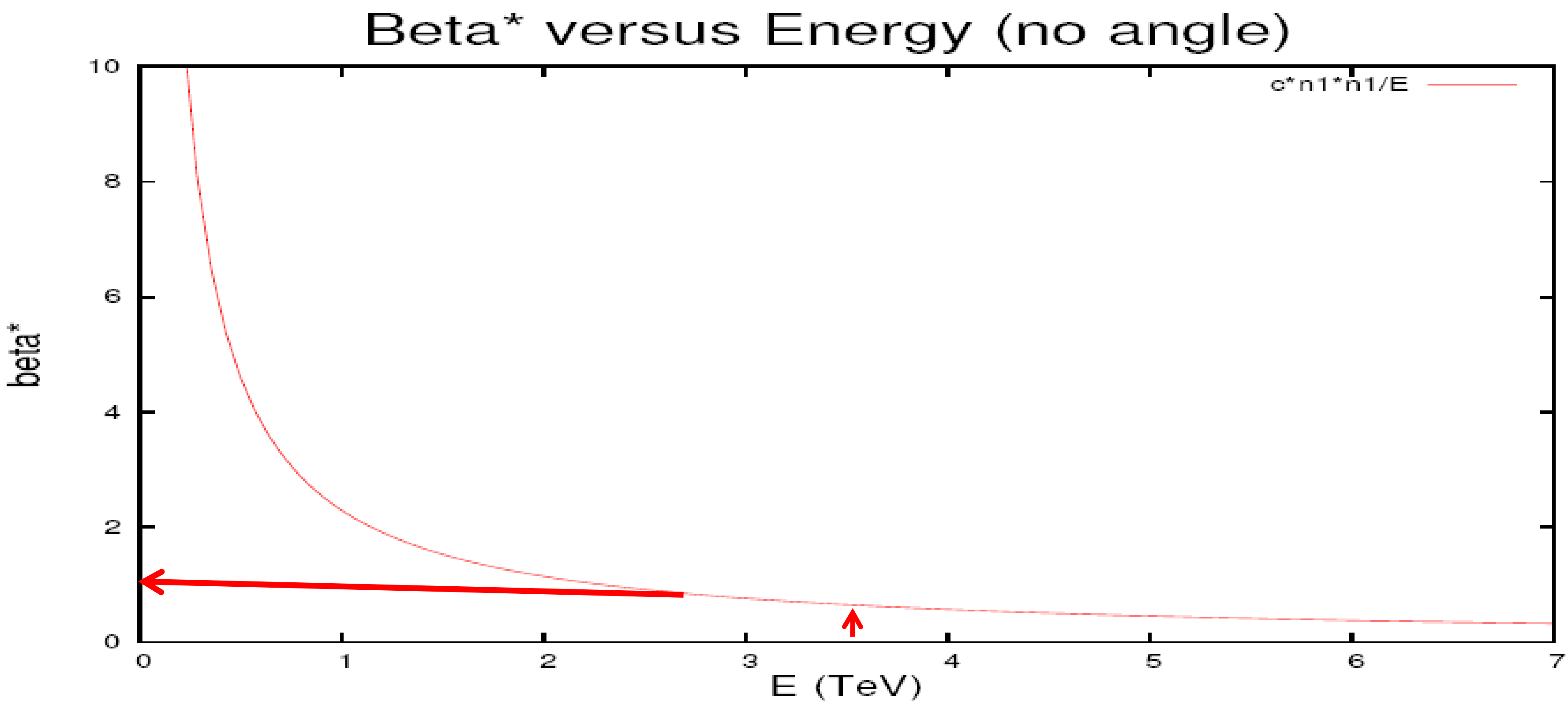
Limit stored energy versus beam energy



Ralph Assmann

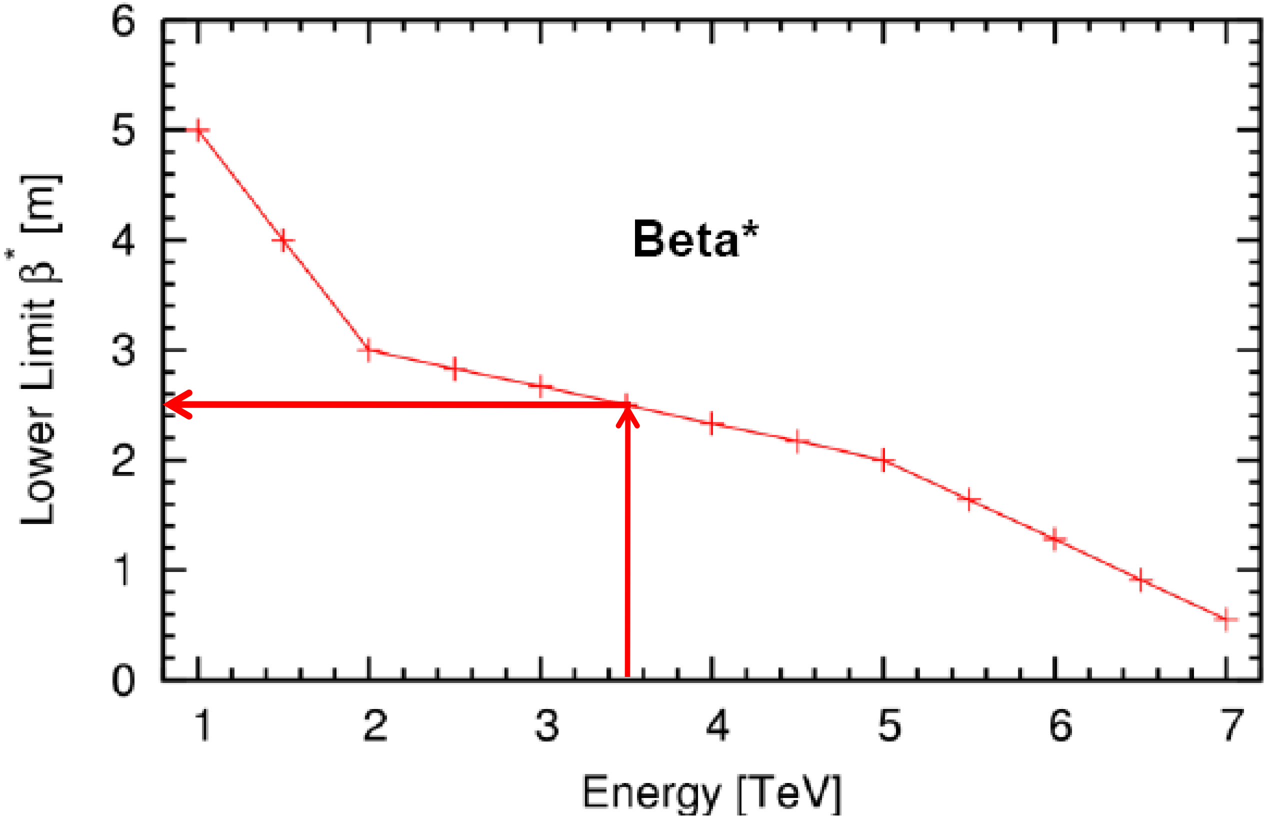
Beta* - no angle

- **Requiring minimum $n1$ of 7.0**



Werner Herr

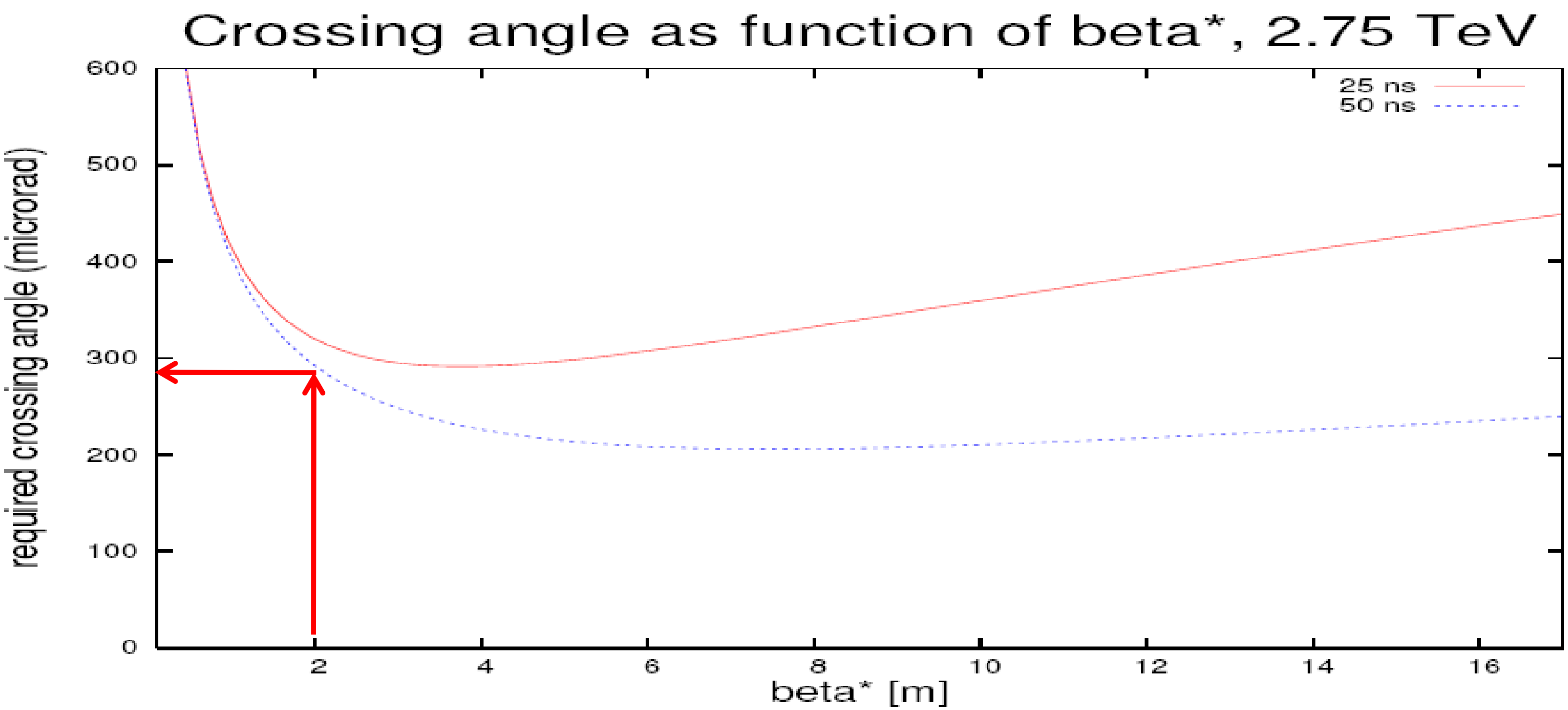
Beta* - with crossing angle



Werner Herr

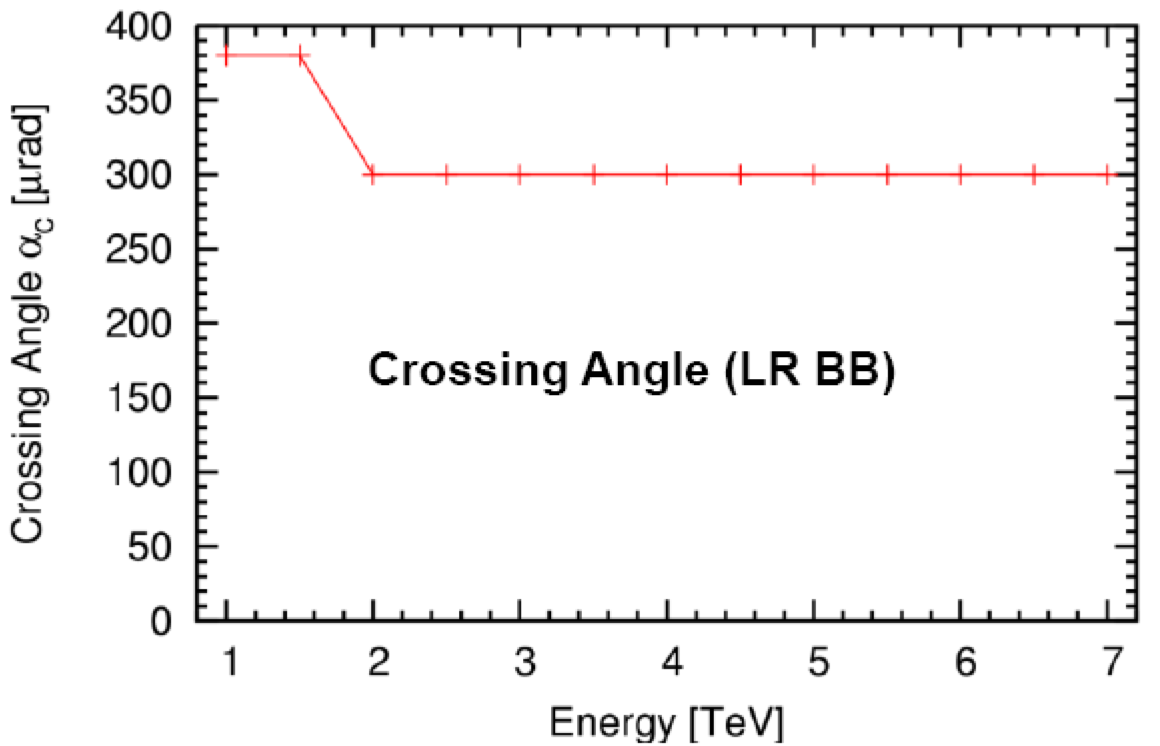
Crossing angle versus beta*

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

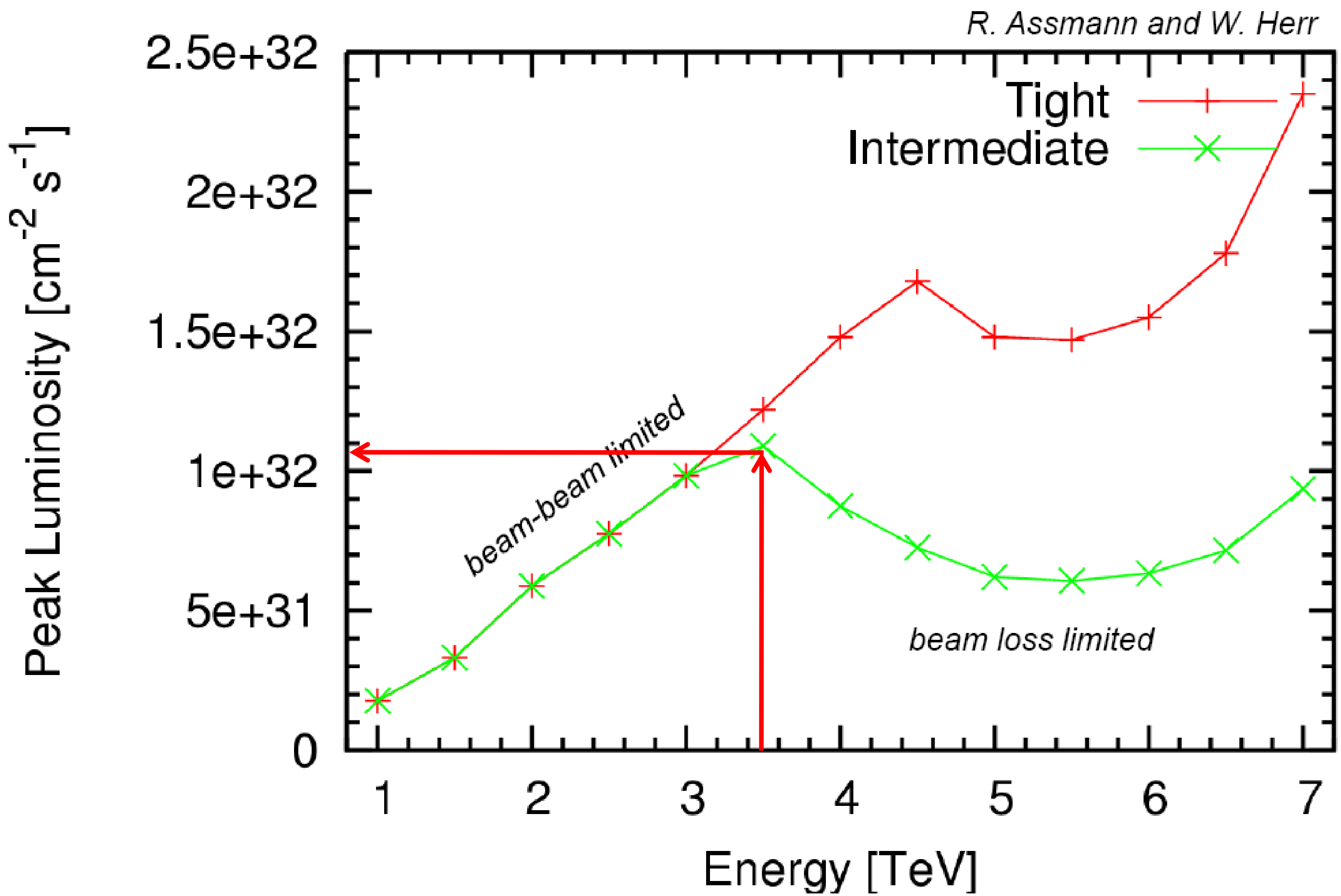


Werner Herr

Crossing angle – LRBB v. energy



Peak luminosity



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}	~200 nb^{-1}		
3		43	5×10^{10}	4	2.4×10^{30}	~1 pb^{-1}		
4		156	5×10^{10}	2	1.7×10^{31}	~9 pb^{-1}	2.5	
5a	No crossing angle	156	7×10^{10}	2	3.4×10^{31}	~18 pb^{-1}	3.4	
5b	No crossing angle – pushing bunch intensity	156	1×10^{11}	2	6.9×10^{31}	~36 pb^{-1}	4.8	1.6
6	partial 50 ns – nominal crossing angle	144	7×10^{10}	2-3	3.1×10^{31}	~16 pb^{-1}	3.1	0.8
7		288	7×10^{10}	2-3	8.6×10^{31}	~32 pb^{-1}	6.2	
8		432	7×10^{10}	2-3	9.2×10^{31}	~48 pb^{-1}	9.4	
9		432	9×10^{10}	2-3	1.5×10^{32}	~80 pb^{-1}	12	
10		432	9×10^{10}	2-3	1.5×10^{32}	~80 pb^{-1}	12	
11		432	9×10^{10}	2-3	1.5×10^{32}	~80 pb^{-1}	12	

Plugging in the numbers with a step in energy

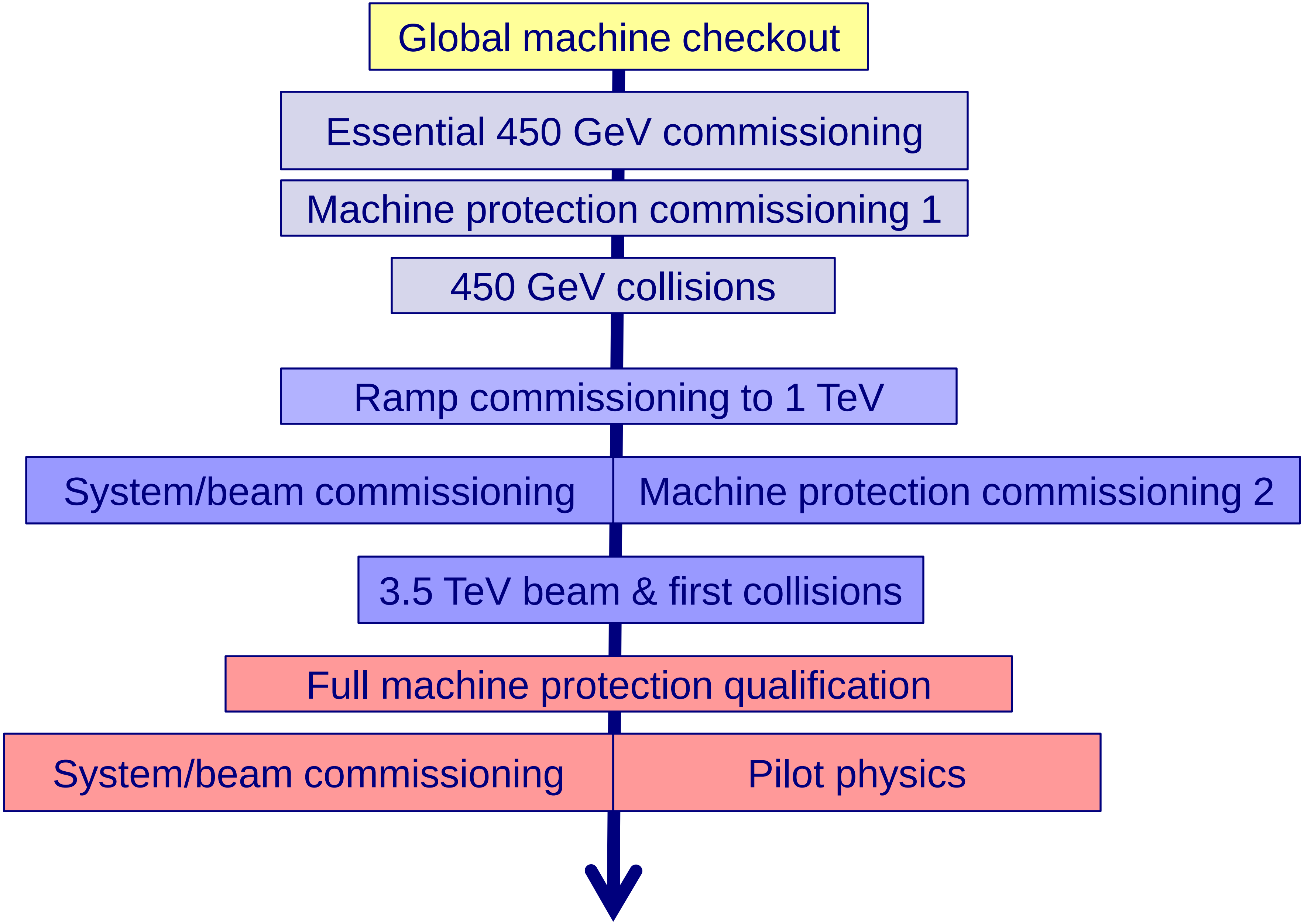
Month	OP scenario	Max number bunch	Protons per bunch	Min beta*	Peak Lumi	Integrated	% nominal	events/X
1	Beam commissioning							
2	Pilot physics combined with commissioning	43	3×10^{10}	4	8.6×10^{29}	~200 nb^{-1}		
3		43	5×10^{10}	4	2.4×10^{30}	~1 pb^{-1}		
4		156	5×10^{10}	2	1.7×10^{31}	~9 pb^{-1}	2.5	
5a	No crossing angle	156	7×10^{10}	2	3.4×10^{31}	~18 pb^{-1}	3.4	0.8
5b	No crossing angle – pushing bunch intensity	156	1×10^{11}	2	6.9×10^{31}	~36 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}	~26 pb^{-1}	3.4	
8	50 ns – nominal crossing angle	144	7×10^{10}	2	4.4×10^{31}	~23 pb^{-1}	3.1	1.1
9	50 ns	288	7×10^{10}	2	8.8×10^{31}	~46 pb^{-1}	6.2	
10	50 ns	432	7×10^{10}	2	1.3×10^{32}	~69 pb^{-1}	9.4	
11	50 ns	432	9×10^{10}	2	2.1×10^{32}	~110 pb^{-1}	12	

Step up in energy

Task	Comment	Time
Hardware commissioning of main circuits	• 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 10^10	16 10^10	4.8 10^11
fraction of nominal beam intensity	0.0001	0.0005	0.0015
beta* [m]	11	11	11
Luminosity [cm^-2 s^-1]	1.7 10^27	6.6 10^27	2 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

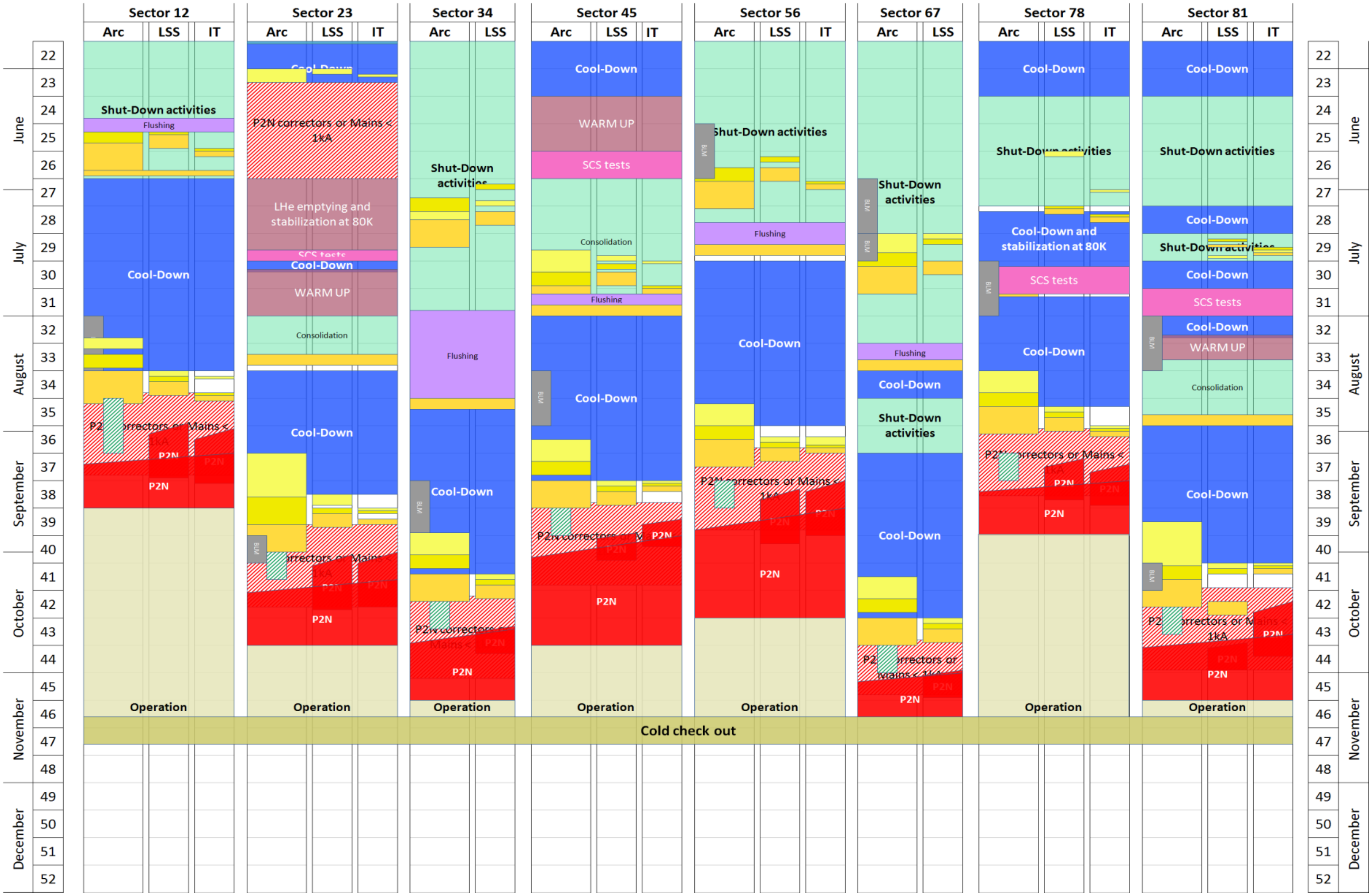
Step up

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

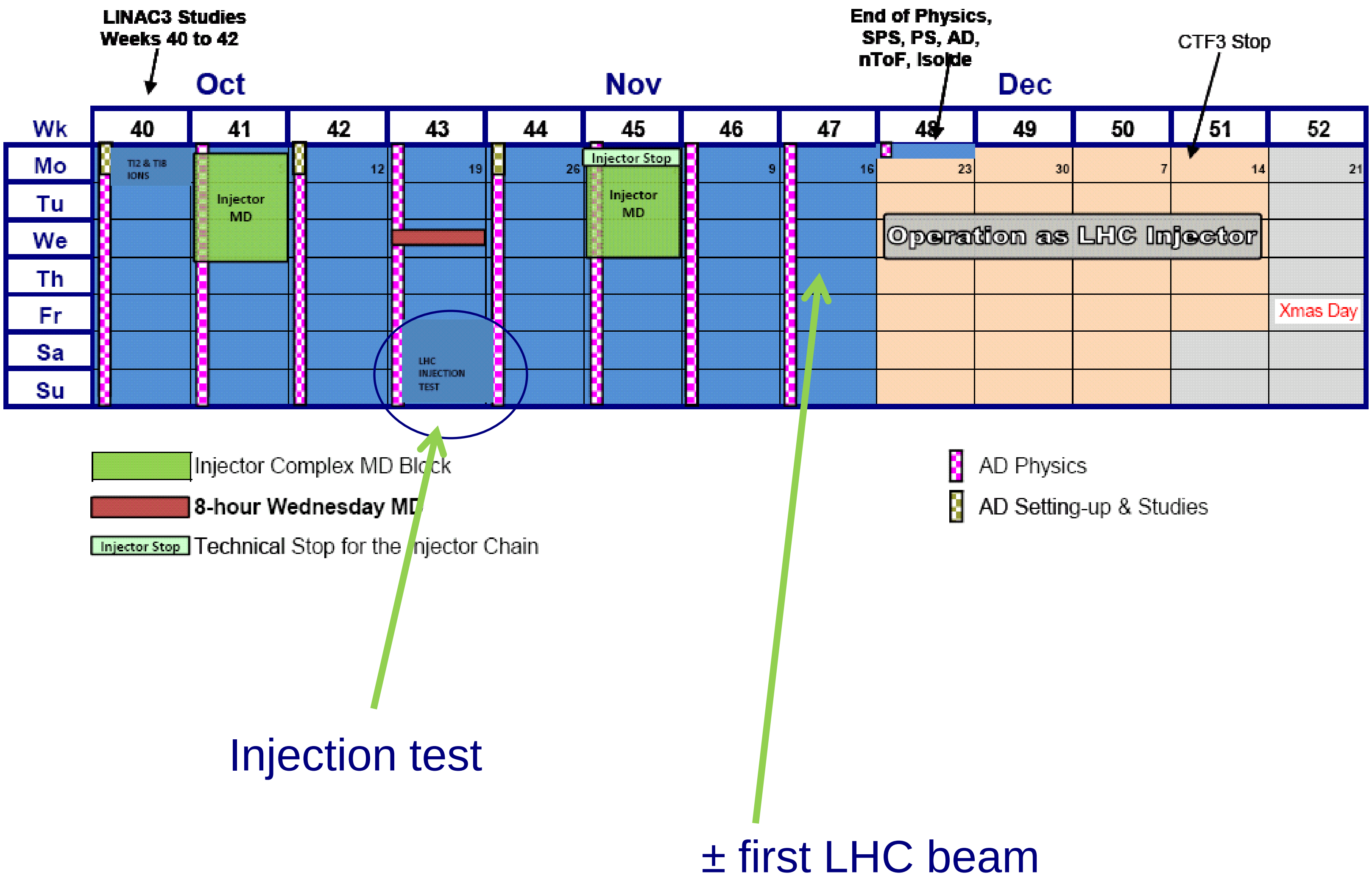
Ramp, squeeze at 4.5 TeV
beta* = 2 m
crossing angle, 50 ns

Latest Schedule

Katy Foraz



Injectors


LINAC3 Studies
Weeks 40 to 42
End of Physics,
SPS, PS, AD,
nToF, Isolde
CTF3 Stop
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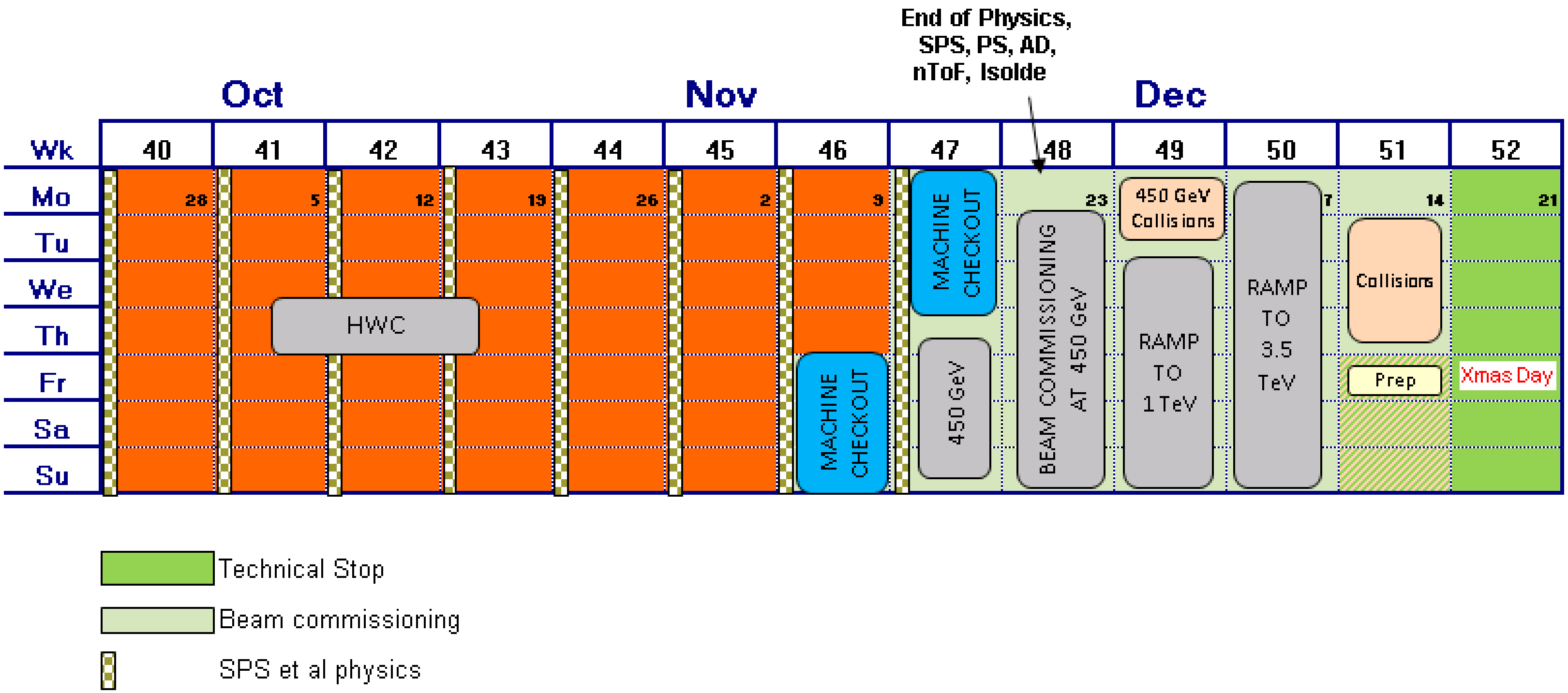
TI2 & TI8 IONS
Injector MD
Injector Stop
Injector MD
LHC INJECTION TEST
Operation as LHC Injector
Xmas Day
Injector Complex MD Block
8-hour Wednesday MD
Injector Stop
Technical Stop for the Injector Chain
AD Physics
AD Setting-up & Studies
Injection test
± first LHC beam

LHC 2009



End of Physics, SPS, PS, AD, nToF, Isolde
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HWC
MACHINE CHECKOUT
MACHINE CHECKOUT
450 GeV
BEAM COMMISSIONING AT 450 GeV
450 GeV Collisions
RAMP TO 1 TeV
RAMP TO 3.5 TeV
Collisions
Prep
Xmas Day
Technical Stop
Beam commissioning
SPS et al physics

LHC 2010 – very draft

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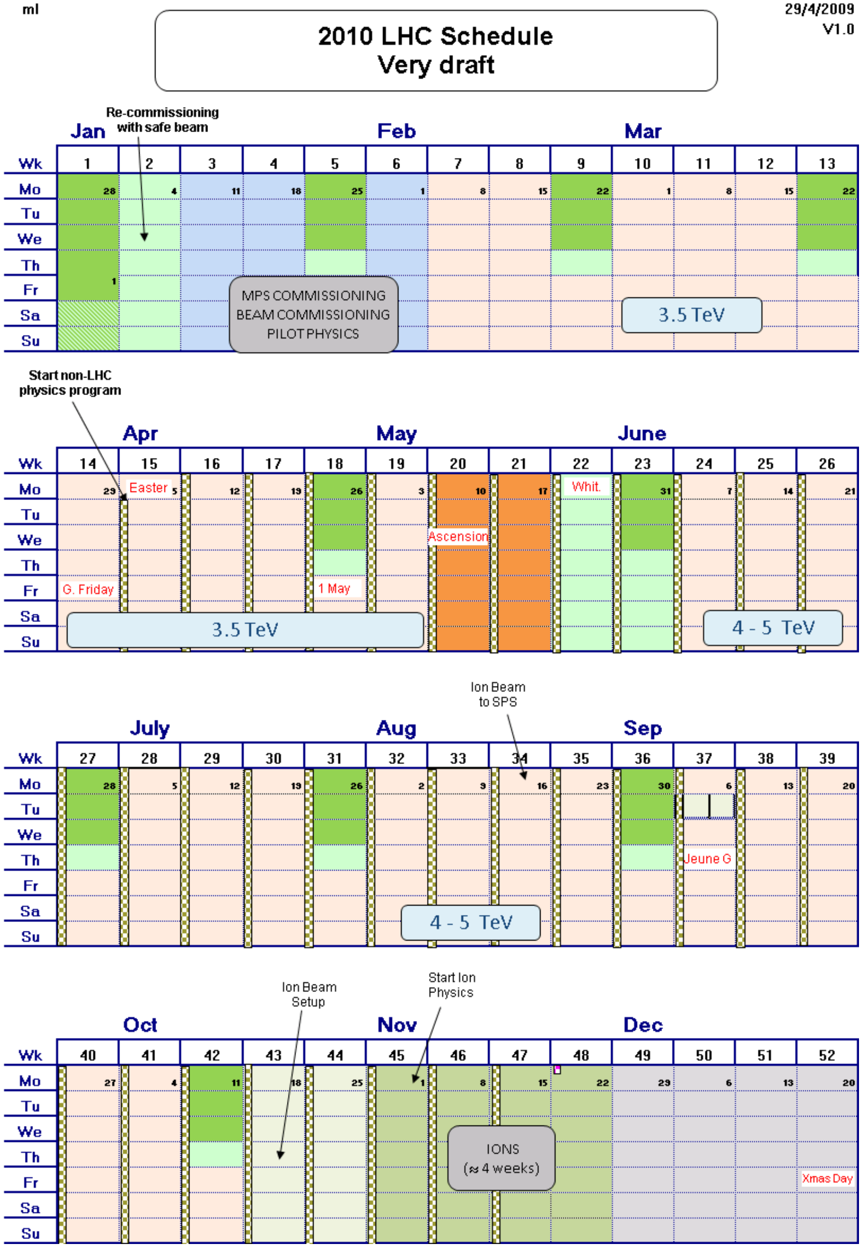

- **2009**:
  - 1 month commissioning
- **2010**:
  - 1 month pilot & commissioning
  - 3 month 3.5 TeV
  - 1 month step-up
  - 5 month 4 - 5 TeV
  - 1 month ions

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