Operational overhead of moving to higher energies

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Thanks for input to: Jan Uythoven,Markus Zerlauth,
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Energy increase - preamble

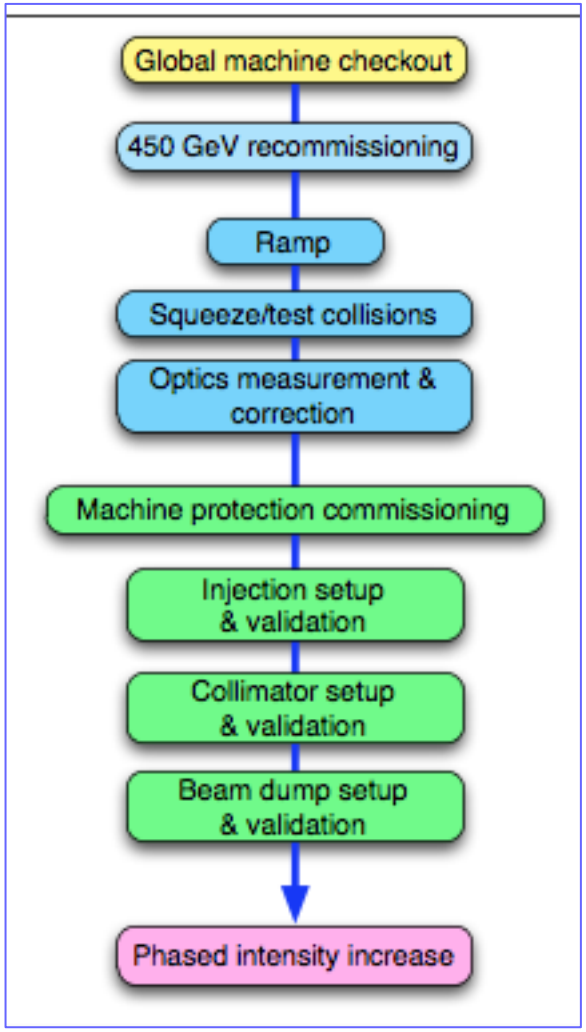
- Options
  - Start 2011 at a new energy
  - Switch to a new energy during year
  - Leave until 2012
  - (Tests in MD)
- Limits
  - BLMs: limitation in energy between 4 and 5 TeV due to noise on cables
  - LBDS: MKD break down along switch resulting in asynchronous dumps, awaiting isolators to be installed, limit at 4.5 TeV
    - Calibration runs to 5 TeV; Clamp voltages to 4.5 TeV; MKD cooling setupoint for 4.5 TeV
- Assume
  - Snubber capacitors, EE reconfiguration, QPS tests, IPQ tests, HWC… covered by Nuria

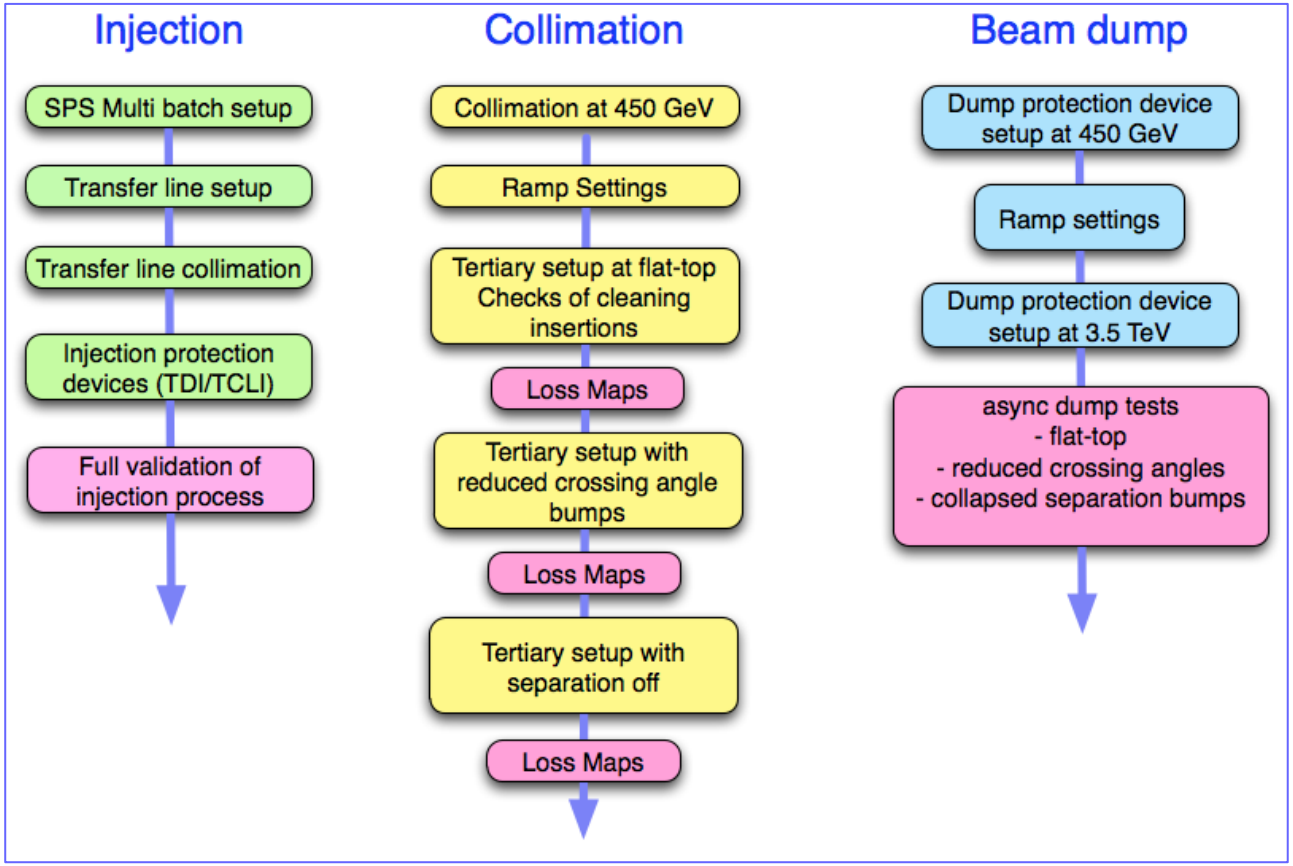
Re-commissioning in 2011

- Starting settings commissioning from scratch
- Regenerate virgin ramp & squeeze (to 1.5 m)
- Cut and paste in relevant experience
- Commission ramp and squeeze
- Full revalidation of LBDS with beam
  - Specific tests also for 4 – 4.5 TeV (BETS, protection)
- Re-set-up collimation and full re-validation
- Machine protection tests with beam
- Configuration and tests of feedbacks, transverse damper, RF etc…

If we start at a higher energy:
squeeze will be fully optimized and commissioned for said energy with optimum beta* etc. (see Werner Herr – Thursday morning)

Re-commissioning in 2011





Give or take some details – see below – starting 2011 at a new energy would be almost cost free (given, of course, readiness of circuits, QPS etc.)

Machine protection

- Most systems energy independent
  - PIC, BIS, PIC, WIC, SIS
  - FMCM – better at higher energy, quick verification of D1 say Energy: FMCM will get more performing with higher energies!
  - BLM threshold tables
- LBDS
  - Good to go to 4.5 TeV
  - Power supply limits. MSD calibration curves.

MPS team fairly relaxed about 0.5 to 1 TeV increase

Precycle

- Precycle and ramp-down precycle combination works with 3.5 TeV values for MB, MQ, IPQ, ITs, IPDs etc
- Would clearly take main circuits up to 4 TeV values etc.
- Slightly longer pre-cycle/ramp-down combo but nothing dramatic
- Some minor effect on decay at injection and snapback – mopped up with usual tools
- Diligent off-line preparation required as always

Ramp

- Optics don't change – magnet strengths constant
- Momentum function – careful Parabolic-Exponential-Linear-Parabolic – is the essential driving function
  - Strengths plus Momentum give required field, gradients etc.
  - Transfer functions give required current

- Offline generation of all magnet circuits functions
- Snapback, tune Q' evolution – give or take effects of different precycle - same
- Copy in: tune, chromaticity, coupling, orbit, knobs, beating trims, landau damping, separation, crossing angles, non-closure knobs
- Generate collimator settings, transverse damper, RF etc

> 3.5 TeV ramp

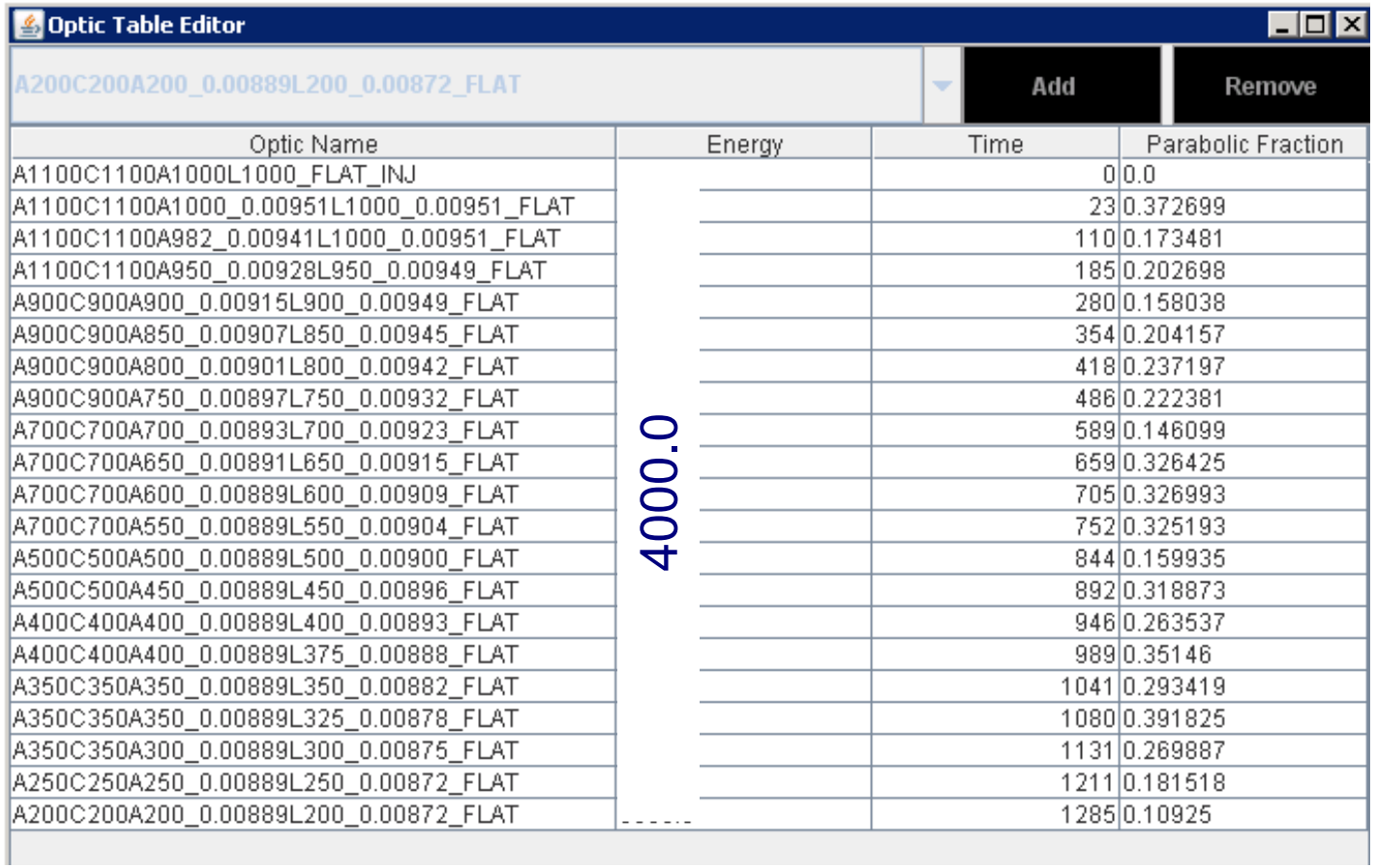
- Should be good to go
  - Pushing a bit further into magnet transfer functions but don't expect any surprises
- Extend orbit corrections at constant kick
- Extend collimator functions to track emittance reduction with energy
- Assume feedbacks, ADT, RF OK

- Low intensity trials to flat-top
  - Optics checks
  - Validation dumps
  - Loss maps

Squeeze reminder

- Stitch together matched optics
- Parabolic round in and round off over fixed time period per segment
  - Respecting time constraints from current decreases in single quadrant power converters
- Move to collisions tunes during first 23 s
- And worry about:
  - Tune feedback, orbit feedback – change of references
  - Q', coupling, optics corrections
  - Position of tertiary collimators

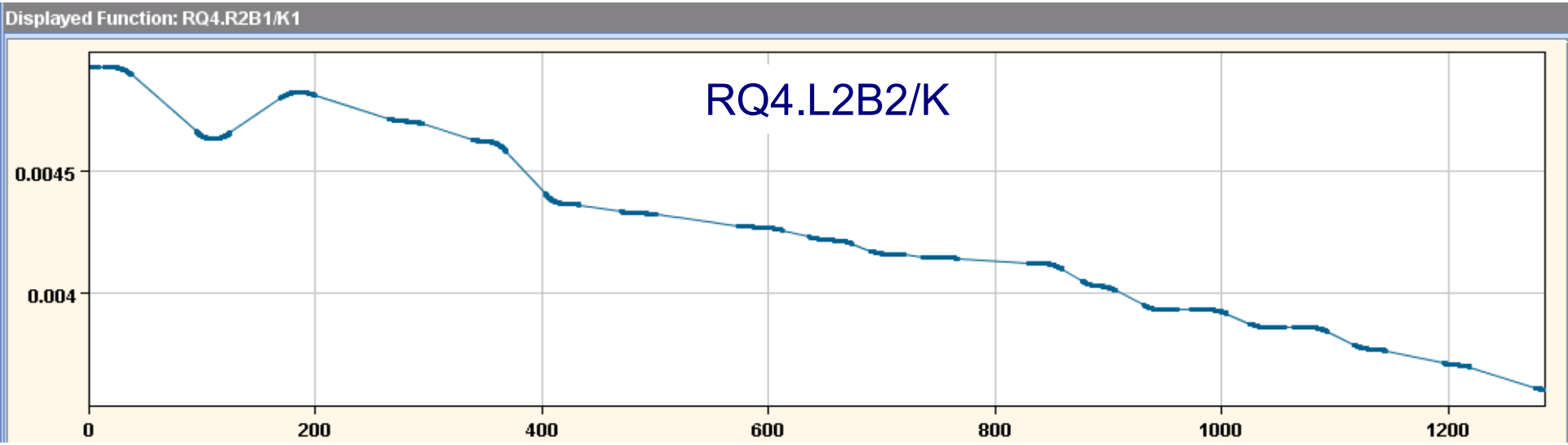
Squeeze skeleton

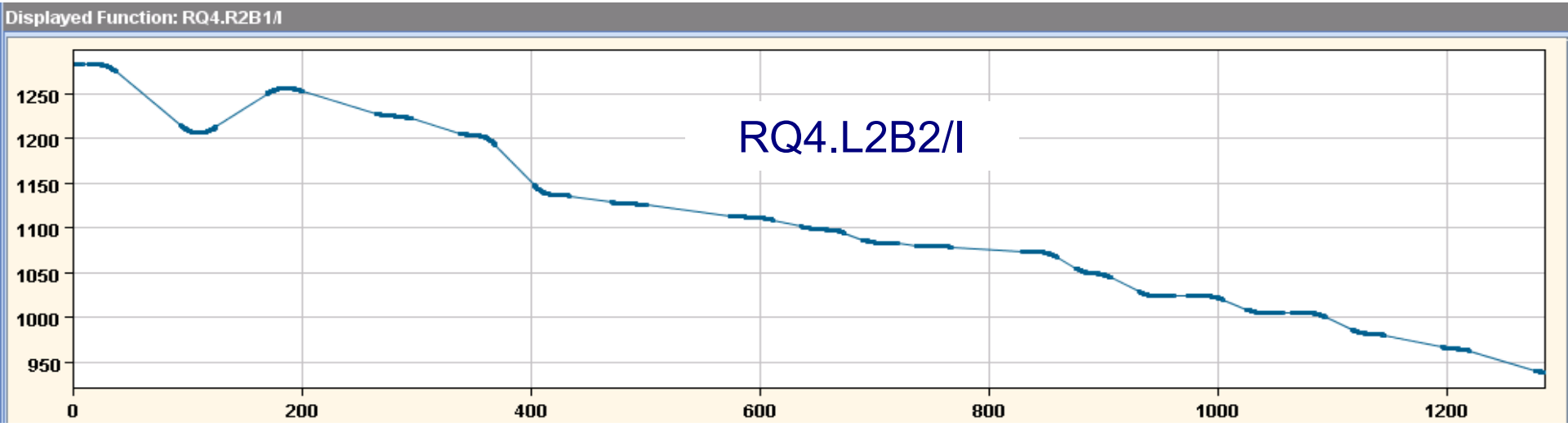


Optic Name	Energy	Time	Parabolic Fraction
A1100C1100A1000L1000_FLAT_INJ	4000.0	0	0.0
A1100C1100A1000_0.00951L1000_0.00951_FLAT		23	0.372699
A1100C1100A982_0.00941L1000_0.00951_FLAT		110	0.173481
A1100C1100A950_0.00928L950_0.00949_FLAT		185	0.202698
A900C900A900_0.00915L900_0.00949_FLAT		280	0.158038
A900C900A850_0.00907L850_0.00945_FLAT		354	0.204157
A900C900A800_0.00901L800_0.00942_FLAT		418	0.237197
A900C900A750_0.00897L750_0.00932_FLAT		486	0.222381
A700C700A700_0.00893L700_0.00923_FLAT		589	0.146099
A700C700A650_0.00891L650_0.00915_FLAT		659	0.326425
A700C700A600_0.00889L600_0.00909_FLAT		705	0.326993
A700C700A550_0.00889L550_0.00904_FLAT		752	0.325193
A500C500A500_0.00889L500_0.00900_FLAT		844	0.159935
A500C500A450_0.00889L450_0.00896_FLAT		892	0.318873
A400C400A400_0.00889L400_0.00893_FLAT		946	0.263537
A400C400A400_0.00889L375_0.00888_FLAT		989	0.35146
A350C350A350_0.00889L350_0.00882_FLAT		1041	0.293419
A350C350A350_0.00889L325_0.00878_FLAT		1080	0.391825
A350C350A300_0.00889L300_0.00875_FLAT		1131	0.269887
A250C250A250_0.00889L250_0.00872_FLAT		1211	0.181518
A200C200A200_0.00889L200_0.00872_FLAT		1285	0.10925

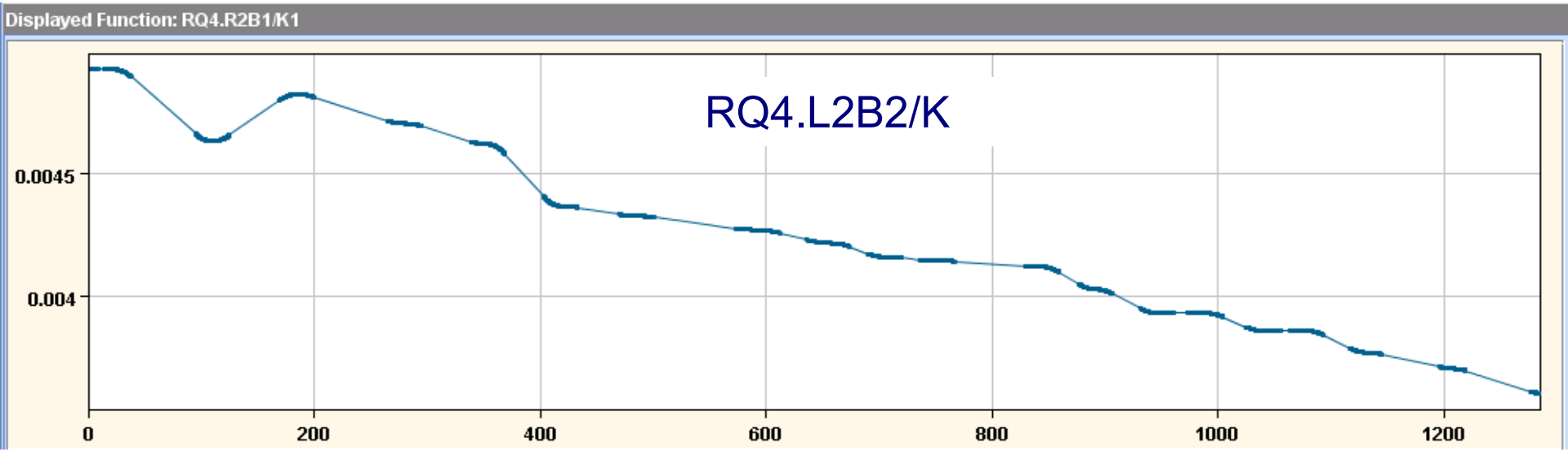
If we can use the same skeleton, we could use the same strength functions and simple re-scale with a new momentum function

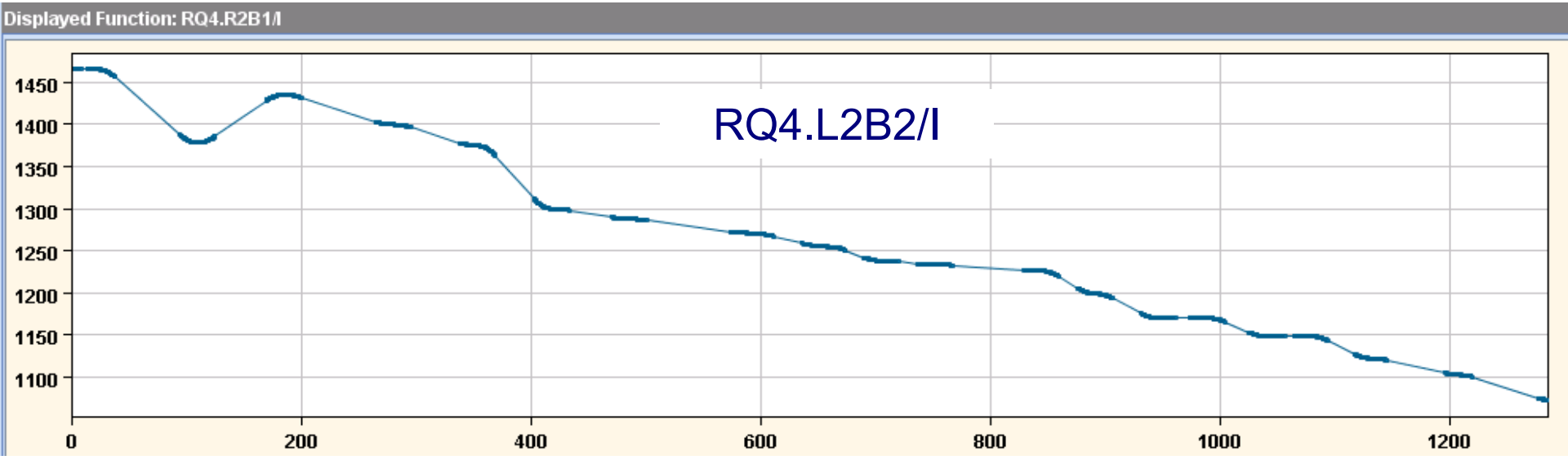
Squeeze strength functions at 3.5 TeV





Squeeze strength functions at 4 TeV





Squeeze re-use

- MAD optics/strengths are identical
- Currents more-or-less scaled up with energy
  - give or take non-linear components in the transfer functions
- Assume that we can keep the same matched optics skeleton and timings
  - sacrifice fully optimized timings and a few seconds.
  - could test in MD before making the step-up
- Also scale up orbit corrections
  - Might hope 3.5 TeV reference orbit holds good
- Tune, chromaticity and coupling corrections can be folded over – some change of persistent current effects
- Similarly beating corrections

Squeeze re-use

- Could sacrifice small potential reduction of beta*
  - For example: 1.6 m to 1.5 m going from 3.5 TeV to 4 TeV (approx. 7% in lumi)
  - Although with appropriate preemptive settings this could be recovered.

- Might hope that if beating and orbit are within limits that re-setup of collimators might not be required
  - slightly smaller beam sizes at collimators

- If this cunning wheeze doesn't work – collimator setup required.

Commissioning with squeeze re-use

Phase	Task	Shifts
Ramp	Low intensity trials, test beam dumps	1
Flat top	Orbit and optics checks	1
Flat top	LBDS – async dump	0.5
Flat top	betatron loss maps & pos off-momentum neg off-momentum	1
Squeeze	Q, Q', coupling, orbit checks, feedbacks	2
Squeeze	Beating & local coupling checks	1
Collision	Test, test lumi scans	0.5
1.5 m. with separation	betatron loss maps & pos off-momentum neg off momentum	1
1.5 m. with separation	Async dump	0.5
1.5 m. colliding	betatron loss maps & pos off-momentum neg off-momentum	1
1.5 m. colliding	Async dump	0.5
TOTAL		**10**

Commissioning for > 3.5 TeV

Around 1 week
with 50% machine availability

Count around another week
if full collimator set-up required

Collimator setup might be required at some point in the year anyway to deal with accumulated drifts.

Intensity ramp back up

- Clear that following successful commissioning and validation of ramp, squeeze etc. with low intensities we might like some circumspection before going back up to full intensity
- A fairly aggressive, staged ramp back up intensity would seem appropriate with:
  - More validation checks
  - Normal cross-system checklist

Count around a week

Beam

	3.5 TeV	4 TeV	4.5 TeV
gamma	3730.26	4263.16	4796.05
norm. emit. [m]	2.5×10^{-6}	2.5×10^{-6}	2.5×10^{-6}
emittance [m]	6.70×10^{-10}	5.86×10^{-10}	5.21×10^{-10}
beta* [m]	1.5 (1.6)	1.5 (1.5)	1.5
sigmaIP [micron]	31.7	29.66	27.96
Nb	930	930	930
Lumi	1.02×10^{33}	1.15×10^{33}	1.28×10^{33}
Stored energy [MJ]	59.9	68.5	77.0
Sigma 145 m	368.9	345.0	325.3
Sigma 85 m	282.4	264.2	249.1

Plus corresponding increase in energy density

Trade off

- In simple terms if the increase in energy:
  - brings an increase in sensitivity of x% (choose your channel)
  - brings an increase in luminosity of y%
  - takes N days to recommission
  - and R days to ramp up back up intensity

  - then we will have run at the increased energy for around (N + R/2)/(x + y) days to make up time.

- For example, 4 TeV
  - N = 7, R = 7, x = 0.25, y = 0.13
  - Around 4 weeks to catch up lost time

Conclusions

- Given any HWC/QPS/MP3 overheads
- Starting a new year at a new energy is almost cost free
  - Full setup from scratch planned anyway
- During run - with squeeze re-scaling
  - Around 1 week re-commissioning
  - Pre-flight checks in MD could be useful
- Without squeeze re-scaling
  - Collimator setup – around 2 weeks re-commissioning
- To be able to make up for lost time – don't leave it too late.
- Or run the whole year at 3.5 TeV