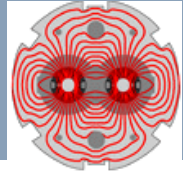
Parameters for 2011 - 2011 operation plans

Acknowledgment to all previous speakers for input and inspiration

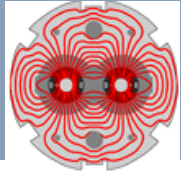
Warning !



This exercise is supposed to outline the possible operating conditions in 2011.

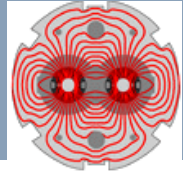
Of course we frequently end up doing things differently!!

The clients



- ATLAS & CMS : L as high as possible.
- LHCb:
  - $L \leq 3\times10^{32}$ Hz/cm^2
  - $\mu \leq 2.5$ events/Xing (σ_{vis} = 72.5 mb)
- ALICE:
  - $L \leq 4\times10^{30}$ Hz/cm^2
- TOTEM:
  - Operate at $\geq 15\sigma$
  - Leading probe bunch in the standard filling scheme.

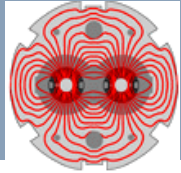
Special client requests



- VdM scans now and then.
  - Move TCTs with beam.
- ALICE:
  - Run at 1.38 TeV (equiv. nucleon energy to Pb-Pb). Collect 50×10^6 events (few fills with low int).
- TOTEM (& ALFA):
  - β^* 90 m, few bunches of ~ $6\text{-}7\times10^{10}$:
    - RPs at 7-8 σ and at 5-6 σ.
    - With ε = 3 μm and ε = 1 μm.

Small holes !!!!!!

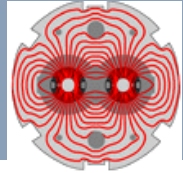
Flipping spectrometers



- LHCb and ALICE want to flip spectrometer polarities (& OFF)
- LHCb: affects only H orbit
  - Correction of non-closure (non-reproducibility) using external compensators working well.
- ALICE: *solenoid is flipped at the same time*.
  - V orbit (spectr.): same as for LHCb.
  - More tricky due to coupling of solenoid >> H orbit. Not done properly this year (knob structure).

Better correction procedure in the pipeline for 2011

Energy and beams



- Assume operation at 4 TeV – confirm or not in Chamonix.
  - Moderate difference to 3.5 TeV:
    - β^* reach, physical ε, quench threshold (UFOs…)
- Assume that 75 ns spacing is our work-horse beam.
  - Start immediately with this beam.
  - 150 ns as (working) hot spare.
  - 50 ns as development (2012 ?) and for beam scrubbing.

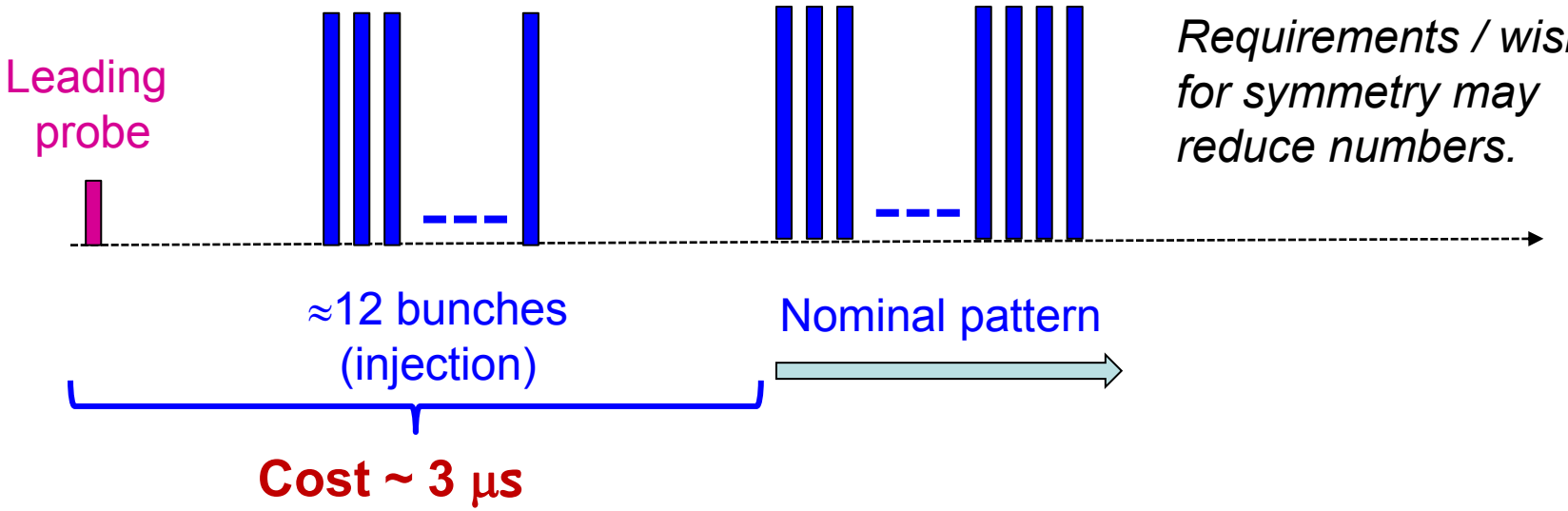
Not limited in total intensity – excellent performance of the collimation system, the machine (stability & FBs), and and good lifetimes !

Filling schemes

– Start with a probe (~10^{10}). Avoids over-injection. Q-diagnostics.

– First injection 12-24(?) bunches.

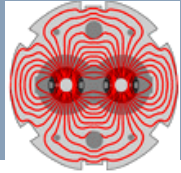
– Followed by nominal injections – up to 96/144 b 'achievable'



Requirements / wishes for symmetry may reduce numbers.

Schema	150 ns	75 ns	50 ns
Approx. max. bunches	450	930	1400

High luminosity IR β* (1)

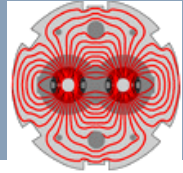


- β* reach given by:
  - (knowledge of) aperture,
  - tolerances → orbit reproducibility.

→ Too tight – less efficiency
Too loose – less lumi

- Quality of the orbit has increased during the 2010 run.
  - **Ions ≥ 150 ns ≥ July/August** – BPM calibration/T correction
  - Residual excursions / month ≈ ± 0.2 mm (peak).
  - Anticipate further quality improvements in 2011.

High luminosity IR beta* (2)

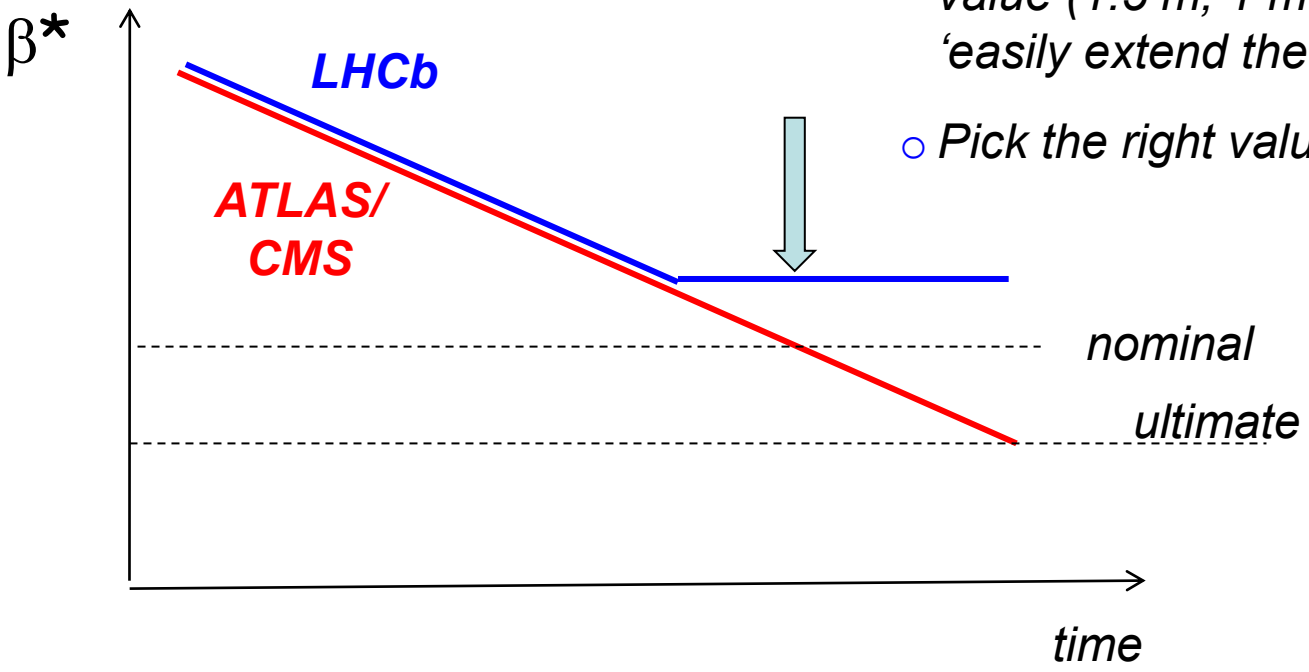


- With 2010 **intermediate** collimators settings: *R. Bruce*
  - **β* = 2.5 m** should be no problem.
- With **moderate** collimators settings (reduced margin TCT-triplet and TCT-TCDQ) could push:
  - to **β* = 2 m**,
  - or even to **β* = 1.5 m**.
  - *Remember that below 2 m squeeze becomes more tricky !!!*
  - *Long-range beam-beam.*
  - **Aperture measurements VERY early in 2011 run could increase our confidence in the choice of β*.** Should prepare settings for β* down to 1.x m (x ≤ 5).

ALICE & LHCb β*

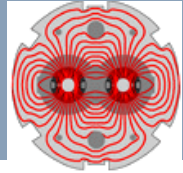
- ALICE:
  - 'Would profit from β* ≤ 2m' (vertex).
  - To reduce the required separation at high L, use β* = 10 m.
    - *Squeeze to same β* as high Lumi IRs would reduce ion switch-over time.*
  - Required separation ~3-4σ.
- LHCb has requested β* = 3.5 m as an optimum (for integrated L) during intensity ramp-up and high L operation (LPC).
  - β* = 4-5 m could represent a better optimum for high L.
  - Required separation ≤ 2σ. Or β* squeeze in collision.
  - *Will come back to this later…*

Squeeze



- *Prepare squeeze to go to ultimate value (1.5 m, 1 m?) – allows to 'easily extend the squeeze.*
- *Pick the right value for LHCb !!*

Separation and Xing angles



- To gain aperture we should reduce the separation from

  ±2 mm (inj. & ramp) to ±0.7 mm (squeeze)

  R. Bruce

  Could do it in the first 1-2 minutes of the squeeze (or in the ramp).

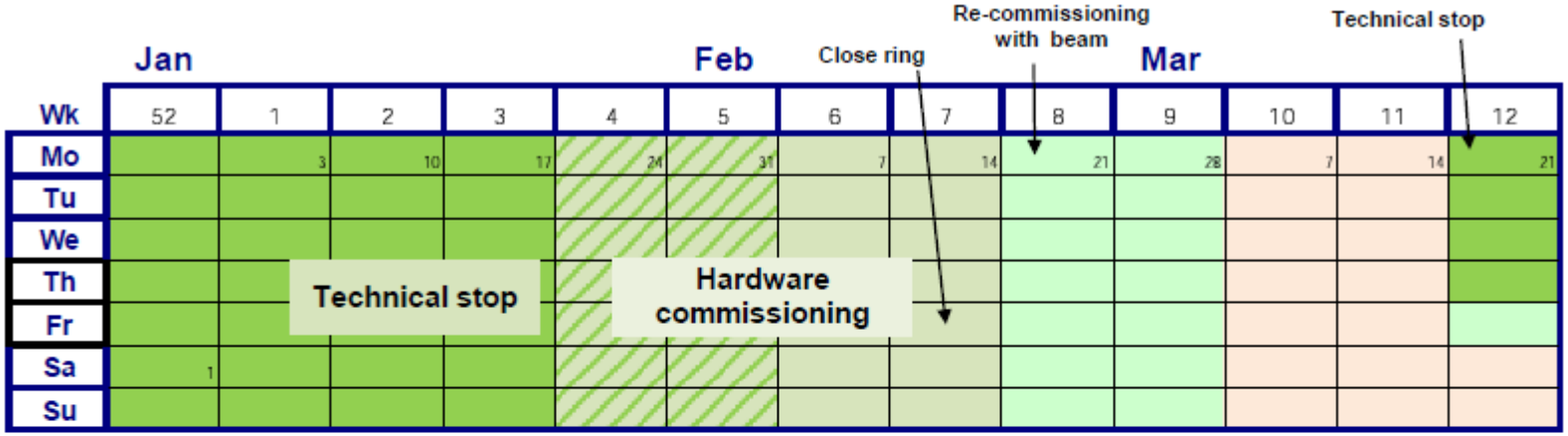
- To keep things simple we should change Xing angles from

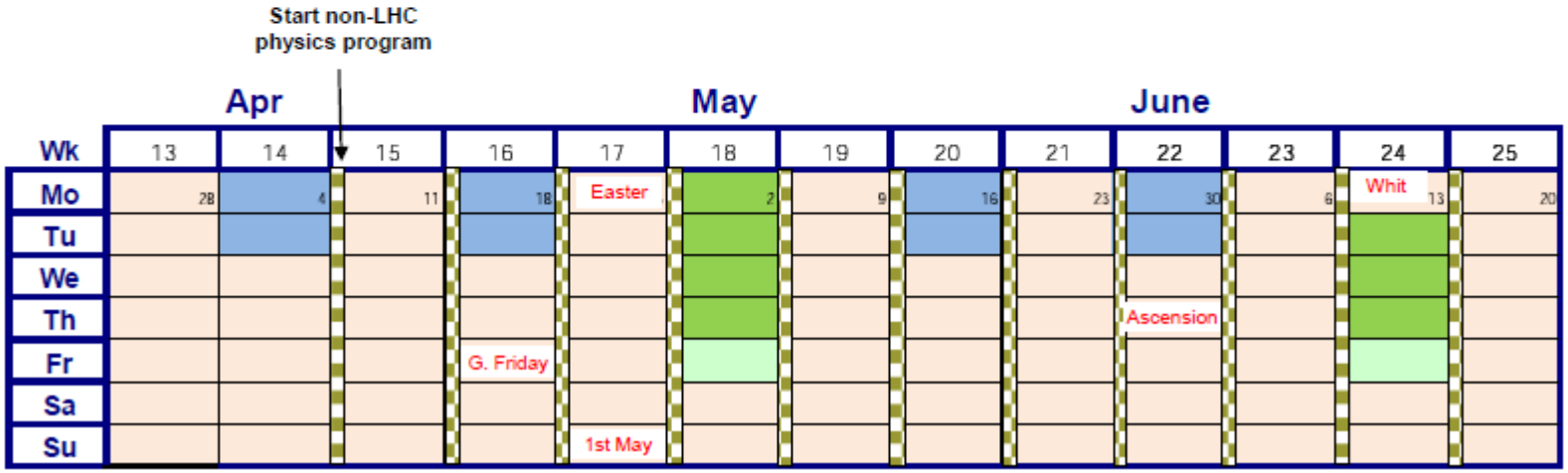
  injection (±170 μrad) to physics (±120-140 μrad)

  at the same time.

- Changes implemented using the bump scaling feature of the OFB.
  - Squeeze in a single step – no intermediate stops.

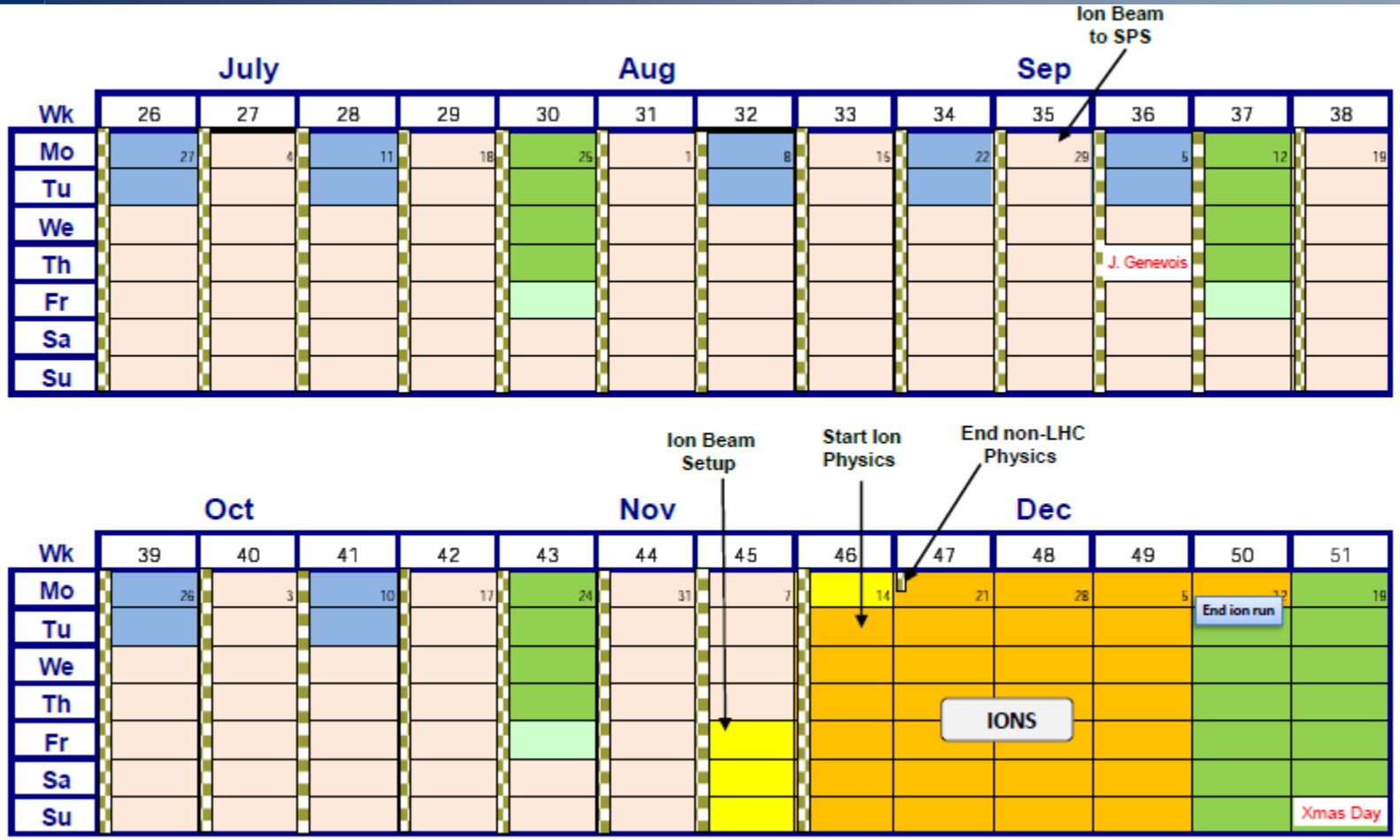
Draft schedule – 1st 1/2



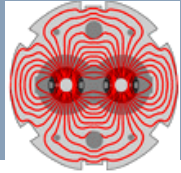


- Technical Stop
- Recommisssoning with beam
- Machine development
- Ion run
- Ion setup

Draft schedule – 2nd 1/2

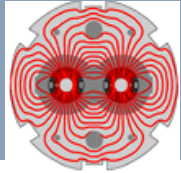


Resurrection in 2011



- Get it in - bootstrap with 2010 settings.
  - *Circulating beam (immediate if we are lucky), injection.*
- Injection.
  - *New base orbit for 2011 – to be used in all phases, only IR bumps (Xing, separation, lumi) should be variable. Well calibrated BPMs !!*
  - *Optics checks.*
  - *Full collimation and absorber setup at injection, validation.*
  - *Aperture measurements.*
  - *Injection & TLs.*
- Ramp and squeeze.
  - *Establish ramp and squeeze base orbit (flat orbit) with safe beams.*
  - *Optics checks and corrections.*
  - *Xing/separation on.*
  - *Full collimation and absorber setup, validation.*

It is all under control…

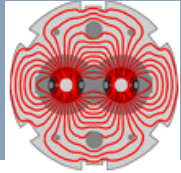


- Numerous controls change are anticipated / have been requested.
  - *Not everything will be transparent – time for testing.*
  - *Equipment and high level (LSA).*
- Nominal sequence will change.
  - *Requires a significant number of test ramps.*
  - *2010 bunch train period: used the collimation/dump loss maps for training and qualification. Could reuse this period in 2011, but we also want to make the loss maps more efficient!?*

A large number of improvements !

And don't forget few changes of the HW...

Ramping up – 75 ns

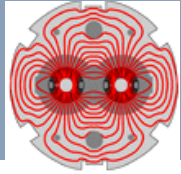


- Ramp up strategy not yet discussed / decided.

  > > 'best guest' - first order proposal.

- Phase 1: back to 200 bunches in 50 bunch steps.
  - *50 – 100 – 150 – 200*
  - *10 days to get back. Finalize sequence. Give experiments something to chew.*
- **Insert scrubbing run here ???**
- Phase 2: progress with 100 (200) bunch steps.
  - *200 – 300 – 400 – 500 – 600 – 700 – 900*
  - *A few fills for each step, count 3+ weeks.*
  - *Pace could be driven by e-cloud/vacuum, beam 'stability', UFOs, MPS, **SEUs**, OP considerations (shift rota)…*

Proton operation day count



Item	Days
Total p OP - 37 ½ weeks	262
11 MDs (2 days)	-22
6 TS (4+1 days)	-30
Special requests	-10
Commissioning	-28
Intensity ramp up	-40
Scrubbing run	-8
Total HIGH INTENSITY	**124**

Assume 125 days at peak luminosity

Stable period shrinks quickly if there are many exotic requests !

Integrated luminosity

- The Hubner **H** factor relates peak lumi, integrated lumi and scheduled time:

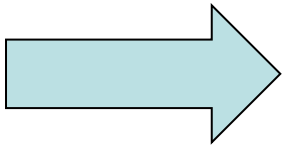
$$L_{\text{int}} = H\ L_{peak}\ \Delta t$$

- To set the scale:

  $L_{peak} = 10^{32}$ Hz/cm^2

  Δt = 100 days

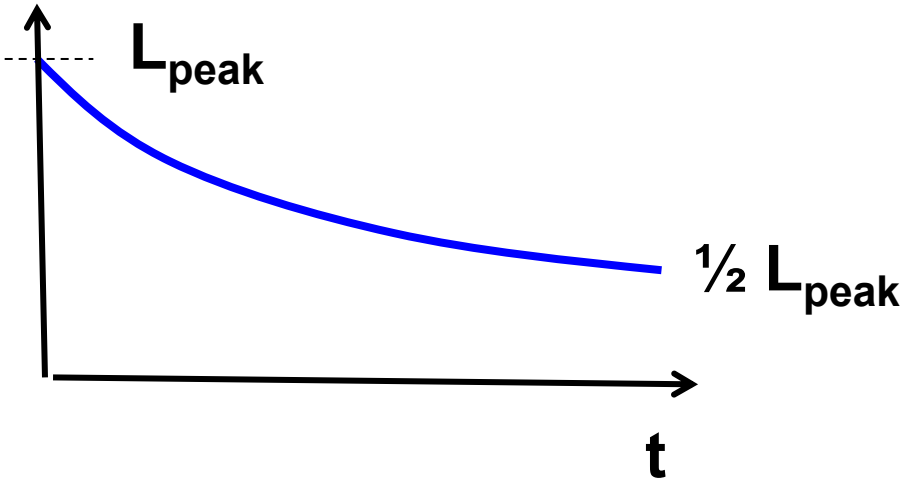
  H =0.2



L_{int} = 172 pb^{-1}

We want ≥ 1000 pb^{-1}

H in a nutshell



Average luminosity <L>:

$$< L > \approx \frac{3}{4} L_{peak}$$

$$e_{st} = \frac{time \;\; in \; stable \;\; beams}{total \;\; scheduled \;\; time}$$

$$L_{\text{int}} = H \; L_{peak} \; \Delta t = < L > e_{st} \; \Delta t$$

$$H = e_{st} < L > / L_{peak} \approx \frac{3}{4} e_{st}$$

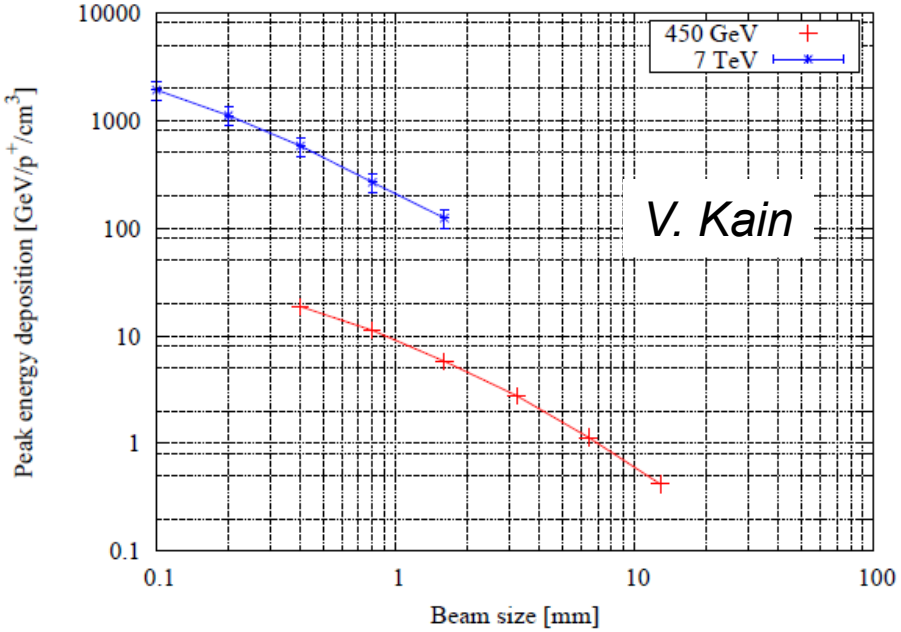
For H = 0.2 we need:
e_{st} = 26%

W. Venturini : Yes !
We can do that!

How dense?

- Collimators are OK for nominal @ 7 TeV, but not the TCDQ – need final answer to define reach in intensity and emittance.
  - *Assume OK for $N_b = 1.2\text{x}10^{11}$, $\varepsilon = 3.75\ \mu m$ for 50 ns spacing @ 7 TeV*
- Deposited energy density scaling – to first order:

$$E_{density} \propto \frac{NE}{(\varepsilon_n / E)} = \frac{NE^2}{\varepsilon_n}$$

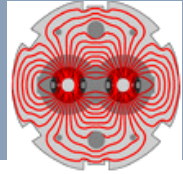


See also Safe beam flag (based on Cu):

$$N_{SBF}\ E^{-1.7} \approx cte$$

(shower effects taken into account)

Beam parameters @ injection (SPS)



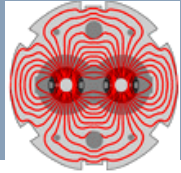
From E. Metral

75 ns	N_b [10^{11} p/b]	ε_n [μm]
1-batch	1.2	2

OK in terms of density

50 ns	N_b [10^{11} p/b]	ε_n [μm]
1-batch	1.15	2.5
1-batch	1.6	3.5
2-batch	1.15	1.5

75 ns performance



Δt = 125 days H =0.2

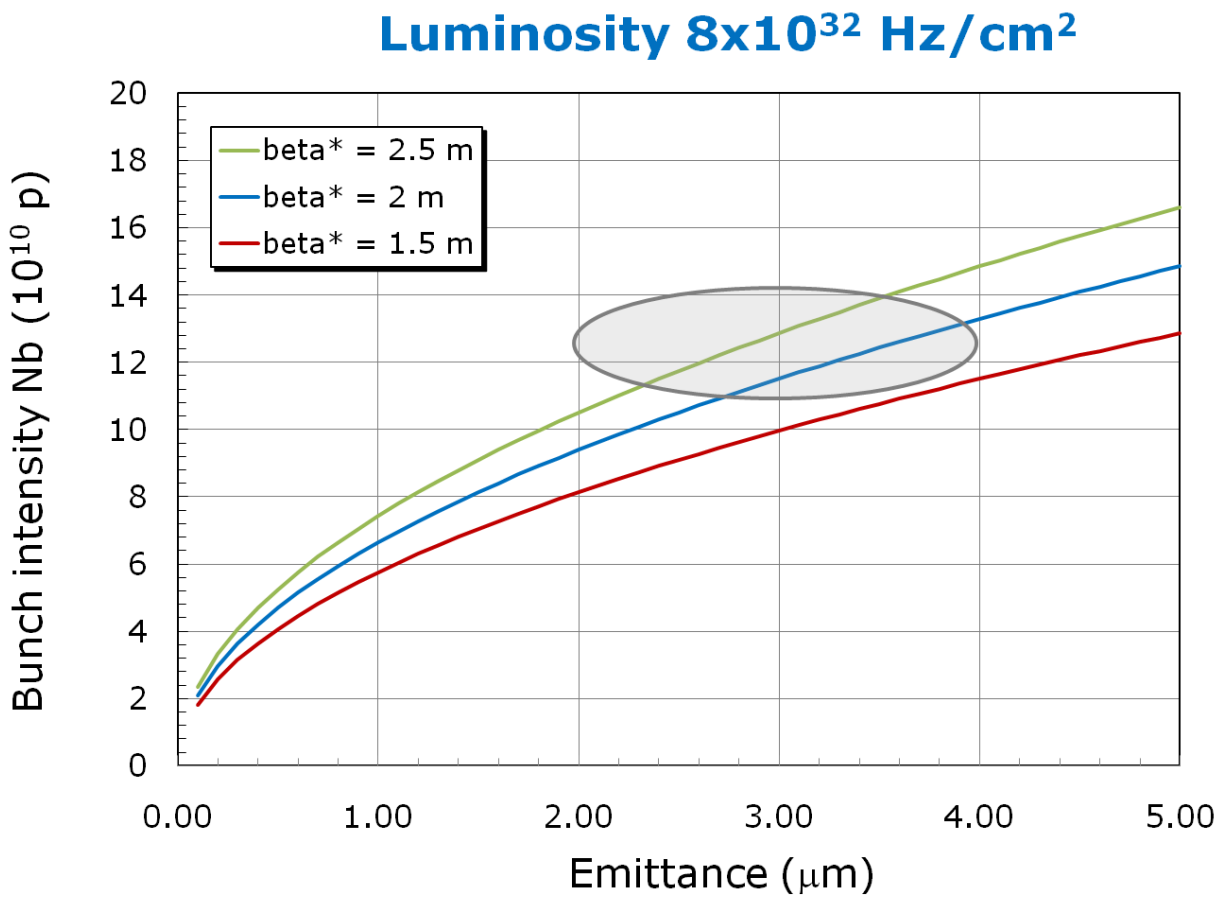
Schema	β^* (m)	kb	Nb	ε (μm)	L (Hz/cm2)	Stored E (MJ)	L int (pb-1)
75 ns	2.5	930	1.10E+11	3.5	4.7E+32	**65.5**	**1011**
75 ns	2.0	930	1.10E+11	3.5	5.9E+32	**65.5**	**1264**
75 ns	1.5	930	1.10E+11	3.5	7.8E+32	**65.5**	**1685**
75 ns	2.5	930	1.20E+11	2.5	7.8E+32	**71.4**	**1685**
75 ns	**2.0**	**930**	**1.20E+11**	**2.5**	**9.8E+32**	**71.4**	**2106**
75 ns	1.5	930	1.20E+11	2.5	**1.3E+33**	**71.4**	**2808**

→ **1-3 fm^{-1}**

Similar head-on bb than with 150 ns

With 150 ns spacing: 1 fm^{-1} feasible !

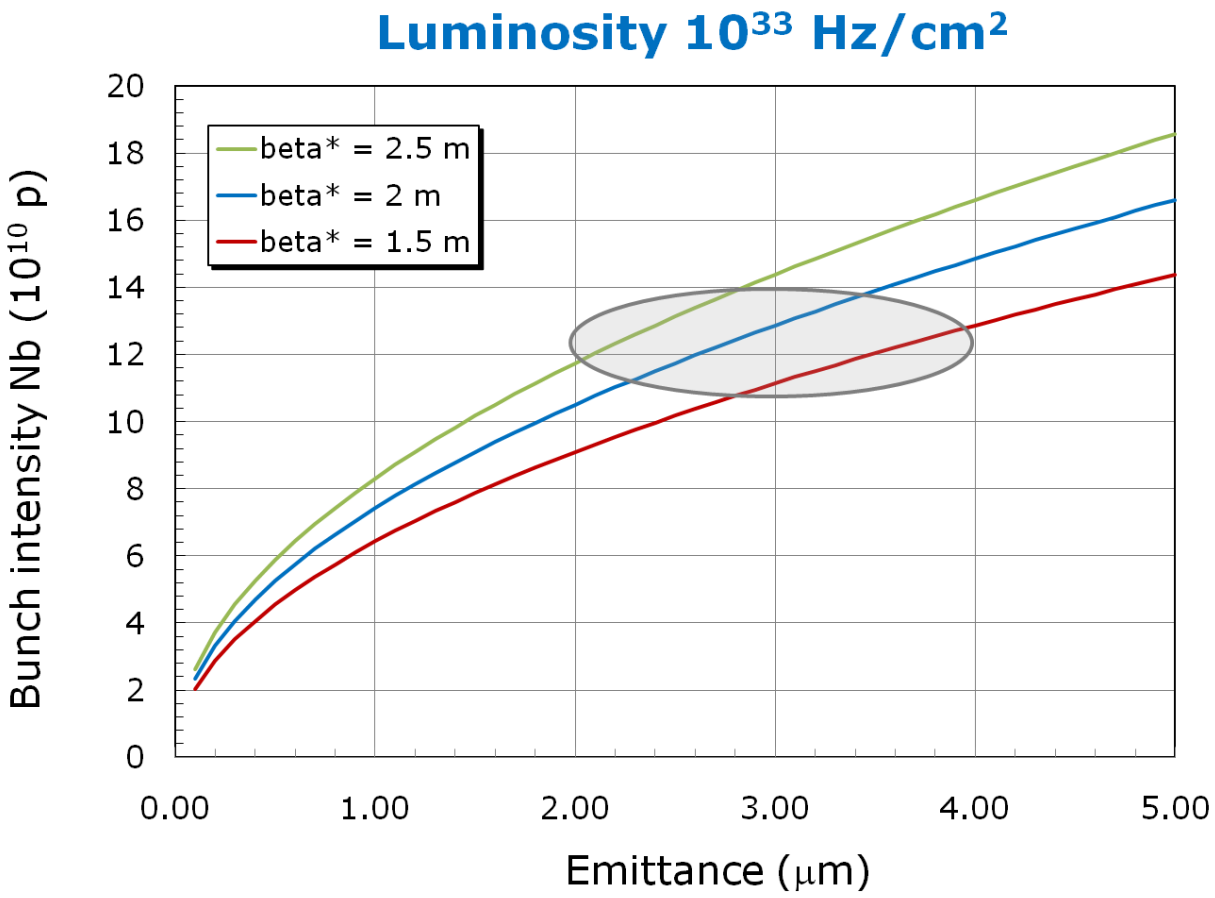
8x10^{32}



75 ns beam

950 bunches

Feasible with ~nominal beam parameters.

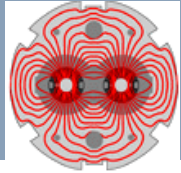


75 ns beam

950 bunches

$L \geq 10^{33}$ Hz/cm^2 reachable for β^* of 2-2.5 m.

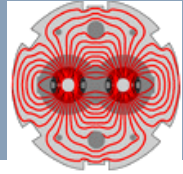
50 ns performance



Δt = 125 days H =0.2

Schema	β^* (m)	kb	Nb	ε (mm)	L (Hz/cm2)	Stored E (MJ)	L int (pb-1)
50 ns	2.5	1400	1.10E+11	2.5	**9.9E+32**	98.6	**2131**
50 ns	2.0	1400	1.10E+11	2.5	**1.2E+33**	98.6	**2664**
50 ns	1.5	1400	1.10E+11	2.5	**1.6E+33**	98.6	**3552**
50 ns	2.5	1400	1.60E+11	3.5	**1.5E+33**	143.4	**3221**
50 ns	2.0	1400	1.60E+11	3.5	**1.9E+33**	143.4	**4026**
50 ns	1.5	1400	1.60E+11	3.5	**2.5E+33**	143.4	**5368**

Luminosity leveling - LHCb



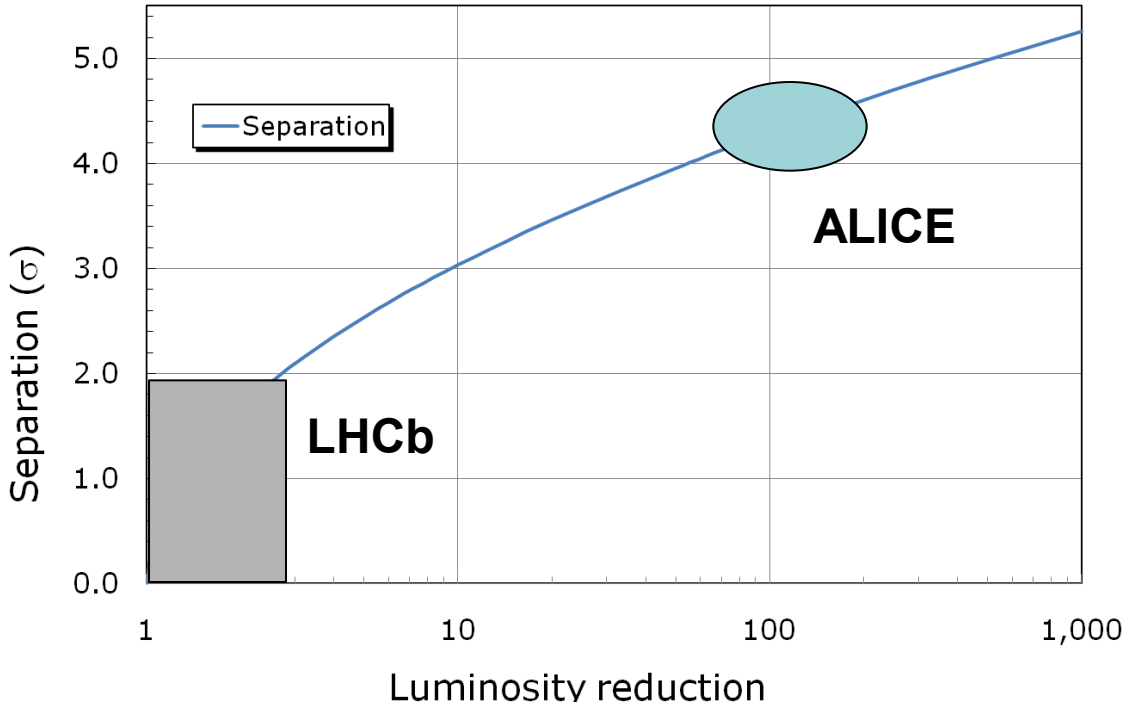
By beam separation:

- Pick peak luminosity, divide by 2 → end of fill luminosity.
  - *Pick β^* from end of fill luminosity to match to LHCb peak L.*

  → β^* = 3-5 m depending on assumptions.
  - *Take some margin (lower β^*).*
- Level luminosity with beam separation.
  - *Some debate if that works – in 2010 we have not really seen detrimental effects.*
  - *Gain experience.*

This would clearly be a very simple way to serve LHCb well !

ALICE – LHCb separation



$$Sep\,[\sigma] = 2\sqrt{\ln(L_0 / L)}$$

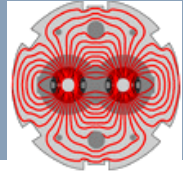
We should separate in the V plane in both IRs to 'decouple' from asynchronous dump.

Tricky in ALICE??

ALICE : β^* = 10 m, head-on L = (1-2)×10^{32} Hz/cm^2

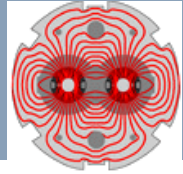
LHCb : β^* = 3.5 m, head-on L = (4-7)×10^{32} Hz/cm^2

Dynamic β* for LHCb



- In 2010 we clearly demonstrated that we can make very smooth squeezes – thank you FBs!
- Technically we could define a number of squeeze points for LHCb.
  - *Jump from one point to the next every now and then.*
- But:
  - *Must be done in stable beams – else waste too much time.*
  - *Extra collimator setups and validations.*
  - *This is something that we would **NOT** like to commission with 900 bunches → start early on…*

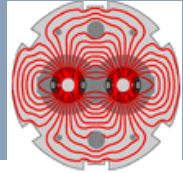
Ions



- Ion luminosity will profit from β^* reduction.
  - Current schedule foresees only 4 days of setup.
  - To stick to that time we must squeeze ALICE in p+ operation – else we may need more time !
- To really boost the ion performance we must switch to the nominal ion scheme (100 ns separation).
  - Boost no. bunches from 120+ to ≈500.

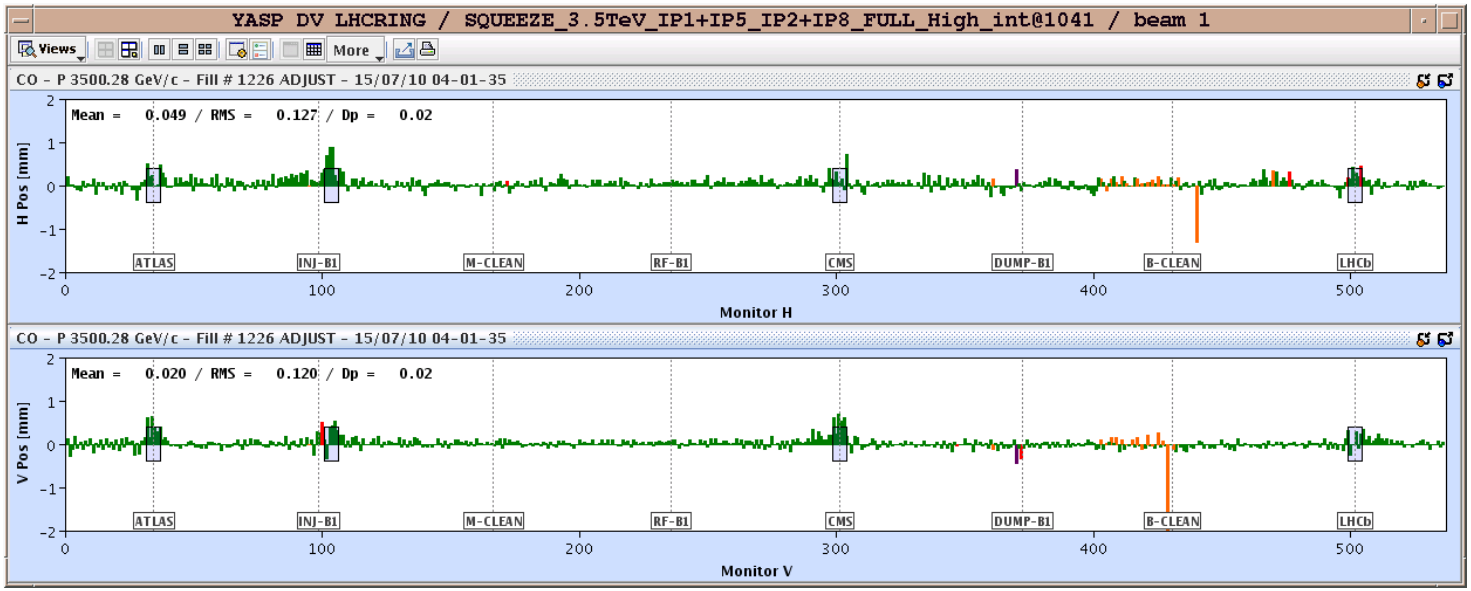
Potential luminosity gain by factor 6-10 !

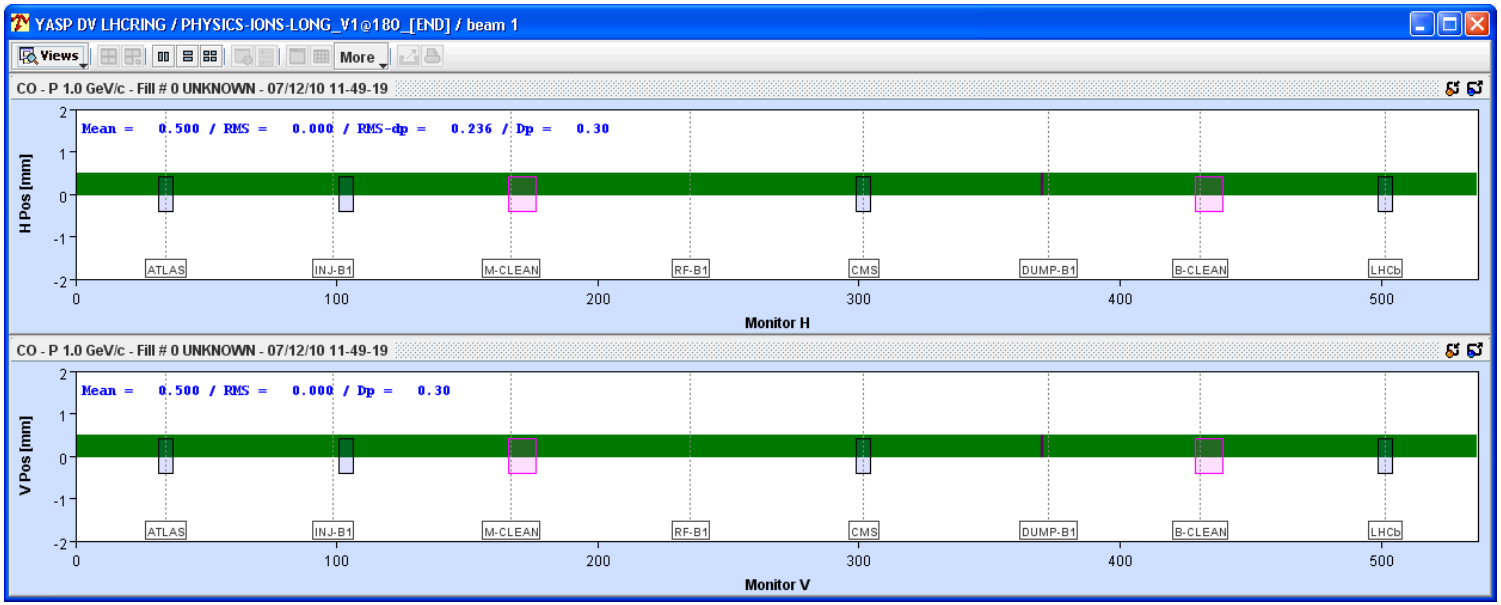
Conclusions

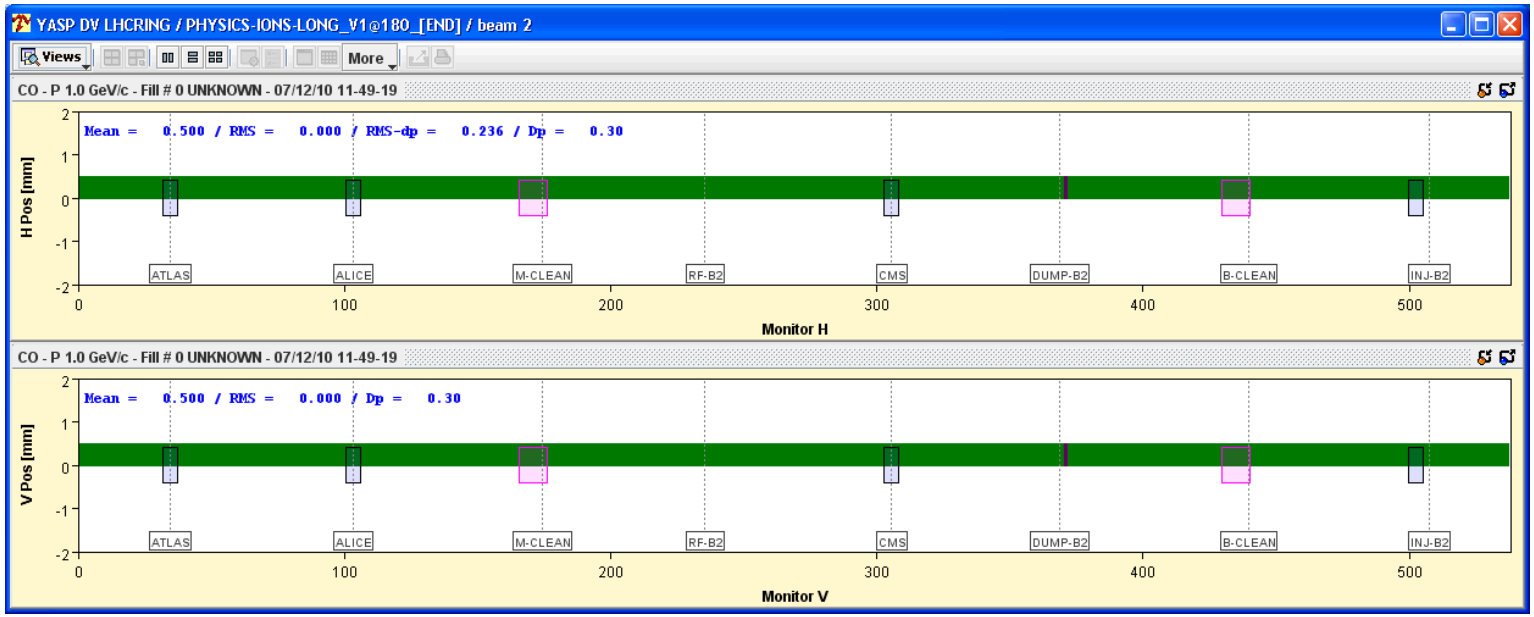


- Estimated no. of days at high luminosity ~125 days (for a total time of 260 days !) – 50% !!
  - *In order not to waste time we must have a good plan and not let ourselves be diverted from the target of stable high intensity running.*
- Luminosity of 10^{33} $cm^{-2}s^{-1}$ could be reached with 75 ns beams.
  - *Integrated L ~1-3 fb^{-1}.*
  - *Optimum parameters to be selected carefully taken into account all parameters – for example injection efficiency may favor low ε over high bunch charge.*
  - *Efficiency, efficiency, efficiency.*
- LHCb:
  - *Should find a consensus on the best approach for leveling : separation versus squeezing.*

Flat top orbit : Now versus June




YASP DV LHCRING / PHYSICS-IONS-LONG_V1@180_[END] / beam 1
Views
More
CO - P 1.0 GeV/c - Fill # 0 UNKNOWN - 07/12/10 11-49-19
Mean = 0.500 / RMS = 0.000 / RMS-dp = 0.236 / Dp = 0.30
H Pos [mm]
ATLAS
INJ-B1
M-CLEAN
RF-B1
CMS
DUMP-B1
B-CLEAN
LHCb
Monitor H
CO - P 1.0 GeV/c - Fill # 0 UNKNOWN - 07/12/10 11-49-19
Mean = 0.500 / RMS = 0.000 / Dp = 0.30
V Pos [mm]
Monitor V


YASP DV LHCRING / PHYSICS-IONS-LONG_V1@180_[END] / beam 2
Views
More
CO - P 1.0 GeV/c - Fill # 0 UNKNOWN - 07/12/10 11-49-19
Mean = 0.500 / RMS = 0.000 / RMS-dp = 0.236 / Dp = 0.30
H Pos [mm]
ATLAS
ALICE
M-CLEAN
RF-B2
CMS
DUMP-B2
B-CLEAN
INJ-B2
Monitor H
CO - P 1.0 GeV/c - Fill # 0 UNKNOWN - 07/12/10 11-49-19
Mean = 0.500 / RMS = 0.000 / Dp = 0.30
V Pos [mm]
Monitor V


YASP DV LHCRING / PHYSICS-IONS-LONG_V1@180_[END] / beam 1
Views
More
CO - P 1.0 GeV/c - Fill # 0 UNKNOWN - SVD / 480 eigenv. / V - 07/12/10 11-53-09
Mean = 0.062 / RMS = 0.164 / Dp = 0.30
Pos [mm]
ATLAS
INJ-B1
M-CLEAN
RF-B1
CMS
DUMP-B1
B-CLEAN
LHCb
Monitor V
CO - P 1.0 GeV/c - Fill # 0 UNKNOWN - SVD / 480 eigenv. / V - 07/12/10 11-53-09
Mean = -5.88 / RMS = 1.90
Kick [urad]
YASP DV LHCRING / PHYSICS-IONS-LONG_V1@180_[END] / beam 2
Views
More
CO - P 1.0 GeV/c - Fill # 0 UNKNOWN - SVD / 480 eigenv. / V - 07/12/10 11-53-09
Mean = 0.061 / RMS = 0.164 / Dp = 0.30
Pos [mm]
ATLAS
ALICE
M-CLEAN
RF-B2
CMS
DUMP-B2
B-CLEAN
INJ-B2
Monitor V
CO - P 1.0 GeV/c - Fill # 0 UNKNOWN - SVD / 480 eigenv. / V - 07/12/10 11-53-09
Mean = -5.91 / RMS = 1.94
Kick [urad]
Corrector V