LHC status report

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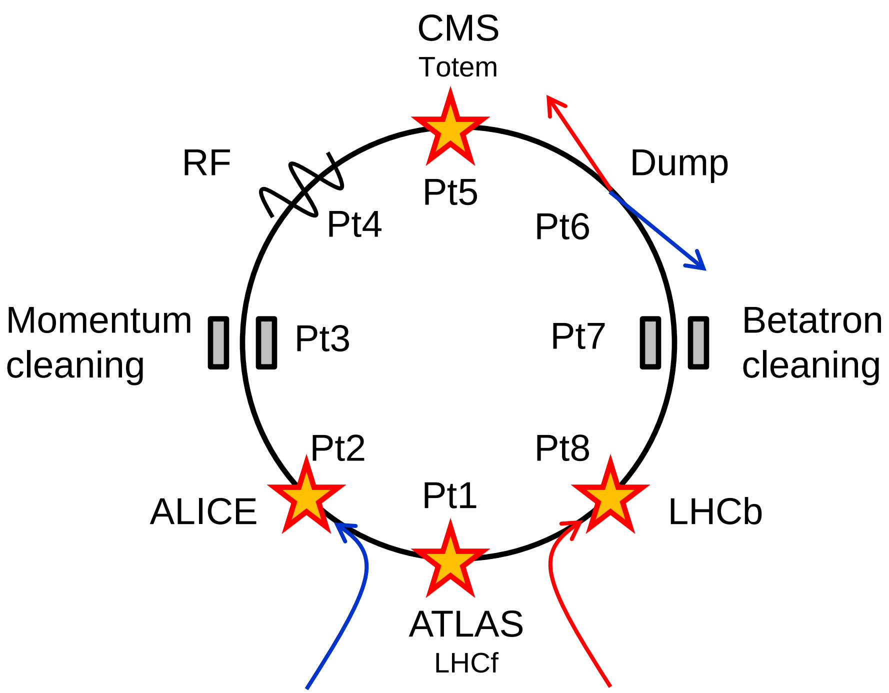
- Overview of machine progress
  - rough chronology, recent achievement, current status
- Luminosity calibration
  - $s^{1/2}$ = 0.9 & 7 TeV
- Prospects and outlook
  - 2010, aiming for 1e32 Hz/cm^2
  - 2011, deliver $1fb^{-1}$
  - and beyond

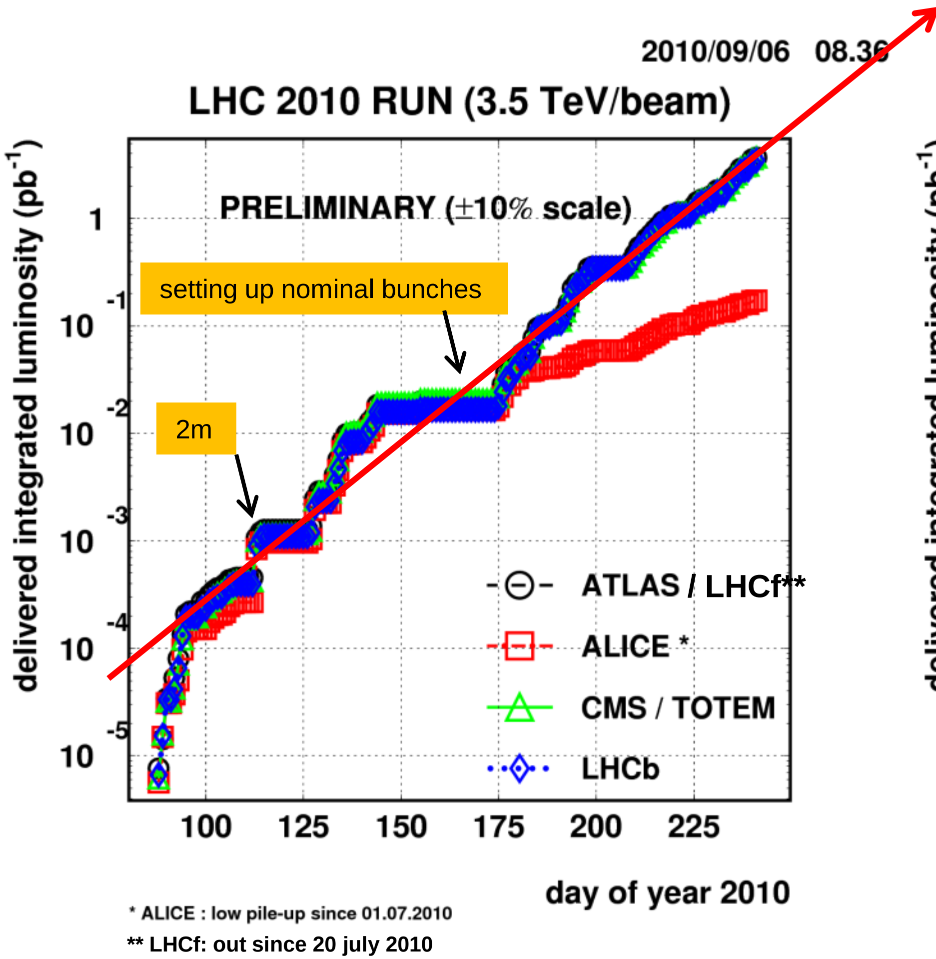


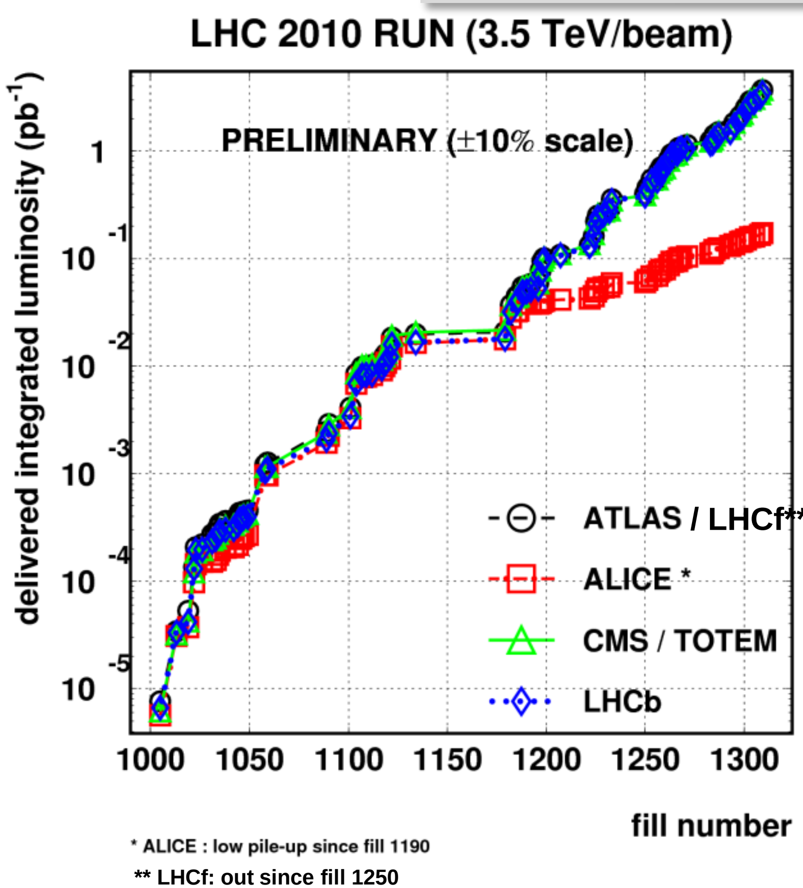
Rough chronology

Oct 2008 – Oct 2009: recovered from s34 incident	
20 Nov 2009:	Resuming (circulating) beam commissioning
6 Dec 2009:	First physics collisions at 450 GeV/beam
13-14 Dec 2009:	Ramps and collisions to 1.18 TeV/beam
Mid Dec 2009 – End Feb 2010 --- Technical stop	
27 Feb 2010:	Started LHC (first beams 2010), commissioning
20 Mar 2010:	First ramps to 3.5 TeV
30 Mar 2010:	First physics collisions at 3.5TeV/beam
23 Apr 2010:	First run with squeezed optics (β^* = 2m)
mid Jun 2010:	Go to β^*=3.5 m, push bunch&beam intensity
25 Jun 2010:	First physics with nominal bunches (β^*=3.5 m)
19 Aug 2010:	Exceeded 2 MJ/beam in physics (2.7 MJ).
mid Sep 2010:	Bunch trains, crossing angle
end 2010:	Reach ~1e32 Hz/cm^2

Integrated lumi (delivered, in STABLE BEAMS)

Plots at http://cern.ch/lpc

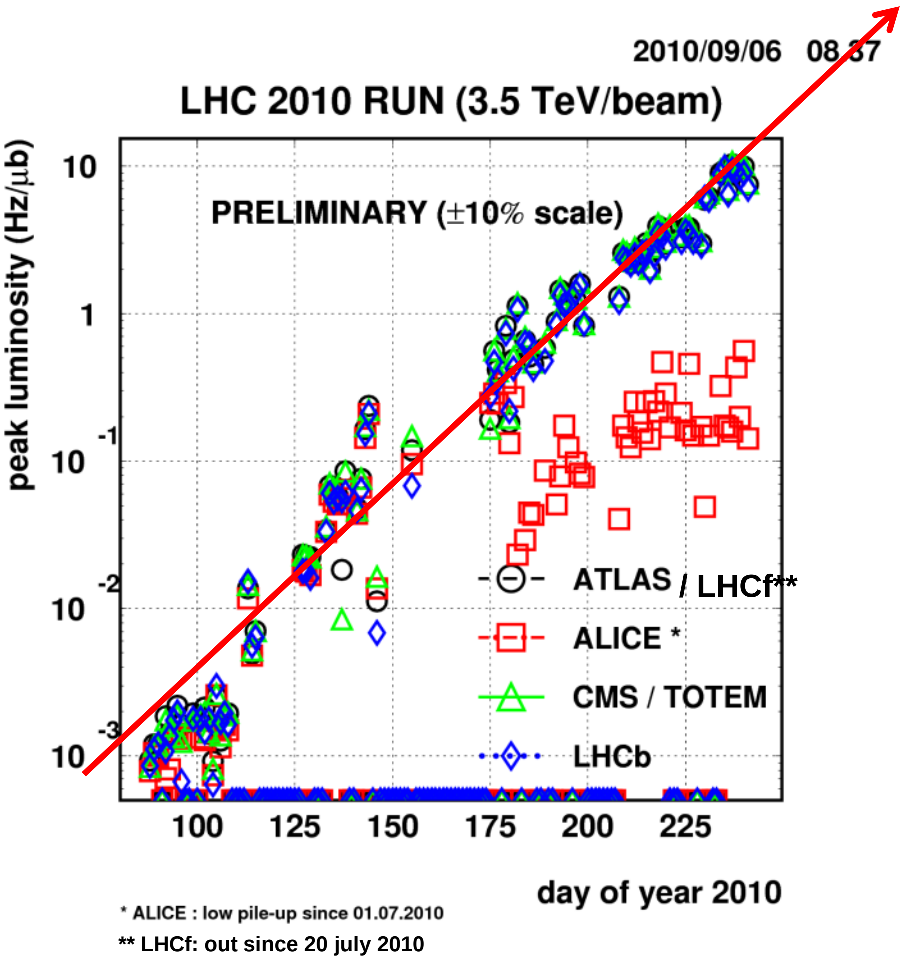


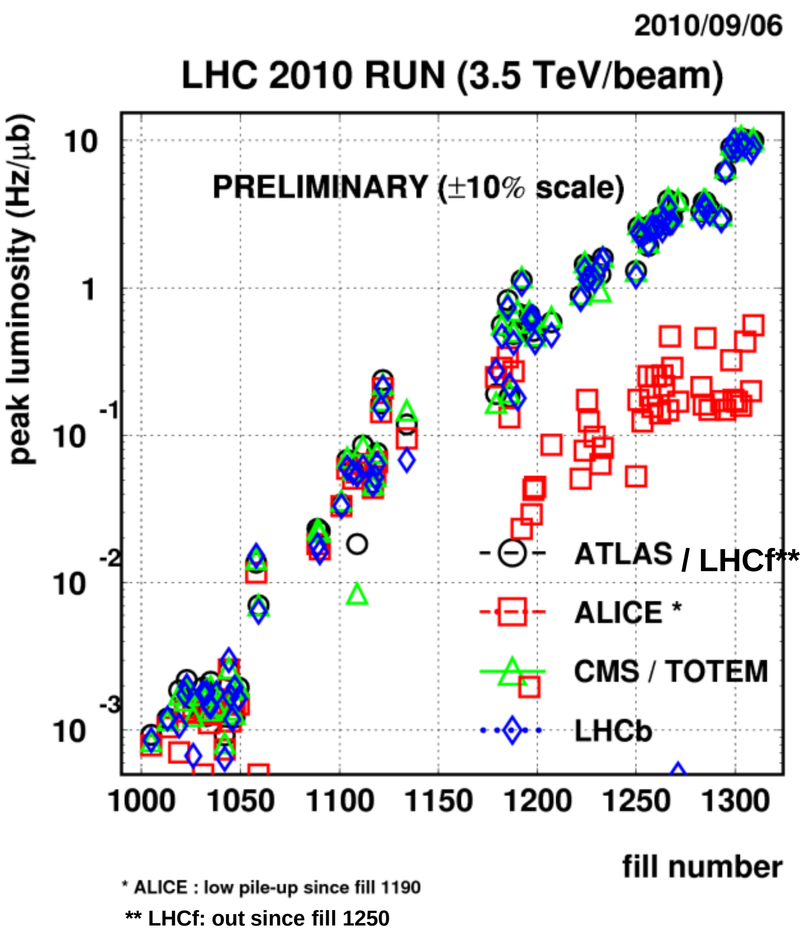


Goal end 2011: 1 fb^{-1}

Also: ~360 ub^{-1} at 450GeV/beam and ~1 ub^{-1} data with 1.18 TeV/beam

Peak luminosity (delivered, in STABLE BEAMS)

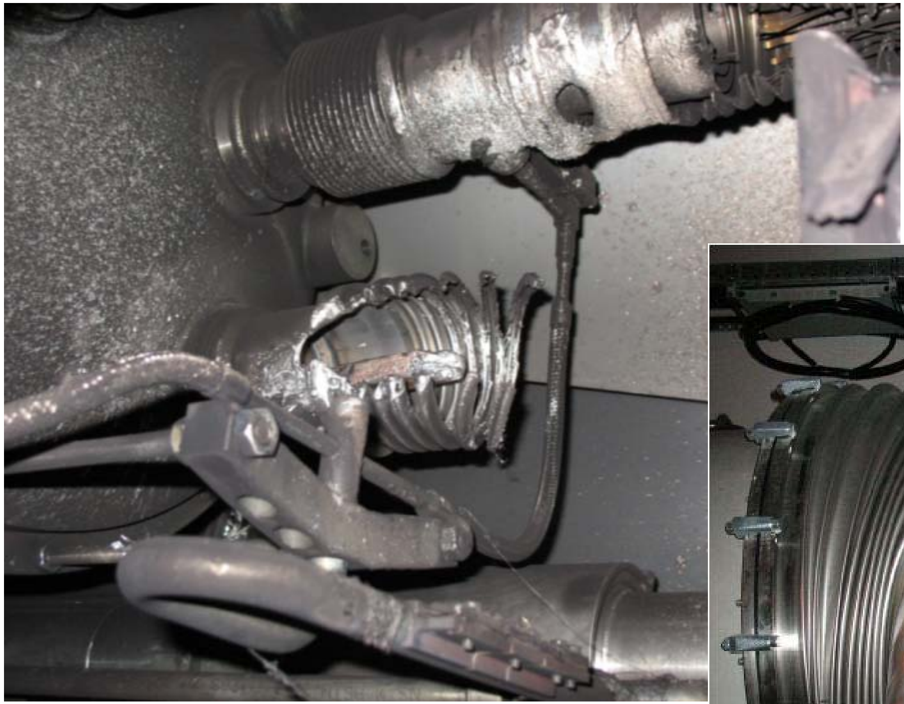


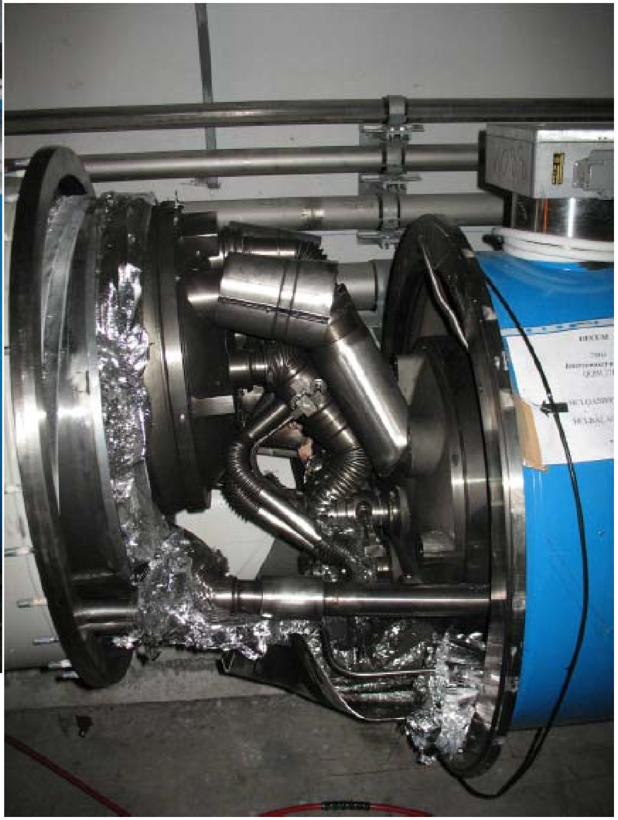


Goal end 2010: ~ 1e32 Hz/cm^2 = 100 Hz/ub
During 2011: exceed 2e32 Hz/cm^2 = 200 Hz/ub

why not faster ?

2008 sector 3-4 incident

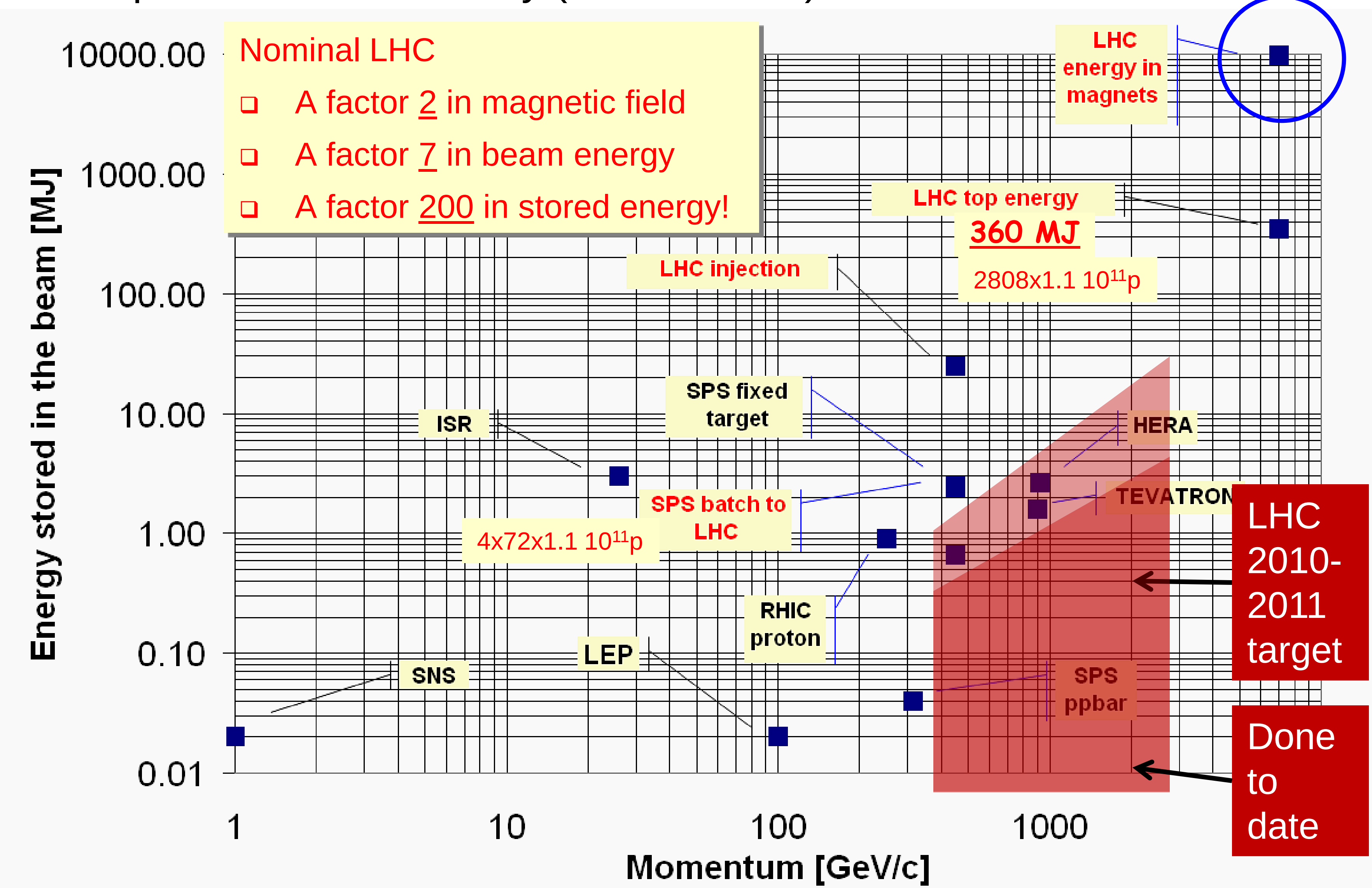




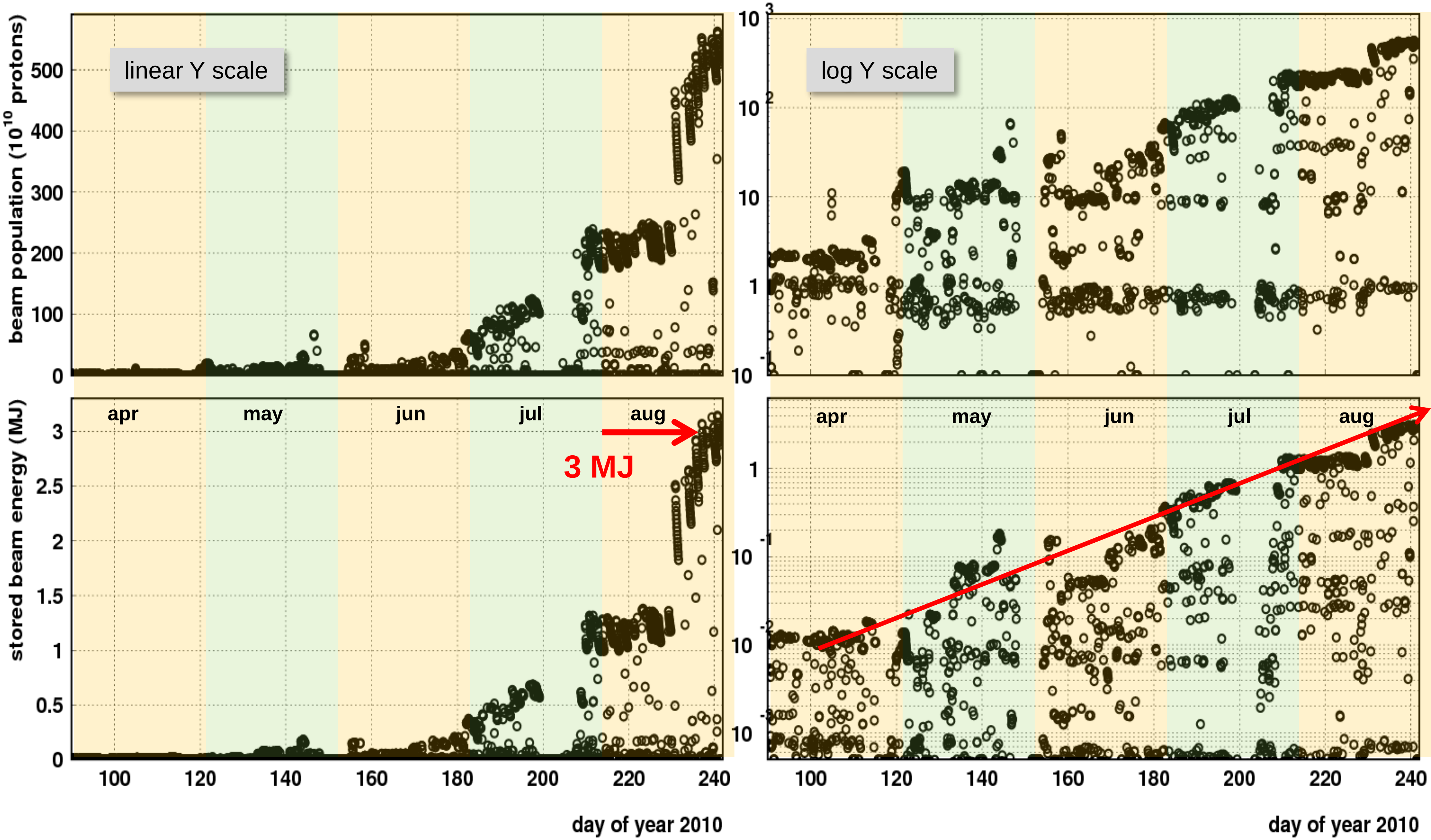
remember this ?

LHC stored energy

- Despite modest luminosity (1e31 Hz/cm^2) we are at 2.7 MJ



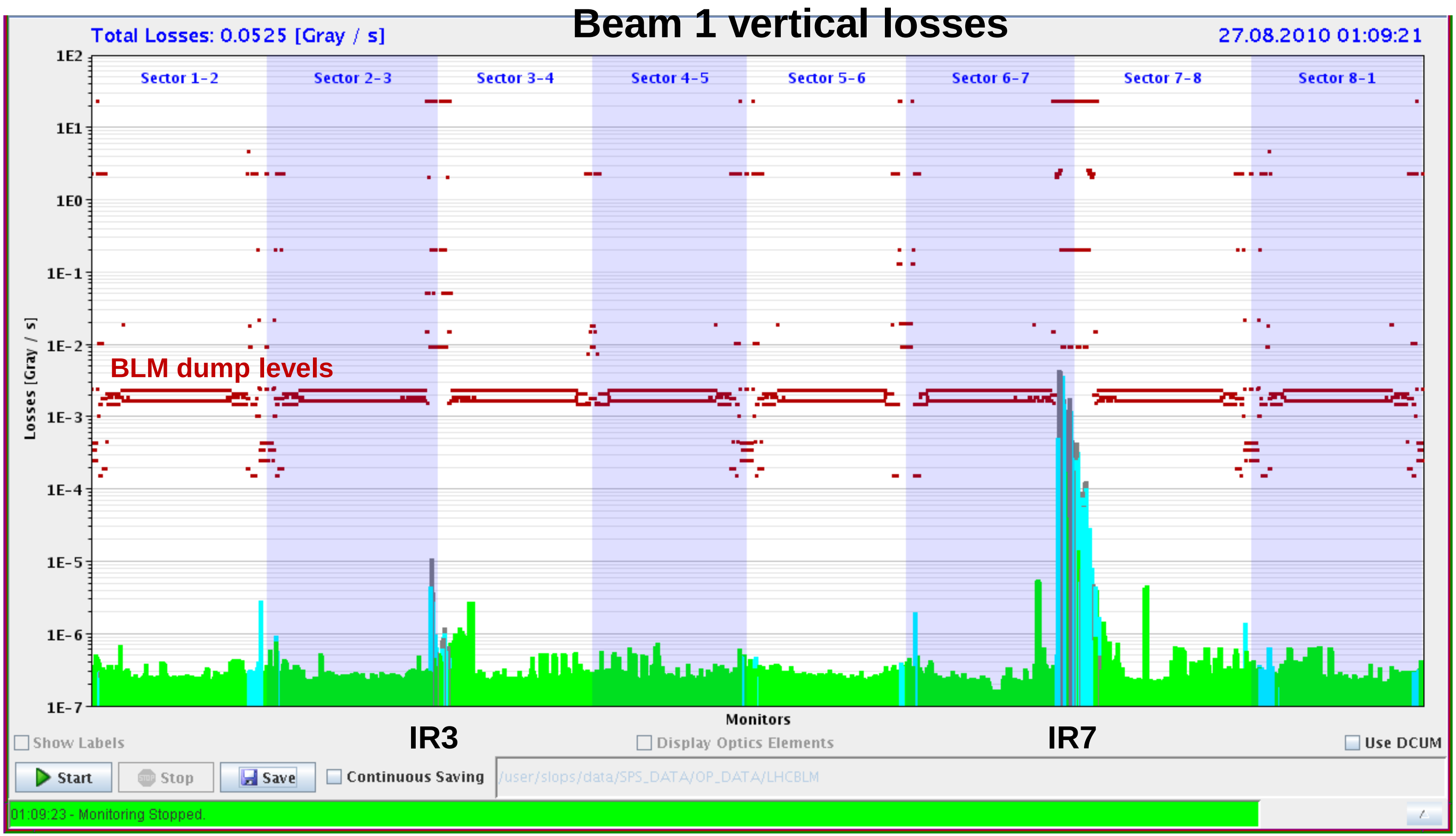
Increasing stored energy in the LHC beams



Reach approx 20 MJ by end of 2010, approx 30 MJ by end of 2011

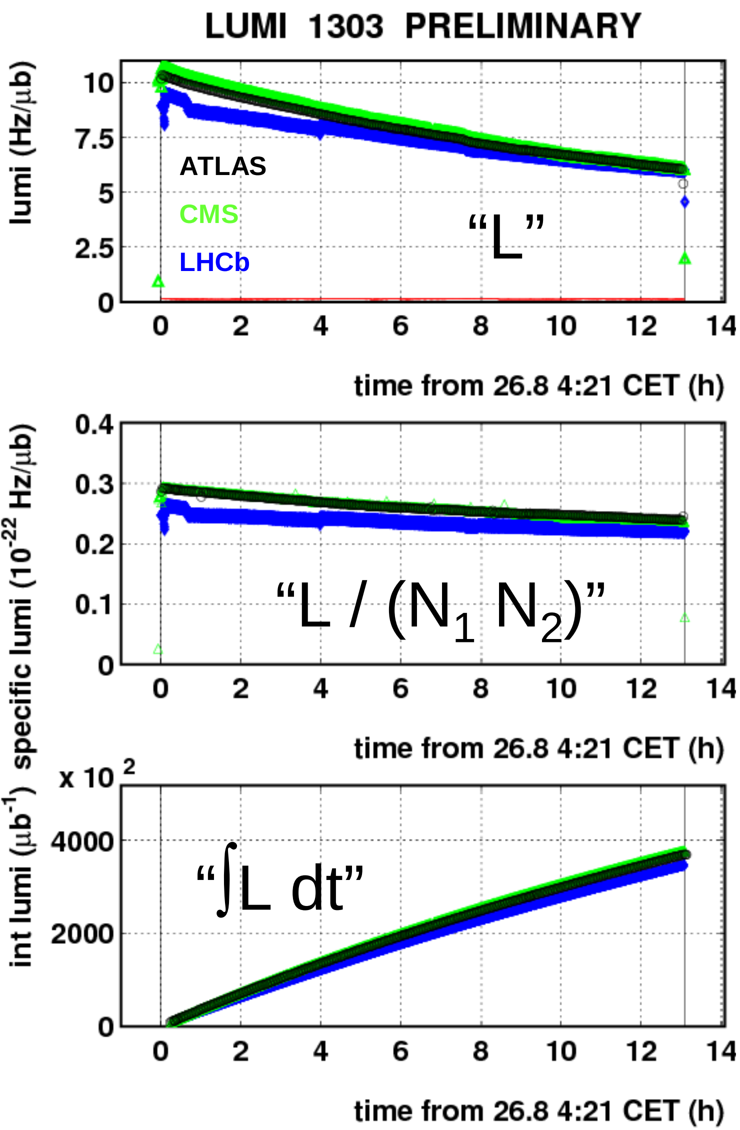
Beam cleaning, regular monitoring

- so far , so good!   (very stable, no readjustments over ~2 months)
- not a single quench os SC magnet with circulating beam

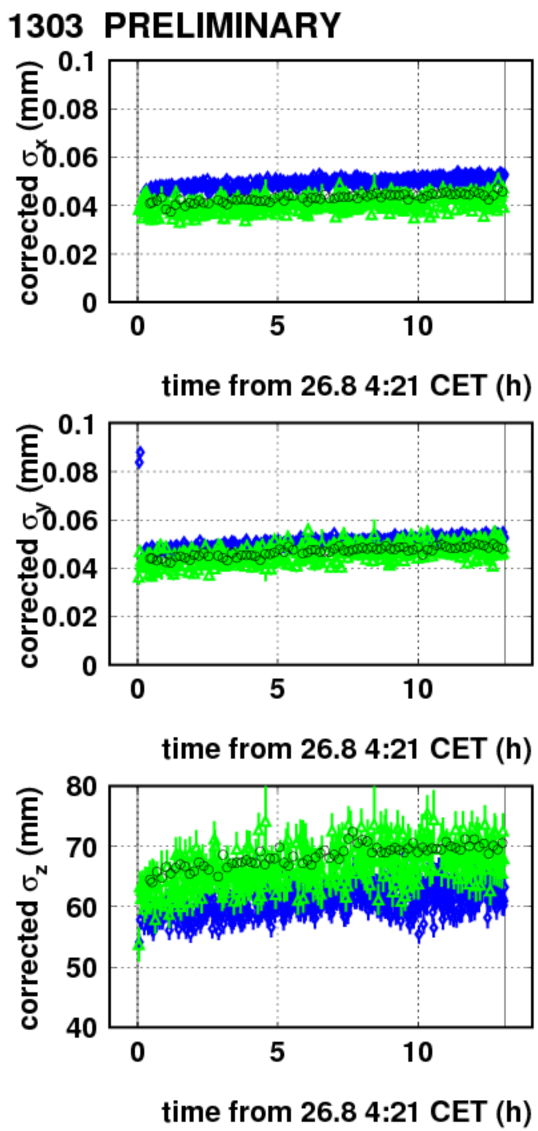


A typical recent fill (end of August)

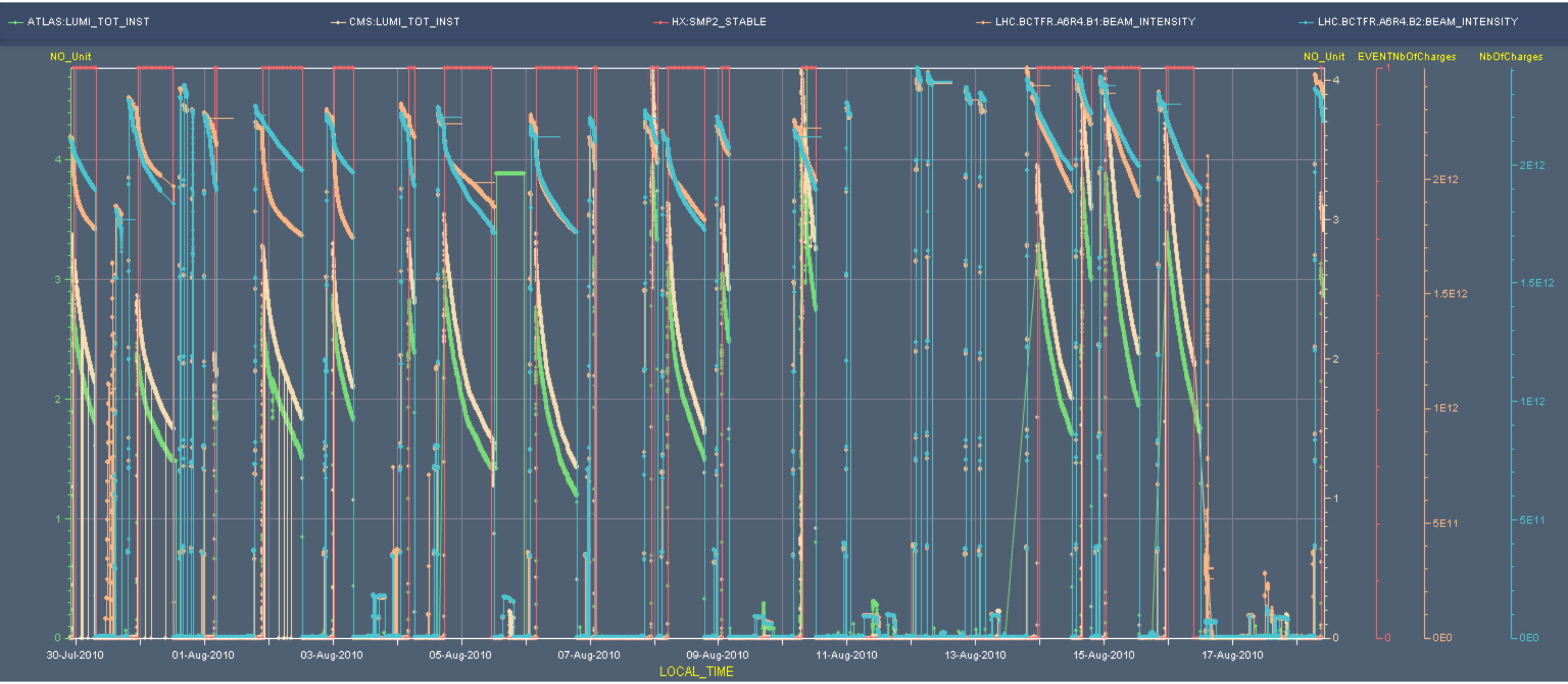
as imaged by vtx detectors



- lumi life time ~25 h
- due to both beam current decrease and to transverse emittance blow-up
  - here about 20% in current and 20% in emittance per plane over 13h



Overview Thu 29.07.2010 22:00 to Tue 18.08.2010 10:00



Given a total time T, a delivered lumi $\mathcal{L}$ and a peak lumi L, define an "overall factor" for quick estimations (Hűbner):

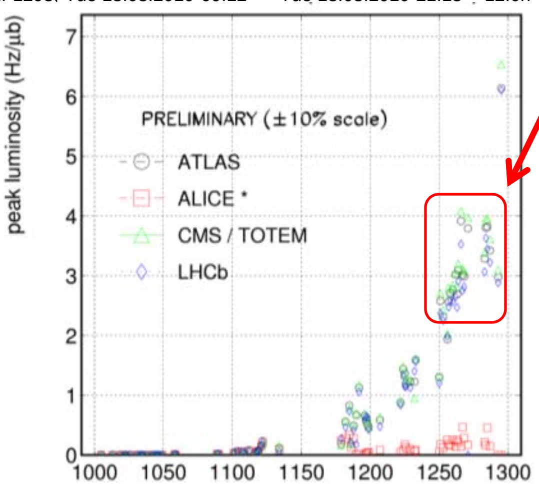
$$H = \frac{\mathcal{L}}{T \cdot L}$$

At LEP & Tevatron, H ~0.2-0.25 in their late years…

From Thu 29.07.2010 22:00 to Tue 18.08.2010 10:00

All fills with 25 bunches, 3.5m, 3.5 TeV:

FillNr 1251, Thu 29.07.2010 23:28 => Fri 30.07.2010 07:25 ~8.0h
FillNr 1253, Fri 30.07.2010 23:11 => Sat 31.07.2010 12:20 ~13.1h
FillNr 1256, Sun 01.08.2010 03:50 => Sun 01.08.2010 04:49 ~1.0h
FillNr 1257, Sun 01.08.2010 22:00 => Mon 02.08.2010 12:35 ~14.5h
FillNr 1258, Tue 03.08.2010 00:22 => Tue 03.08.2010 07:39 ~7.3h
FillNr 1260, Wed 04.08.2010 04:31 => Wed 04.08.2010 06:38 ~2.1h
FillNr 1262, Wed 04.08.2010 17:40 => Thu 05.08.2010 11:19 ~17.65h
FillNr 1263, Fri 06.08.2010 03:52 => Fri 06.08.2010 19:08 ~15.25h
FillNr 1264, Sat 07.08.2010 01:42 => Sat 07.08.2010 02:14 ~0.5h
FillNr 1266, Sat 07.08.2010 23:12 => Sun 08.08.2010 01:10 ~2.0h
FillNr 1267, Sun 08.08.2010 05:18 => Sun 08.08.2010 18:52 ~13.5h
FillNr 1268, Mon 09.08.2010 01:29 => Mon 09.08.2010 04:02 ~2.5h
FillNr 1271, Tue 10.08.2010 07:24 => Tue 10.08.2010 12:22 ~5.0h
FillNr 1283, Fri 13.08.2010 23:06 => Sat 14.08.2010 12:04 ~13.0h
FillNr 1284, Sat 14.08.2010 15:44 => Sat 14.08.2010 19:13 ~3.5h
FillNr 1285, Sun 15.08.2010 00:39 => Sun 15.08.2010 13:02 ~12.4h
FillNr 1287, Sun 15.08.2010 23:01 => Mon 16.08.2010 09:24 ~10.4h
FillNr 1293, Tue 18.08.2010 09:12 => Tue 18.08.2010 21:13 ~12.0h



total time T :	468h
time in stable beams :	153.7 h
delivered lumi $\mathscr{L}$:	1.2 pb^{-1}
typical peak lumi L :	2.5 to 4 Hz/ub

$$H = \frac{\mathscr{L}}{T \cdot L} = 0.18 \text{ to } 0.28$$

(caveat: this is a 3-week period with no technical stop)

fraction time in stable beams: 32.8%

Luminosity calibration

Why luminosity determination is important

Rate = Luminosity x Cross section

- Allows to determine cross section of interaction processes on an absolute scale
  - At the LHC: Heavy flavour production, couplings of new particles, total (inelastic, elastic) cross section, …

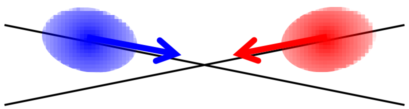
    (=> what precision should we aim for ?)

- Allows to quantify the performance of the collider
  - Important to verify experimental conditions, to understand quantitatively beam-beam effects, …

Luminosity measurements

$$L = f\,N_1\,N_2\,2c\,\cos^2(\phi/2)\int_{4-\text{fold}} \rho_1(\mathbf{x},t)\,\rho_2(\mathbf{x},t)\,d^3x\,dt$$

revolution freq — bunch populations — crossing angle — beam overlap



- First absolute normalisation of luminosity and cross section were performed at the LHC (450 GeV / beam and 3.5 TeV / beam)
- Two <u>direct methods</u> were used:
  - van der Meer method: measure reaction rate vs beam transverse separation
  - **new!** beam-gas imaging method: reconstruct vertices of interactions with residual gas => get the beam profiles
- Results accuracy dominated by beam current normalisation uncertainty (~10%, being worked on)
- Potentially, could hope to aim for total uncertainty ~5% (future measurements)
  - will first have to work hard on the beam current normalisation
  - then on other smaller systematic uncertainties

Chronology

2009

- All experiments started off with a normalisation based on a generator model including detector simulation

  => uncertainties at the level of 20% for 450 GeV

- LHCb performed first direct luminosity normalisation at 450 GeV using the beam-gas imaging method (see later)

2010

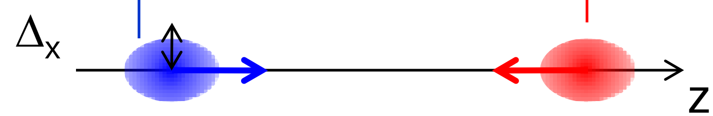
- At 3.5 TeV, started off again with a normalisation based on a generator model including detector simulation

- Then, April-May, performed first direct luminosity measurement at each IP with van der Meer scans (+continuous beam-gas imaging normalisation, LHCb)

Van der Meer's trick

Consider single circulating & colliding bunch pair with zero crossing angle

$$R = \sigma \cdot L = \sigma \cdot f\, N_1\, N_2 \int \rho_1(x,y)\, \rho_2(x,y)\, dx\, dy$$



With transverse displacements Δ_x , Δ_y of one beam w.r.t. the other:

$$R(\Delta_x, \Delta_y) = \sigma \cdot L(\Delta_x, \Delta_y) = \sigma \cdot f\, N_1\, N_2 \int \rho_1(x-\Delta_x, y-\Delta_y)\, \rho_2(x,y)\, dx\, dy$$

$$\int R(\Delta_x, \Delta_y)\, d\Delta_x\, d\Delta_y = \sigma\, f\, N_1\, N_2 \int \rho_1(x-\Delta_x, y-\Delta_y)\, \rho_2(x,y)\, dx\, dy\, d\Delta_x\, d\Delta_y$$

$$= \sigma\, f\, N_1\, N_2 \int \rho_2(x,y) \underbrace{\left[\int \rho_1(x-\Delta_x, y-\Delta_y)\, d\Delta_x\, d\Delta_y \right]}_{=1} dx\, dy$$

$$= \sigma\, f\, N_1\, N_2 \overbrace{\int \rho_2(x,y)\, dx\, dy}^{=1} = \sigma\, f\, N_1\, N_2$$

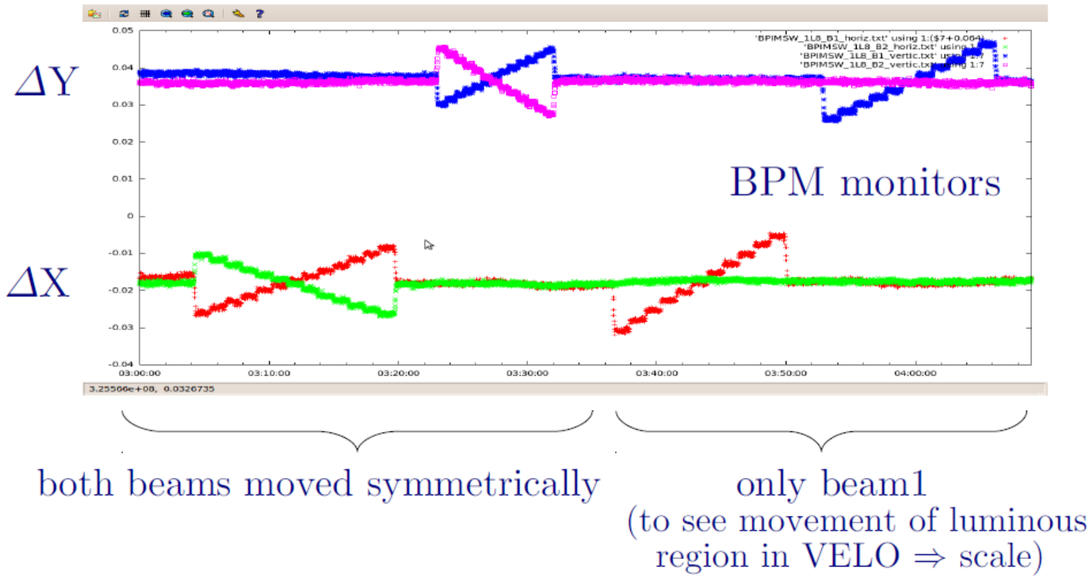
Assumptions…

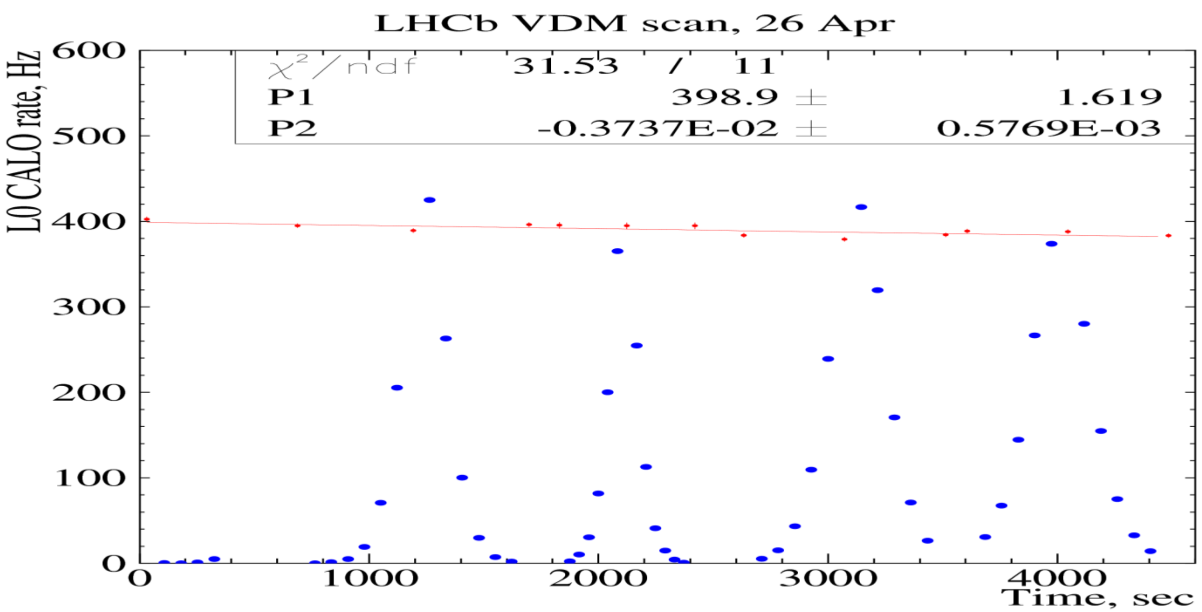
- Beams do not change when they are moved across each other
  - correct for (or neglect) beam-beam effects
  - correct for (or neglect) slow emittance growth
  - correct for (or neglect) slow bunch current decay

- Scan range sufficiently large to cover the distributions
  - negligible tails

- Relation between transverse displacement parameters (magnet currents) and the actual displacement is known on absolute scale
  - calibrate the absolute displacement scale with vertex detectors

LHCb scans (fill 1059)





- 4 scans
- L0CaloRate corrected for small pile-up effect

- Checked rate at "working point" R(Δ_{x0} , Δ_{y0}), red points, throughout the scans (~1h)
  - correct for small decay (~30 h life time)

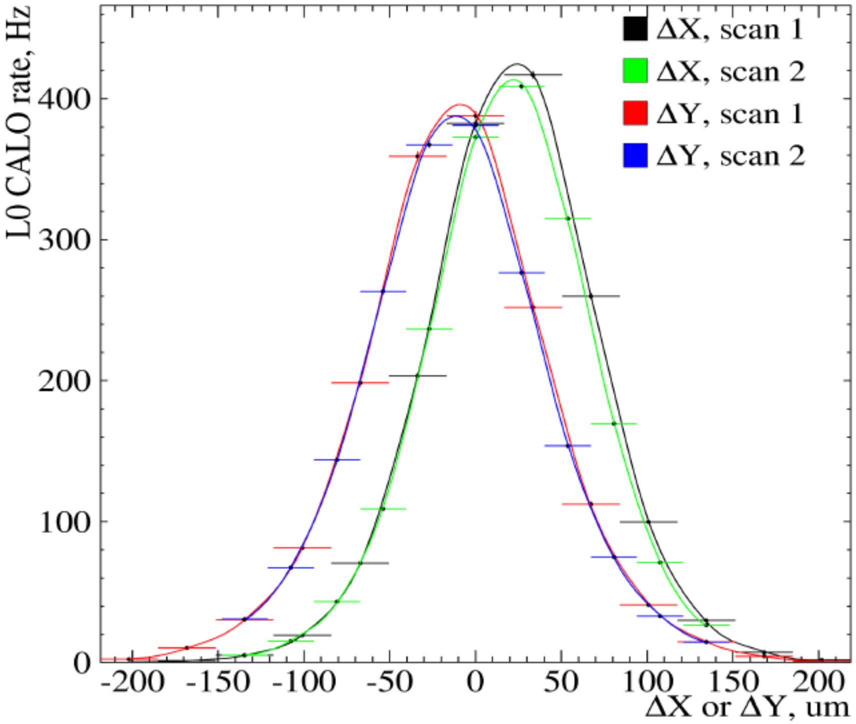
Van der Meer scans

- Scans done at all IPs
  - 2xIP1
  - 2xIP5
  - 1xIP8
  - 1xIP2
- Profit from modest bunch charge (small beam-beam effects)
- First attempts, give ~10% uncertainty on absolute luminosity determination
  - Uncertainty dominated by knowledge of individual bunch populations

Preliminary results

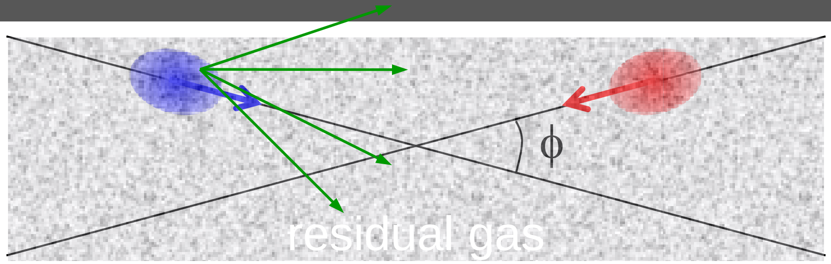
Comparison of two scans

1) both beams moved
2) only beam1 (×0.8 smaller step)



Beam-gas imaging method

Again, luminosity



$$L = f N_1 N_2 \;\; 2c \;\; \cos^2(\phi/2) \int \rho_1(\mathbf{r},t) \;\; \rho_2(\mathbf{r},t) \;\; d^3r \, dt$$

- Beam interacts with residual gas around the interaction region
- Reconstruct beam-gas interaction vertices

  => sample transverse beam profile

  measure individually the ρ_1 and ρ_2 and rebuild the overlap

  (measure also ϕ and hourglass effect and and and…)

Requires:
(1) vtx detector resolution smaller (or at least comparable) to the beam sizes
(2) residual pressure & acceptance must be adapted to this method

- Strength with respect to van der Meer method:

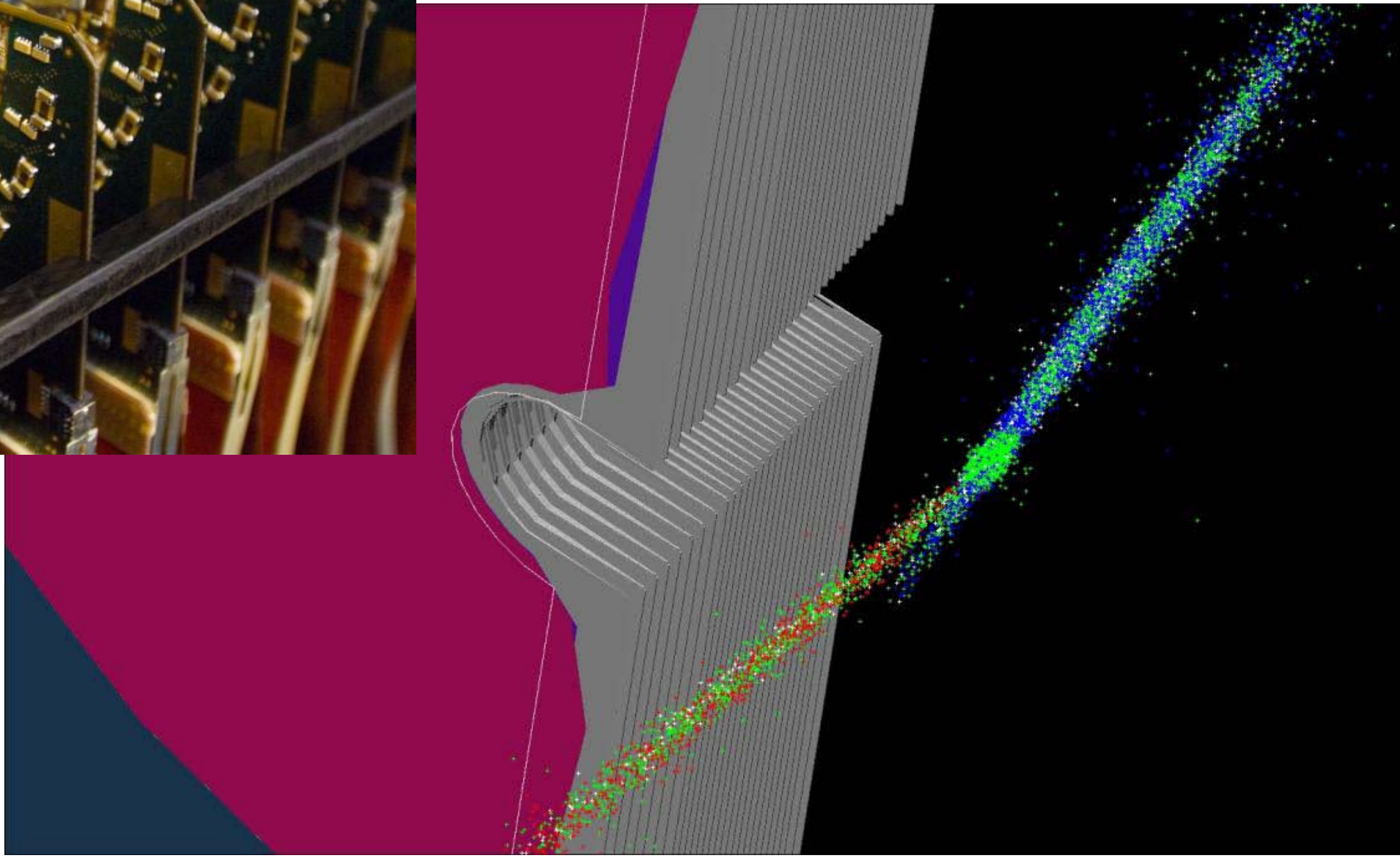
  (a) non disruptive, **do not affect the beams** !

  (b) can run fully parasitically during physics running time

  => potentially smaller systematics uncertainties

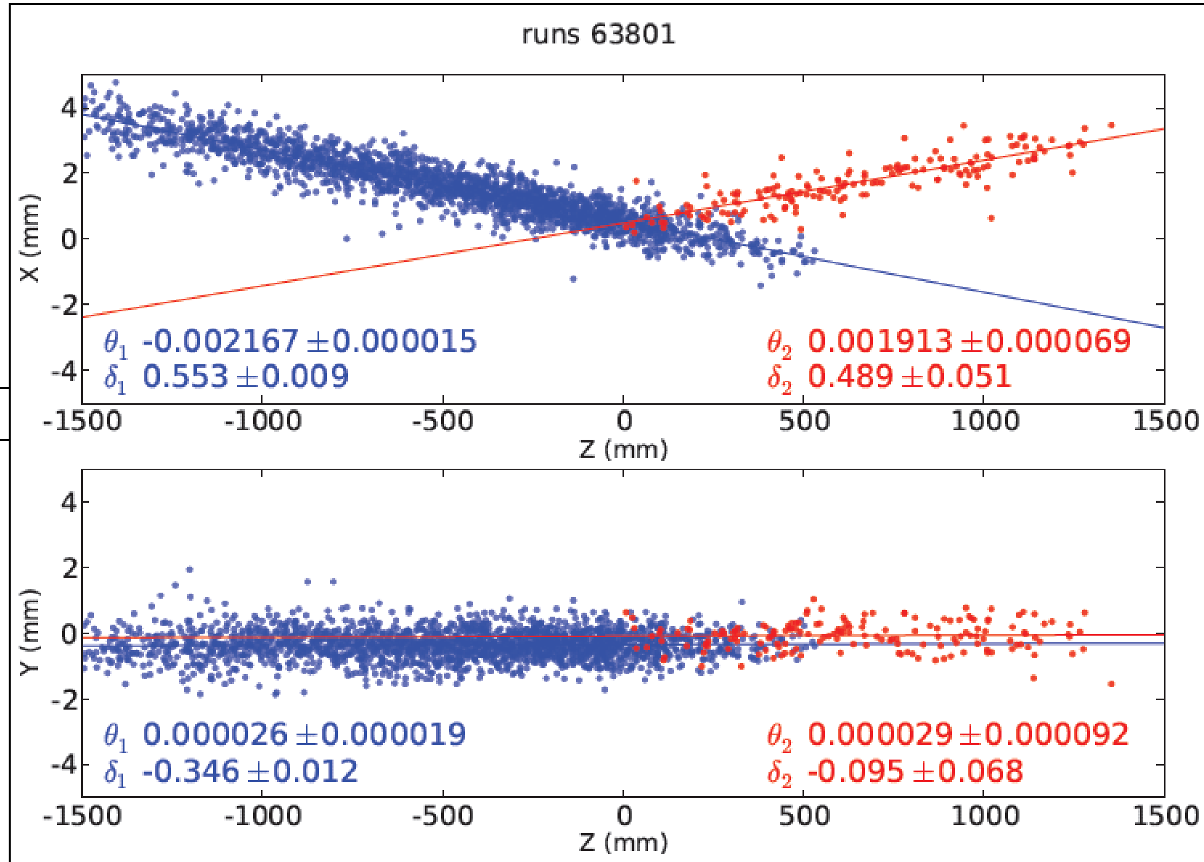
The LHCb VELO as a beam imaging device

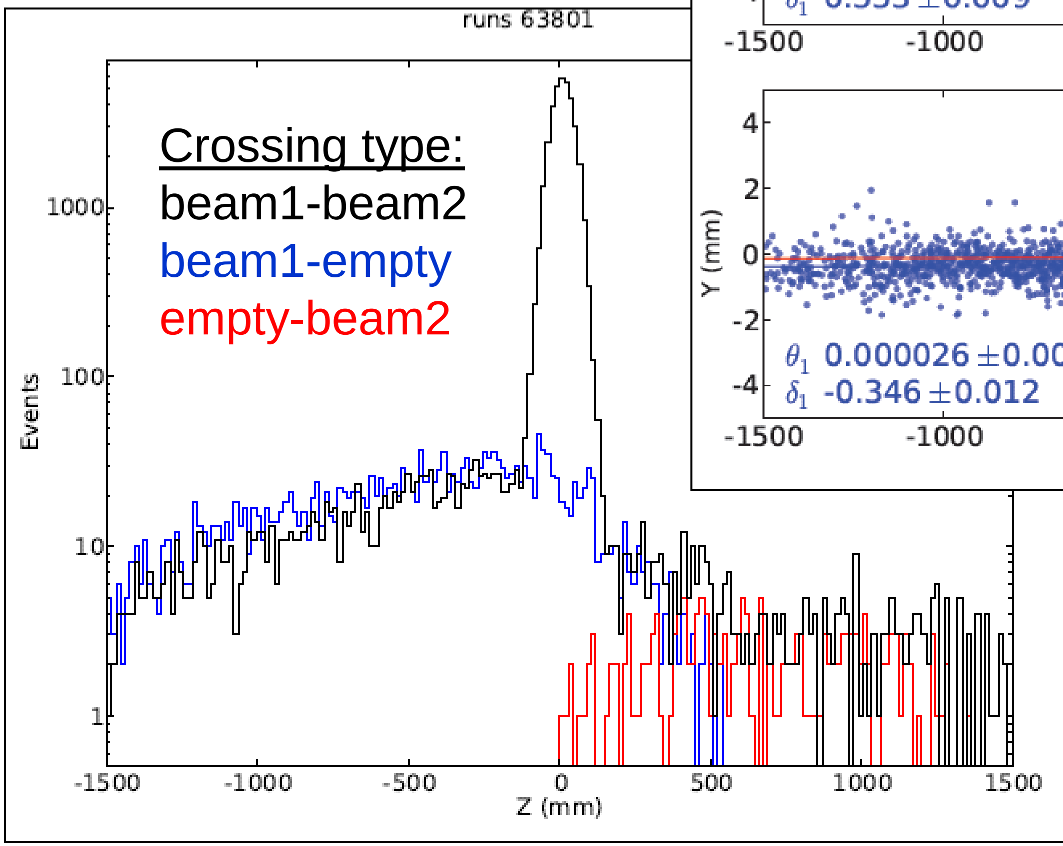
- At 450 GeV the VELO is not fully closed around the beam (for safety reasons)
- Still, can reconstruct the beams!



Example, 450 GeV beam imaging (2009)

Angle from dipole spectrometer bump





And the VELO was not even closed around the beams…

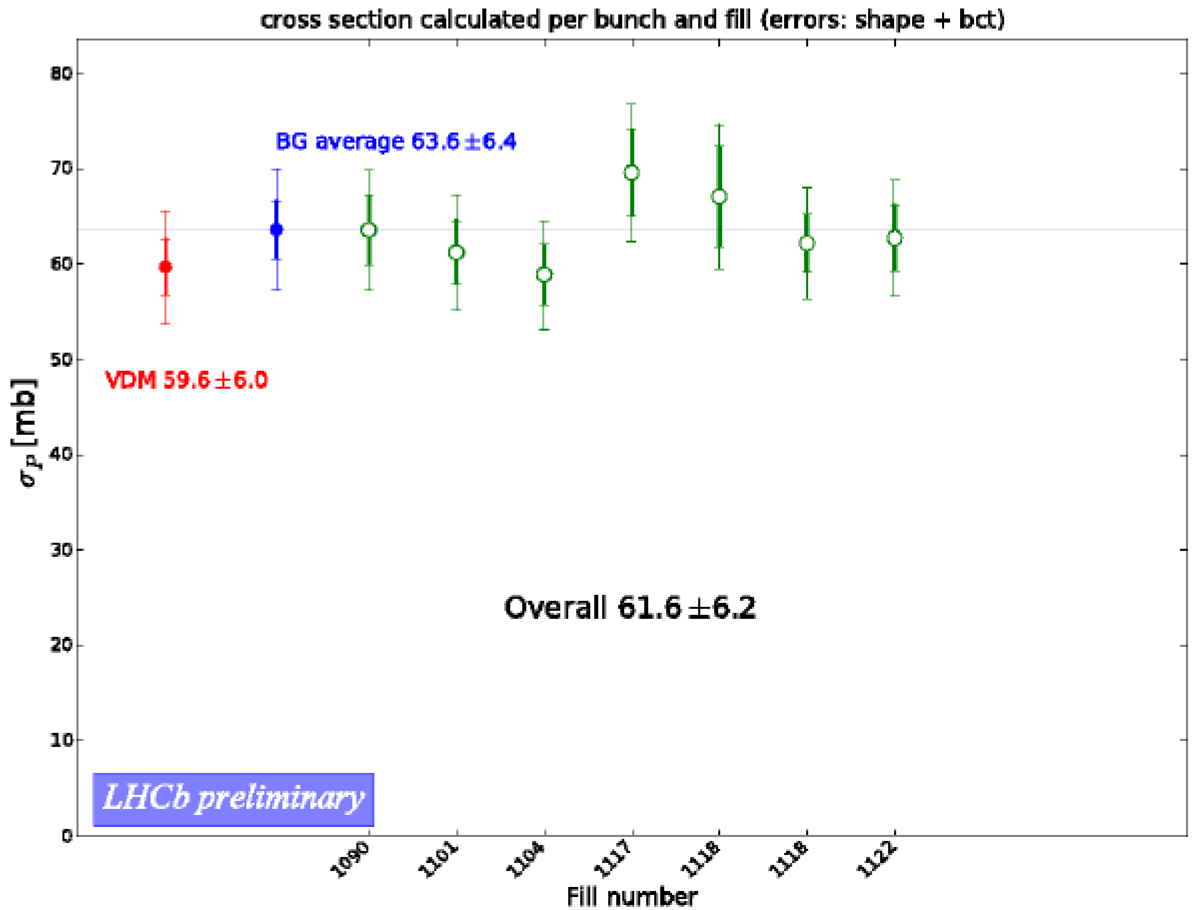
LHCb beam-gas imaging and VdM results at 3.5 TeV

- Agreement between two methods (vdm and beam-gas)
- Thin error bars include beam current normalisation uncertainty
- Thick error bars: without beam current normalisation uncertainty

Putting it together in a plot

Effective cross-section results (assuming ±8% for the I^2 error)

σ_P = cross section of event with 2 or more RZVelo tracks



Outlook

- what next ?
  - end of 2010
  - 2011
  - and long term

Luminosity parameters

using ε_T =3.3 um , N=1e11 , k_b=35 , β^*=3.5m

$$L = \frac{f \; k_b \; N^2}{4\pi \; \beta^* \; \varepsilon_T} = 1e31 \; Hz/cm^2$$

(as obtained)

or desired

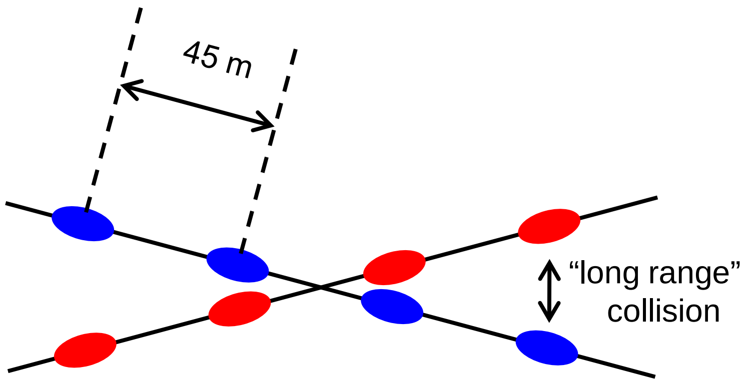
Parameter	value now	realistic target for 2011	ratio
N	$10 \cdot 10^{10}$	$11 \cdot 10^{10}$	11 / 10 = 1.1
β^*	3.5 m	2 m	3.5/2 = 1.75
$\gamma\varepsilon_T$	3…4 μm	3…4 μm	~ 1
k_b	36	~800	800/36 = 22 !!

The only parameter which is still very far away from a “realistic 2011 target” is the **number of bunches**

Highest priority for Autumn 2010

Get a few hundred nominal bunches stably colliding in the LHC

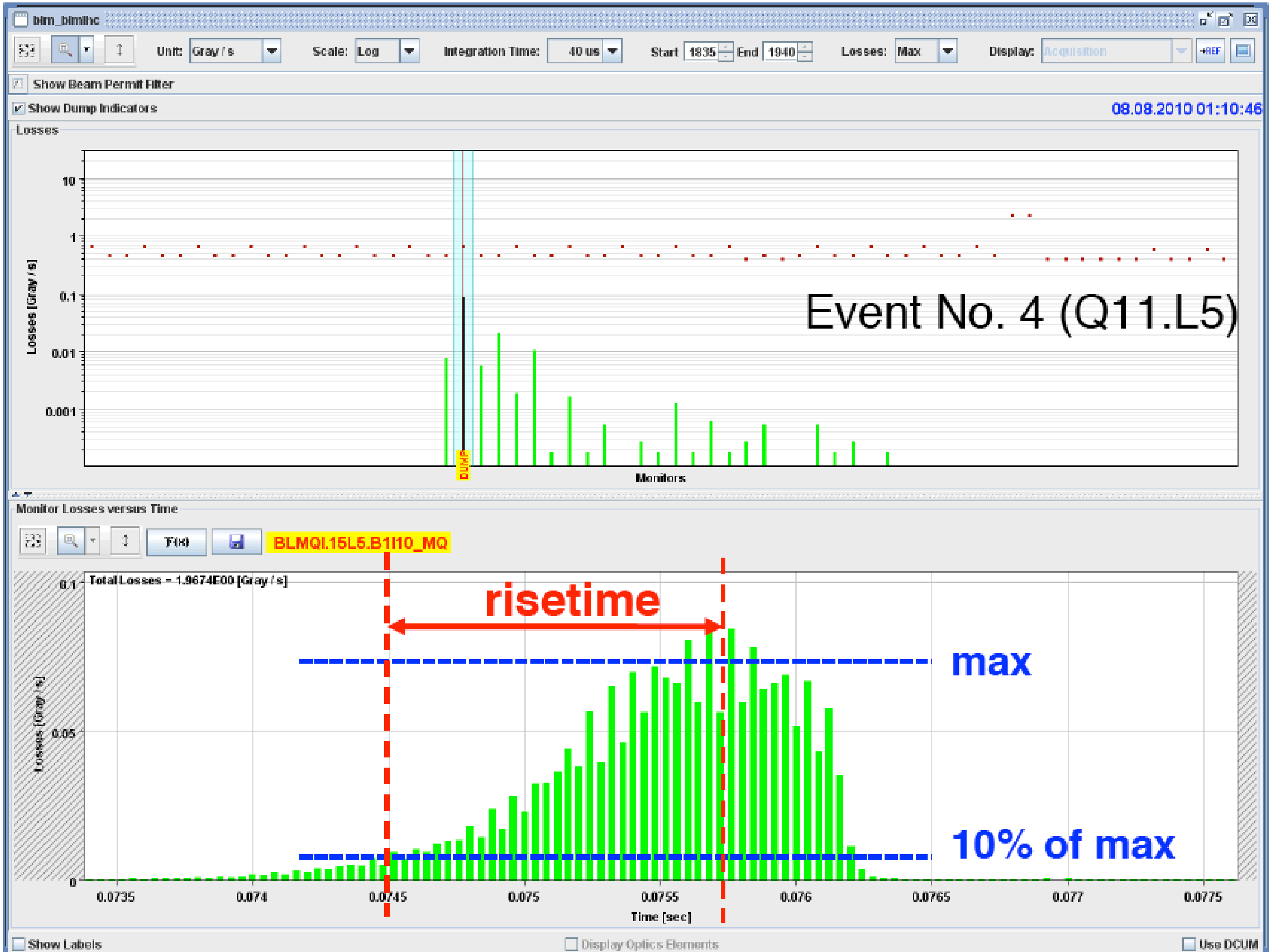
- Reduced bunch spacing
  - opted for 150ns spacing to start with
  - will allow up to ~400 bunches
  - next year, move to 50 ns or 75 ns



- Requires crossing angle in all IRs
  - avoid parasitic collisions away from IP
  - still get many long-range collisions between bunches
    (up to 18 long-range + 3 head-on collisions for some bunches)
    - beam-beam effects ?
    - minimum crossing angle ?

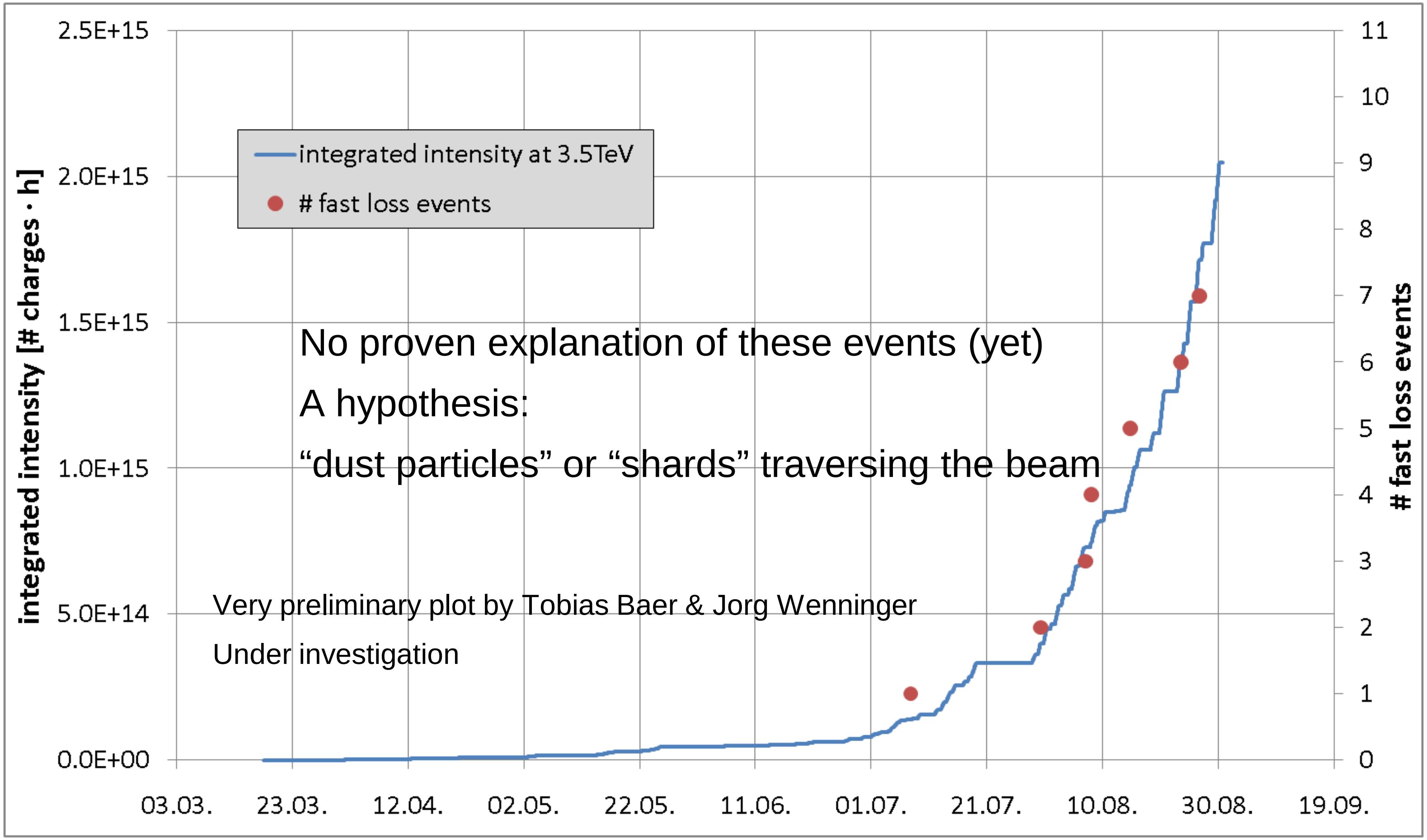
How easy will it be ?

For example… Observed fast local loss events



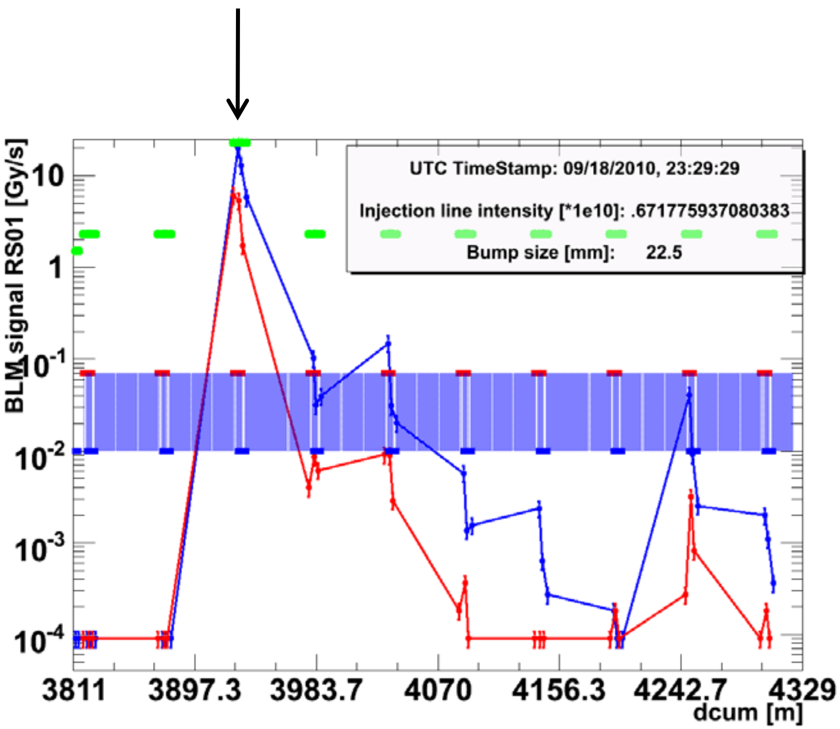
Fast local loss evts: occurrence scaling with intensity ?

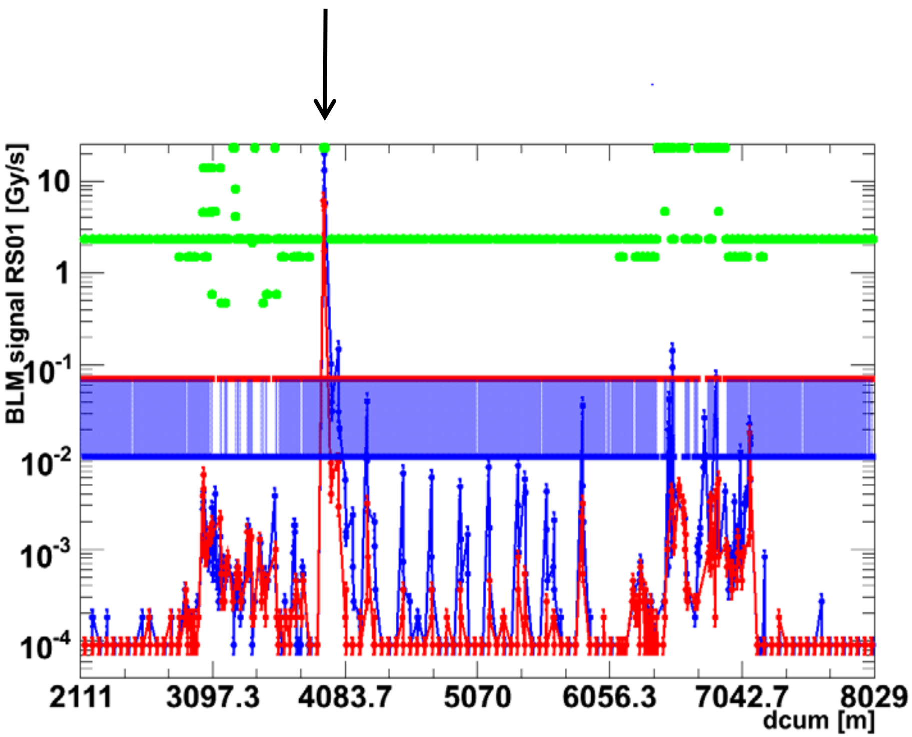
- 7 such events have provoked non-programmed dumps (prematurely interrupted a fill)
- Time scale of losses ~1-2 ms
- These events have occurred in the whole machine (no obvious preference for an area)



Quench test , 18-19 sep 2010

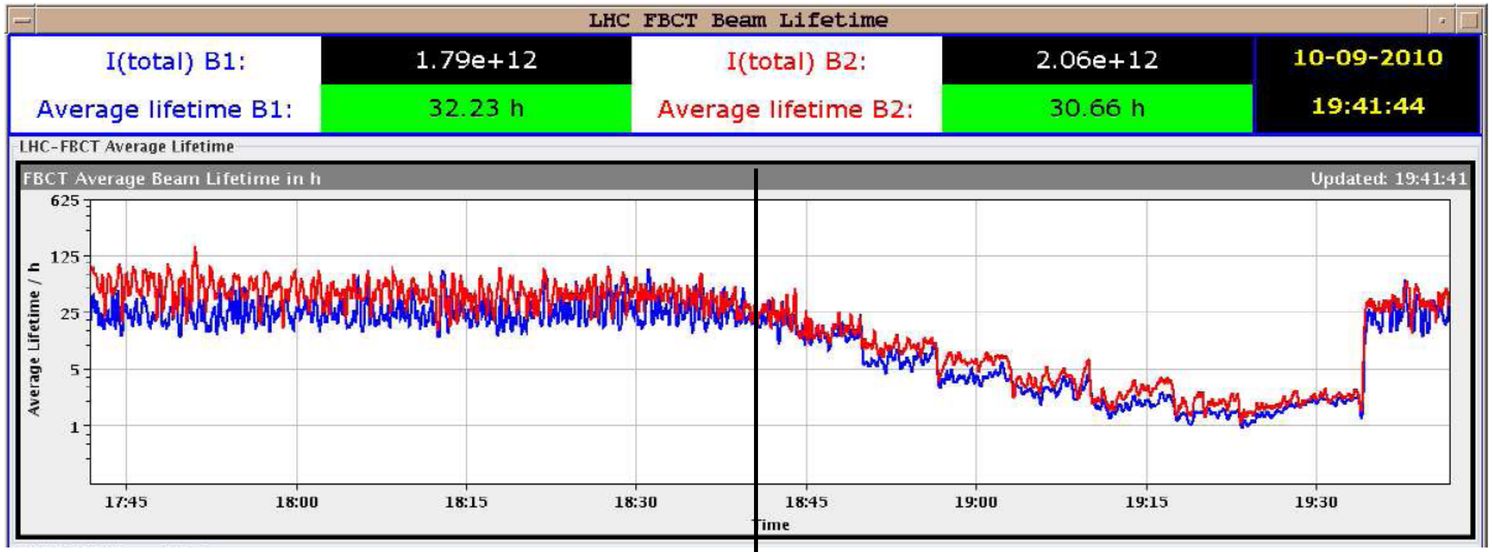
- Beam1 bump beam inward at 14R2.B1, by up to 24mm
- One bunch of ~8e9p , "inject and dump" mode
- BLM thresolds raised a factor 3 above calculated quench level
- no quench…

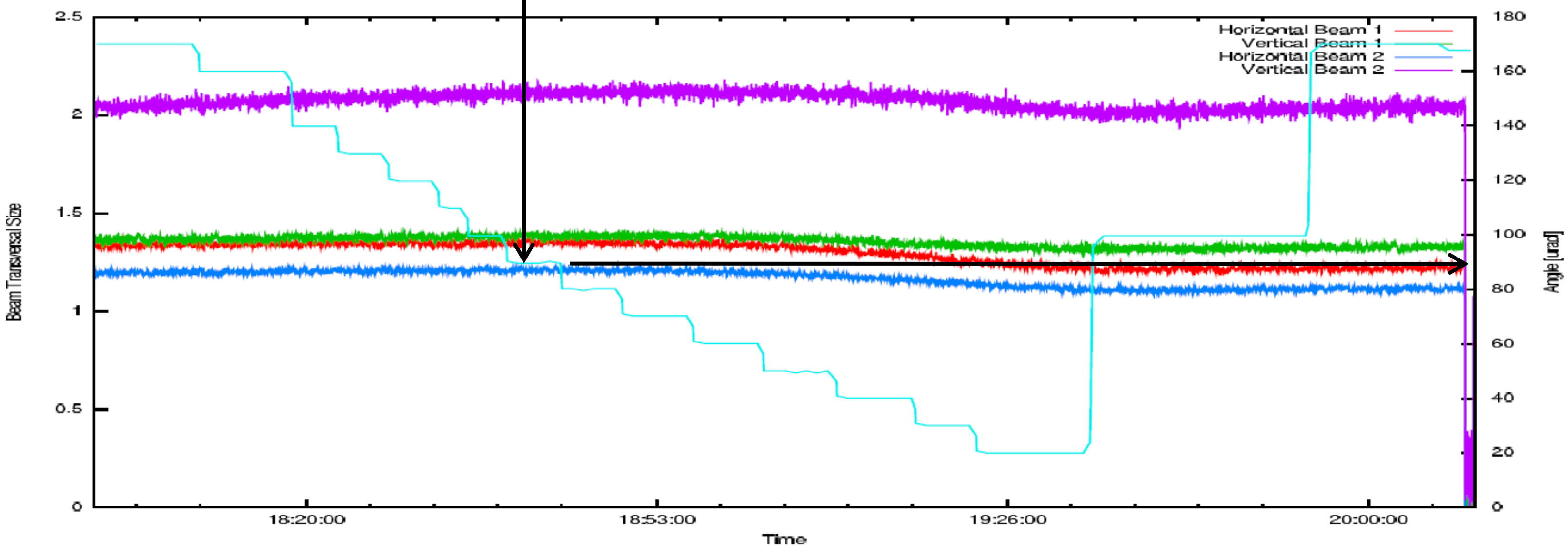




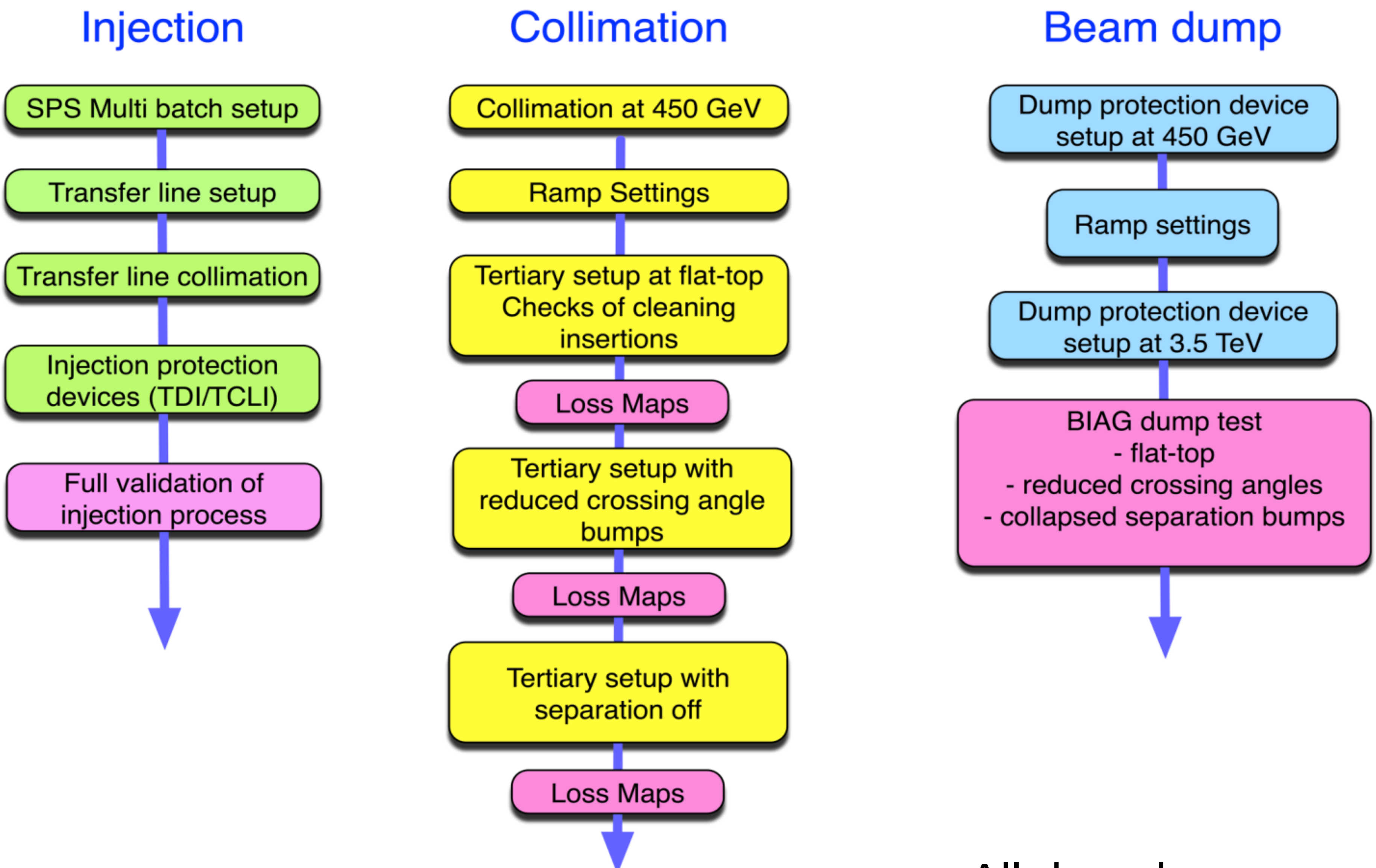
Beam-beam effects

- Scanning crossing angle at injection (450 GeV), online observations





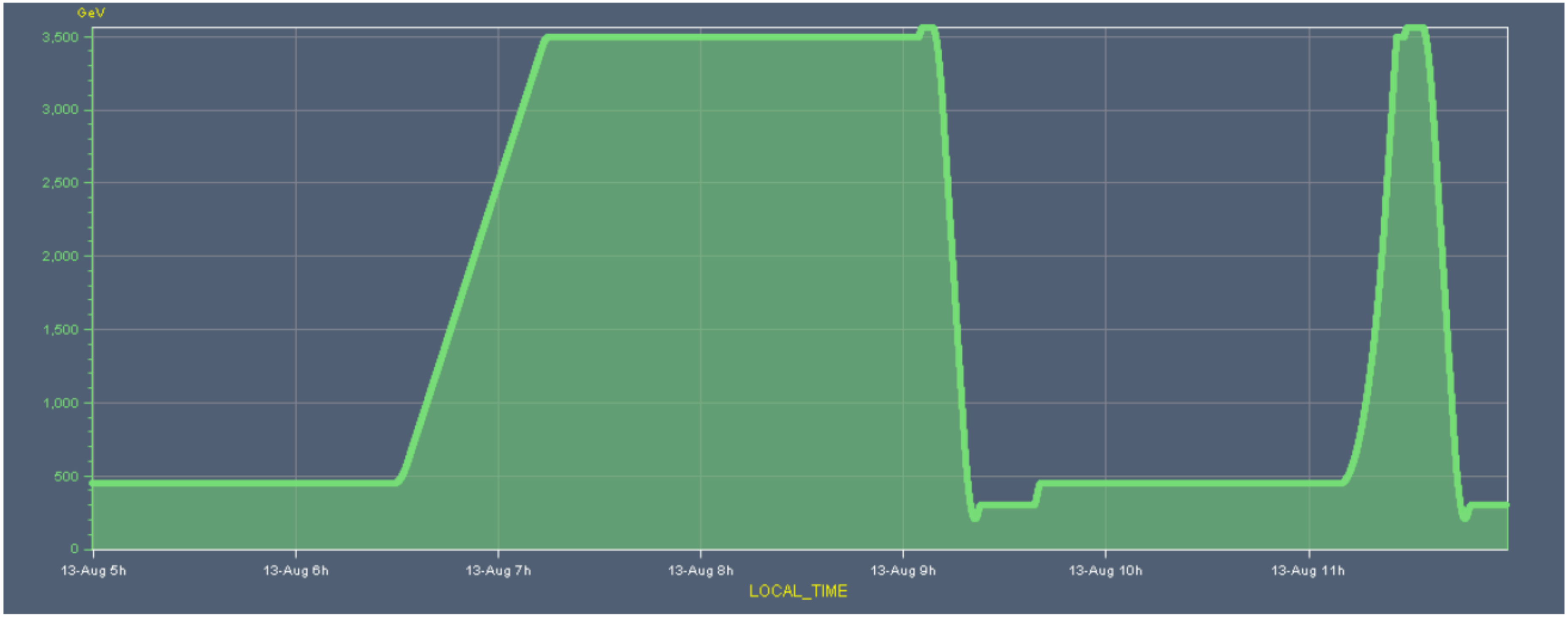
Commissioning bunch trains



All done by now

Speeding up the turn-around time

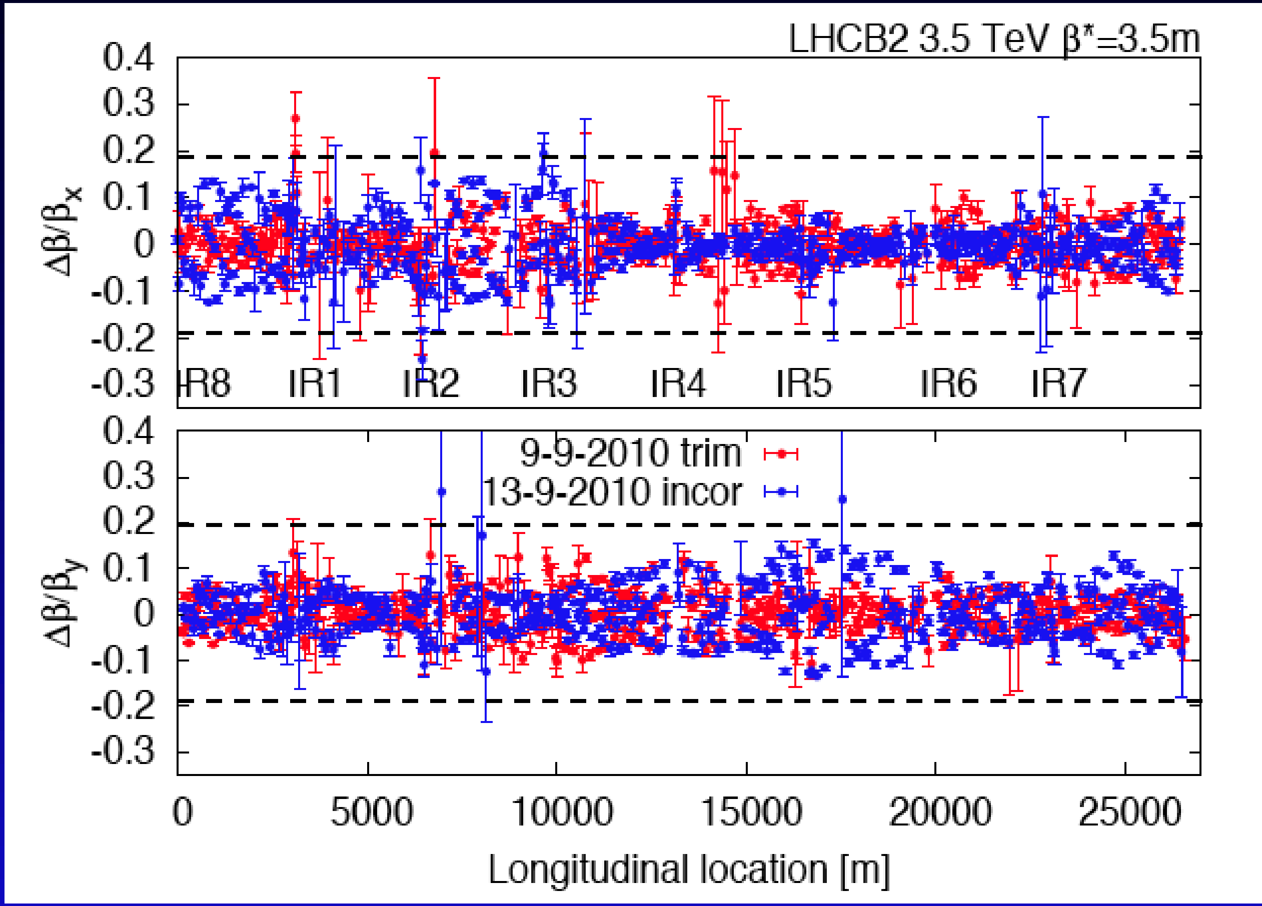
- going from 2A/s to 10A/s ramp rates



Ramp duration reduced from 46 to 16 minutes

Great optics

Global correction (incorporated), Beam 2



indeed ≈15%.

Excellent reproducibility

Many more nice results from recent hard work…

Unfortunately, no time to show them all…

- Dump protection: revalidating with the newly defined machine
- RF: preparing for hundreds of bunches
  - all cavities are on at reduced voltage, adjusted longitudinal blow-up, bunch length reduced from 1.4ns to 1.2ns (and later to the nominal 1ns?)
- Beam instrumentation, continuous improvements
- Aperture studies
- etc.

A lot of work done by our machine colleagues in the past 2 weeks
which sets the basis for moving from ~50 bunches (2.7 MJ)
all the way to 400 bunches (22 MJ) before end of November.

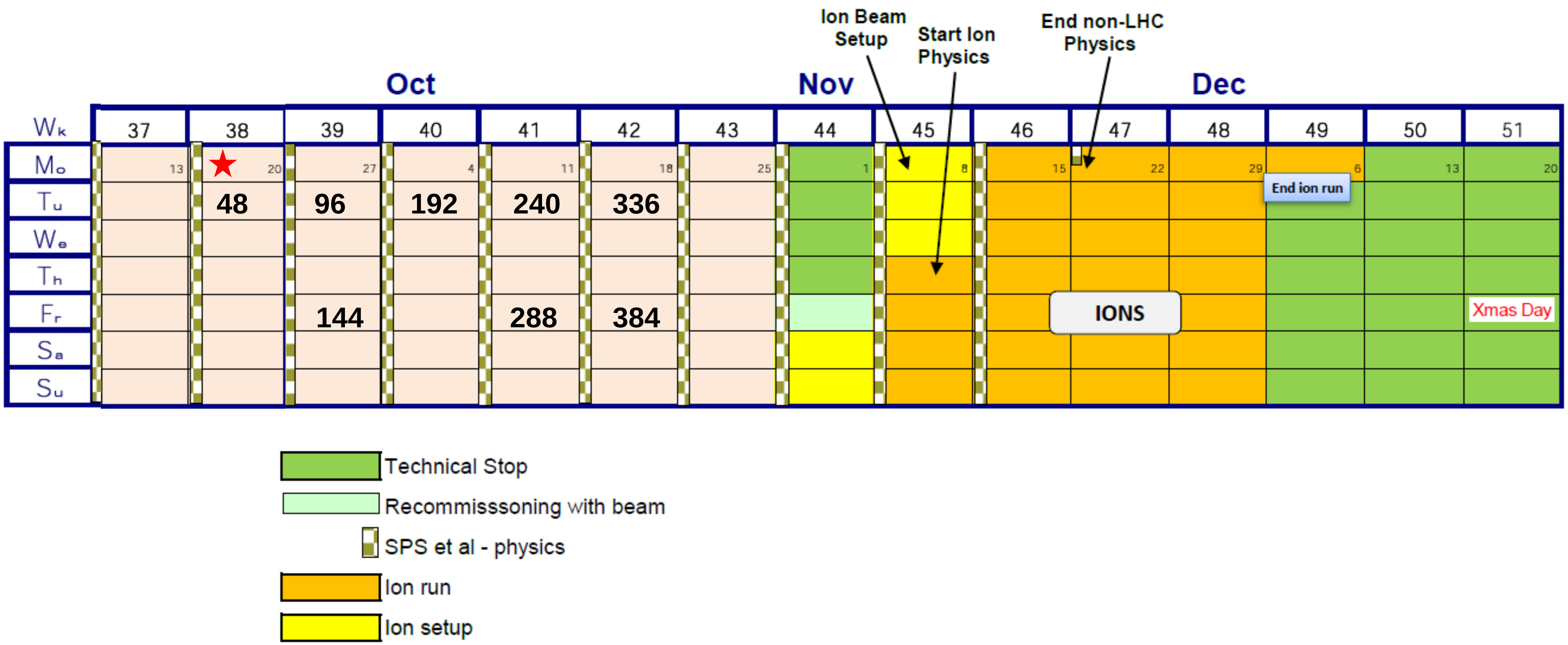
150ns filling schemes: a possible evolution

bunches per LHC injection	PSB bunches per PS injection	LHC injections x bunches (per beam)	Total bunches per LHC beam	Collisions in IP1,5,8
4	2	12 x4 + 1 x4	48 +4	45
8	4	12 x8 + 1 x8	96 +8	93
12	6	12 x12 + 1 x12	144 +12	141
12	6	16 x12 + 1 x12	192 +12	188
12 & 24=12+12	6	4x12+8x24 + 1 x12	240 +12	235
24 =12+12	6	12 x24 + 1 x12	288 +12	282
12 & 24=12+12	6	4x12+12 x24 + 1 x12	336 +12	329
24 =12+12	6	16 x24 + 1 x12 (24?)	384 +12 (24?)	376
36 =12+12+12	6	12 x36 + 1 x12 (24?)	432 +12 (24?)	423

actual PS trains

IP2 bunches (=collisions)

LHC schedule, 2010



Heavy Ion run:

- ❑ magnetically as for pp, except crossing scheme
- ❑ up to at least 62 bunches, 8e24 Hz/cm^2, or more ?

2011

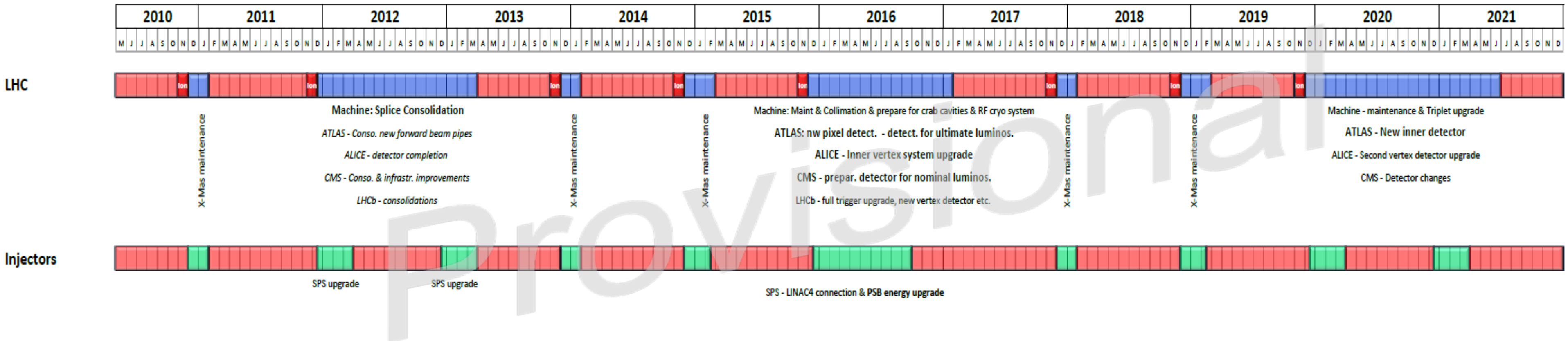
- Technical stop (winter): 6 Dec 2010 to ~1 Feb 2011

- **2011 baseline: deliver 1 fb^{-1} at $s^{1/2}$ = 7 TeV**
  - resume in Feb 2011 at ~1e32 Hz/cm^2 and keep pushing up
    - β^* down to 2m ?
    - nr of bunches up to 900 ?
    - bunch charge beyond $1.1x10^{11}$?
    - slightly reduced transverse emittance ?

    } will have to explore and find the limits
  - run physics for about 9 months Mar-Nov

- Under discussion:
  - push from 3.5 to 4 TeV/beam in Feb 2011 ?
  - would increase the physics reach at same integrated luminosity
    - e.g. 25% more cross section for light Higgs (and of course more gain for heavier, much awaited, new physics objects)
    - implications and overhead time for such a scenario are being looked at

Provisional plan (long term)



shutdowns	2012	2016	2020
LHC machine	**Splices for 7 TeV** **Collimators in IR3** **R2E driven modifications**	**Collimation phase II** **Prepare for crab cavities** **New RF cryogenic system**	**New Triplets** **Crab cavities**
LHC experiments	**ALICE – TID and calorimeter** **ATLAS – forward beam pipes** **CMS – infrastructure** **LHCb – conical beam pipe**	**Assuming 30 to 50 fb^{-1}** **ALICE – new vertex detector** **ATLAS – pixel detector + upgrades** **CMS – many improvements** **LHCb – full trigger upgrade, new vertex detector**	**Assuming 300 to 600 fb^{-1}** **ALICE – vertex detector upgrade** **ATLAS – new inner detector** **CMS – new inner detector** **LHCb –**
Injectors	**In two 3-4 month shutdowns** **• Preparations for PSB energy upgrade** **• SPS upgrade**	**Linac 4 connection to PSB** **Completion of PSB energy upgrade for 2 GeV operation** **PS and SPS consolidation**	**Consolidation of all machines in 3-4 month injector shutdowns**

Summary

- LHC luminosity and intensity are moving up steadily
  - started ~10-11 months ago (seems like a century)
  - now at 3.5 pb^{-1} , 1e31 Hz/cm^2, moving to 150ns trains (crossing angle)
  - first luminosity calibration done (~10% level)
    - would be ~5% if no uncertainty from current measurement!
- 2010:
  - push number of bunches (>300)
  - establish luminosity of $\sim 10^{32}$ Hz/cm^2
  - continue effort on luminosity calibration   what should we aim for ?
  - 1st Heavy Ion run
- 2011:
  - deliver up to 1 fb^{-1} at sqrt(s) = 7 TeV

and hope for surprises

more material

Factorization

Assume x-y factorizable $\rho_i(x,y) = \rho_{ix}(x)\ \rho_{iy}(y)$

$$L(\Delta_x, \Delta_y) = f\, N_1\, N_2 \cdot \underbrace{\int \rho_{1x}(x-\Delta_x)\ \rho_{2x}(x)\ dx}_{1/h_x(\Delta_x) = O_x(\Delta_x)} \cdot \underbrace{\int \rho_{1y}(y-\Delta_y)\ \rho_{2y}(y)\ dy}_{1/h_y(\Delta_y) = O_y(\Delta_y)}$$

$$L(\Delta_x, \Delta_y) = f\, N_1\, N_2\, O_x(\Delta_x)\, O_y(\Delta_y)$$

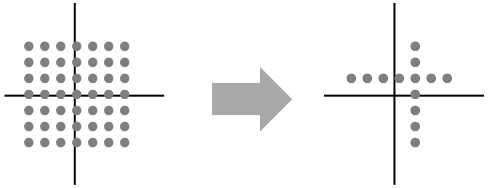
Re-use van der Meer's trick that for a=x or a=y :

$$\int O_a(\Delta_a)\, d\Delta_a = \int \rho_{2a}(a)\ \underbrace{\left[\int \rho_{1a}(a-\Delta_a)\, d\Delta_a \right]}_{\text{normalised to unity}}\ da = \int \rho_{2a}(a)\ da = 1$$

Result with factorization

Measure R while scan Δ_x (at $\Delta_y = \Delta_{y0}$), then while scan Δ_y (at $\Delta_x = \Delta_{x0}$)

$$R(\Delta_x, \Delta_{y0}) = \sigma\ f\, N_1 N_2\ O_x(\Delta_x)\ O_y(\Delta_{y0})$$
$$R(\Delta_{x0}, \Delta_y) = \sigma\ f\, N_1 N_2\ O_x(\Delta_{x0})\ O_y(\Delta_y)$$



$$R(\Delta_x, \Delta_y) = \frac{R(\Delta_x, \Delta_{y0}) \cdot R(\Delta_{x0}, \Delta_y)}{R(\Delta_{x0}, \Delta_{y0})} \qquad R_0 = R(\Delta_{x0}, \Delta_{y0})$$

$$\int R(\Delta_x, \Delta_y)\ d\Delta_x\ d\Delta_y = R_0^{-1} \int R(\Delta_x, \Delta_{y0})\, d\Delta_x \cdot \int R(\Delta_{x0}, \Delta_y)\, d\Delta_y$$

$$\int R(\Delta_x, \Delta_y)\ d\Delta_x\ d\Delta_y = \sigma f N_1 N_2 \cdot \int O_x(\Delta_x)\ O_y(\Delta_y)\ d\Delta_x\ d\Delta_y$$
$$= \sigma f N_1 N_2 \cdot \int O_x(\Delta_x)\, d\Delta_x \cdot \int O_y(\Delta_y)\, d\Delta_y$$

$$= \sigma f N_1 N_2$$

Van der Meer scan with crossing angle

- It has been pointed out that the van der Meer method with bunched beams (like at the LHC) can equally be applied to the case with non-zero crossing angle (V. Balagura).

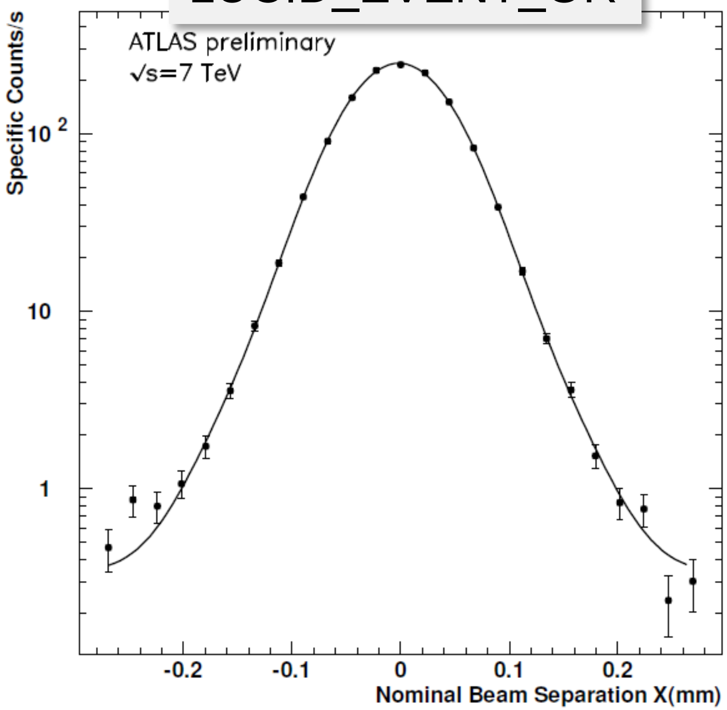
- General formula with full crossing angle ϕ :

$$\sigma = \frac{f\, N_1\, N_2 \int R(\Delta_x , \Delta_{y0})\, d\Delta_x \cdot \int R(\Delta_{x0} , \Delta_y)\, d\Delta_y}{\cos(\phi/2) \cdot R_0(\Delta_{x0} , \Delta_{y0})}$$

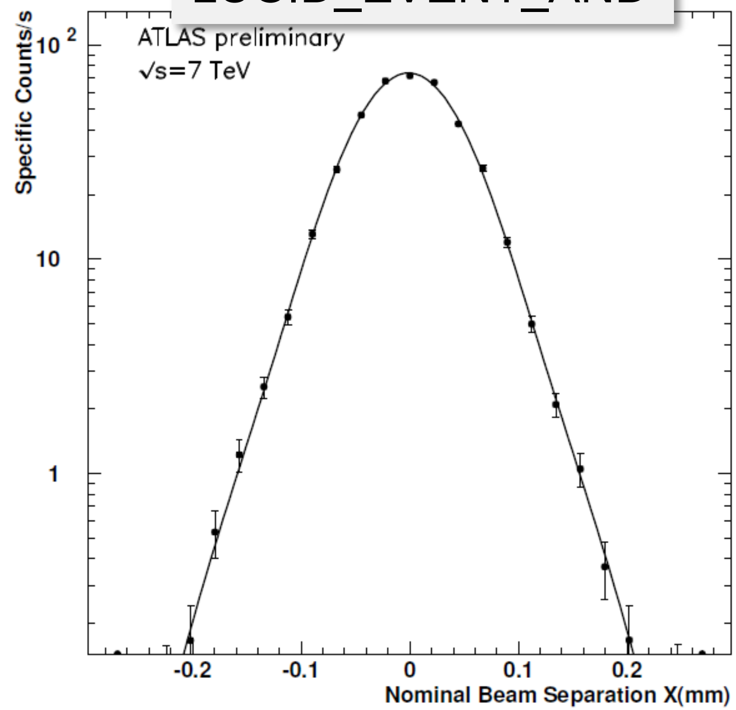
(here shown for the case with x-y factorized)

ATLAS scan fits

LUCID_EVENT_OR



LUCID_EVENT_AND



- Fit with double Gaussian (common mean) and constant bkg
- Similar for Y

$$R_x(x) = \frac{R_x(0)}{\sqrt{2\pi}} \left[\frac{f_a e^{-(x-x_0)^2/2\sigma_a^2}}{\sigma_a} + \frac{(1-f_a) e^{-(x-x_0)^2/2\sigma_b^2}}{\sigma_b} \right]$$

$$\frac{1}{\Sigma_x} = \left[\frac{f_a}{\sigma_a} + \frac{1-f_a}{\sigma_b} \right] \longrightarrow \mathscr{L} = \frac{n_b f_r I_1 I_2}{2\pi \Sigma_x \Sigma_y}$$

ATLAS results PRELIMINARY

Algorithm	σ_{vis}^{meas} (mb)	σ_{vis}^{PYTHIA} (mb)	$\frac{\sigma_{vis}^{PYTHIA}}{\sigma_{vis}^{meas}}$	σ_{vis}^{PHOJET} (mb)	$\frac{\sigma_{vis}^{PHOJET}}{\sigma_{vis}^{meas}}$
LUCID_Event_AND	$12.40 \pm 0.06 \pm 1.36$	15.7	1.27	16.8	1.35
LUCID_Event_OR	$40.18 \pm 0.12 \pm 4.42$	46.7	1.16	53.4	1.32
L1_MBTS_1_1_paired	$51.87 \pm 0.21 \pm 5.70$	58.4	1.13	68.7	1.32
L1_MBTS_1_paired	$58.65 \pm 0.23 \pm 6.45$	66.6	1.14	73.7	1.26
MBTS_1_timing	$50.4 \pm 0.2 \pm 5.7$	57.6	1.14	67.8	1.35
Primary Vertex Counting	$53.6 \pm 0.2 \pm 5.9$	57.9	1.08	70.0	1.31

Scan Number	σ_{vis} mb	$\mathcal{L}_{spec}$ (10^{29} cm^{-2}s^{-1})
1	12.15 ± 0.14	6.80 ± 0.08
2	12.55 ± 0.10	4.85 ± 0.03
3	12.73 ± 0.10	4.88 ± 0.09
1	39.63 ± 0.32	6.85 ± 0.06
2	40.70 ± 0.13	4.88 ± 0.01
3	40.77 ± 0.14	4.92 ± 0.02
1	51.14 ± 0.39	6.78 ± 0.05
2	52.59 ± 0.16	4.87 ± 0.01
3	52.64 ± 0.16	4.90 ± 0.02
1	57.83 ± 0.43	6.79 ± 0.05
2	59.47 ± 0.18	4.89 ± 0.01
3	59.43 ± 0.25	4.90 ± 0.02
1	49.28 ± 0.31	6.76 ± 0.05
2	51.64 ± 0.23	4.87 ± 0.03
3	51.29 ± 0.24	4.93 ± 0.03
1	53.48 ± 0.29	6.73 ± 0.05
2	53.64 ± 0.22	4.89 ± 0.03
3	53.78 ± 0.23	4.89 ± 0.02

- Using six different count rate methods

Source	Uncertainty on σ_{vis} (%)
Beam Intensities	10
Length Scale Calibration	2
Imperfect Beam Centering	2
Transverse Emittance Growth & Other Sources of Non-Reproducibility	3
μ Dependence	2
Total	11

NB: 4.5% uncertainty if knew beam current perfectly

Some numbers to keep in mind

One bunch of 1e11 p
@ 3.5 TeV

↔

56 kJ

1 MJ ~ 18 bunches

20 MJ ~ 360 bunches

One bunch of 1e11 p
@ 3.5 TeV/beam
@ 3.5 m
@3.75 um

↔

2.5e29
Hz/cm^2

1e32 Hz/cm^2 ~ 400 colliding pairs of bunches

2e32 Hz/cm^2 ~ 800 colliding pairs of bunches

More numbers…

3.5 TeV, 3.5m, 3.75 um, 1e11 p/bch, 800 bunches

2e32 Hz/cm² x 9 months operation (23.3e6 seconds)

x 0.6 (turn-around and machine availability)

x 0.5 (lumi decay)

x 0.7 (physics running time)

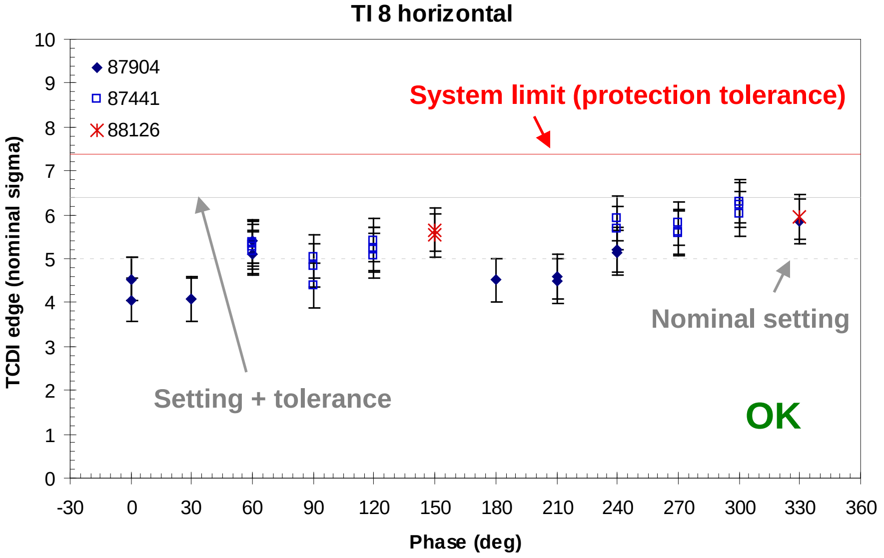
= **1 fb^{-1}**

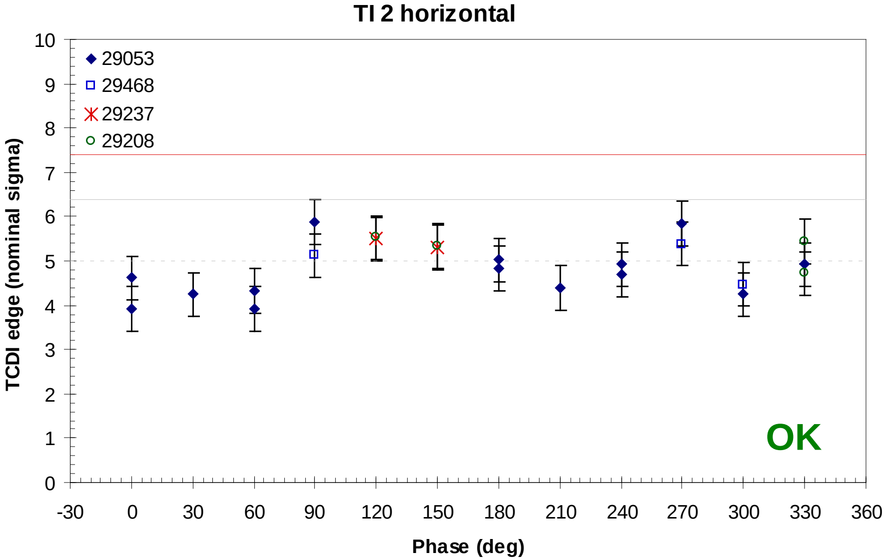
H = 1 fb^{-1} / (2e32Hz/cm^2 23.3e6 s) = 0.21

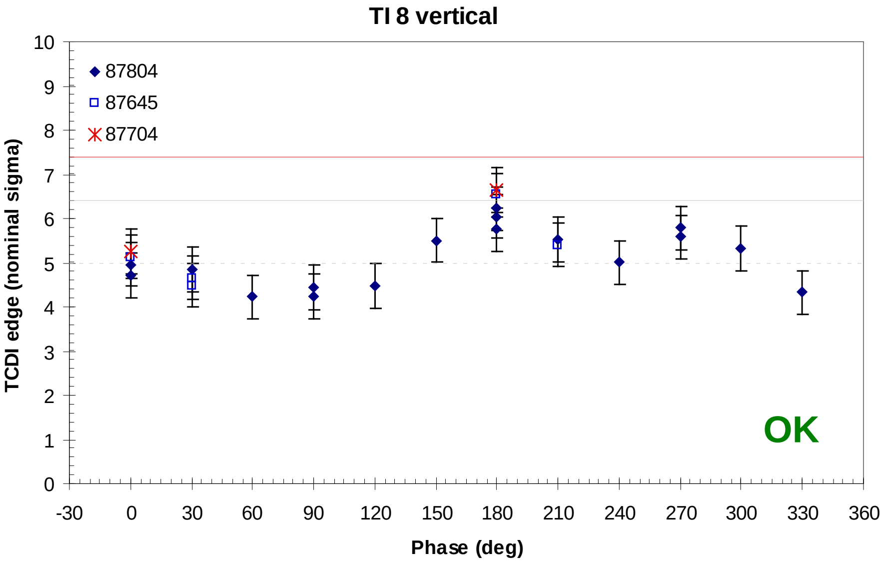
Where can we gain some margins ?

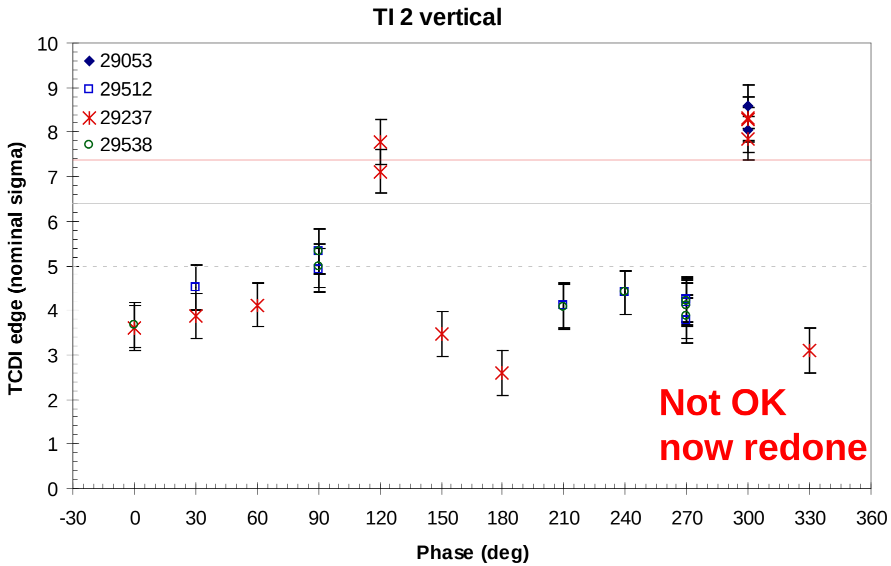
β^* ?	**Could go to 2m in 2011 (factor 1.7)**	
ε_T ?	**Might be tough just to reach nominal…**	
k_b ?	**Too early to say anything ?**	
N ?	**MD in SPS**	we have seen more than 1.1e11p…
H ?	**to be seen**	LEP & Tevatron ~0.2-0.25 at the end

Injection protection

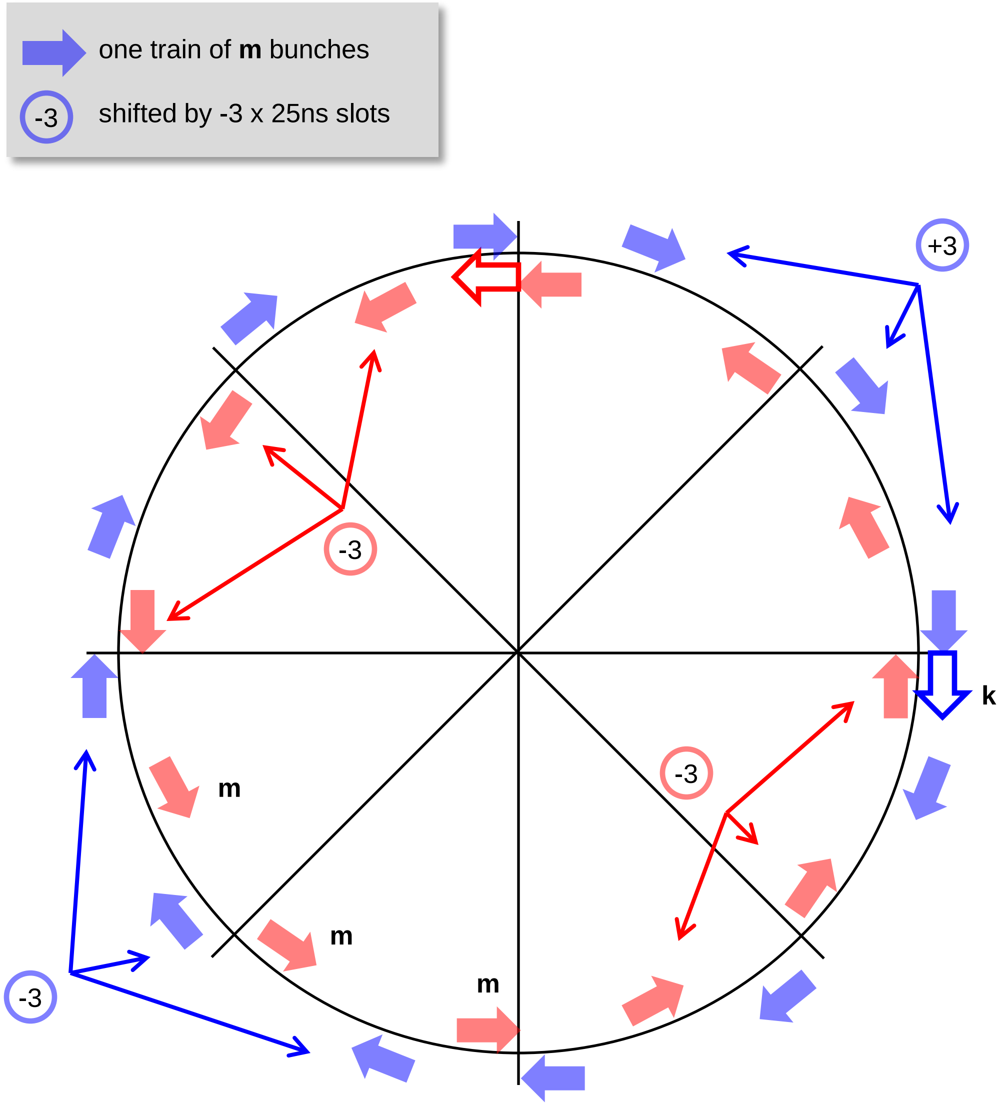








Overview of proposed 150ns "structure"

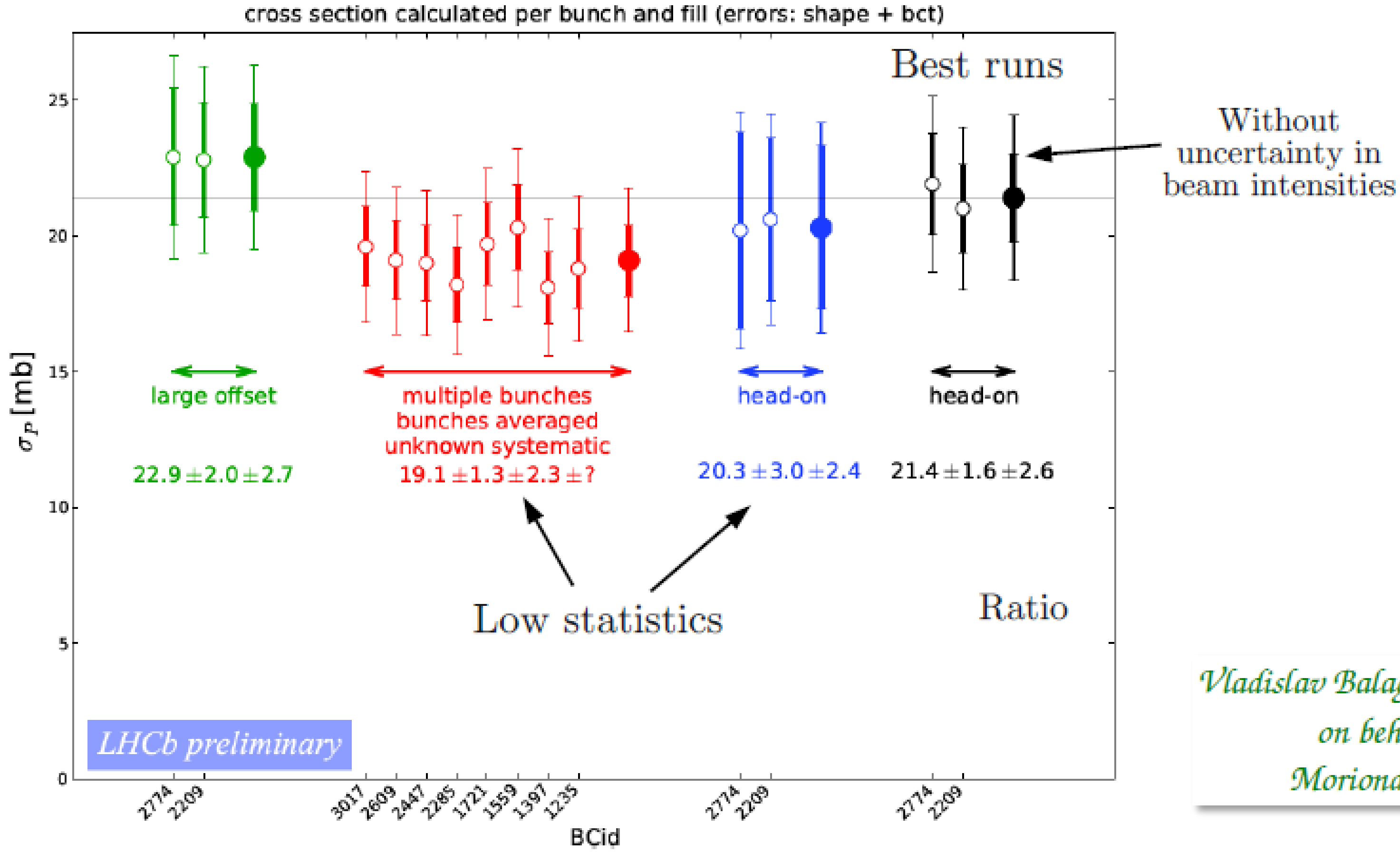


- **n** PS trains of each **m** bunches
- **N = n x m** = tot nr of bunches
- **M = N – n/4** = nr of collisions in each of IP1, IP5 and IP8
- example (**N=48**):
  - **n = 12 & m = 4 => M = 45**
  - **n = 4 & m = 12 => M = 47**
  - – NB: **m=12** is max for 150ns
- Add **k** bunches for ALICE, typically **k = ~ N/16 & k ≤ ~16**
- NB: the **N** bunches will give parasitic encounters at
  - IP2: +/-11.25 m, +/-33.75 m, …
  - IP1,5,8: +/-22.5m, +/-45m, …

Results for 900 GeV (<1 nb^{-1} and VELO open !!)

Time stability

"Visible" cross section (after trigger and recon. eff.):
before beam alignment, with 16+1 bunches, two LHC fills with alignment



Vladislav Balagura, CERN & ITEP
on behalf of LHCb,
Moriond, 14 Mar 2010

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