LHC Heavy Ion Run in 2011

John Jowett

Thanks to numerous colleagues

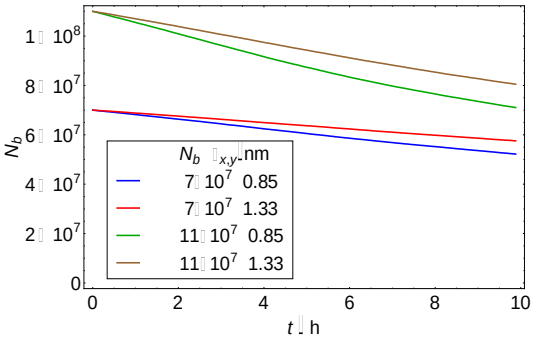
Outline

- The 2011 Pb-Pb run
  - Filling scheme(s)
  - Physics conditions for 3 experiments
  - Performance expectations
- Feasibility test of p-Pb
  - Aims
  - Collisions ?
- Preliminary commissioning schedule

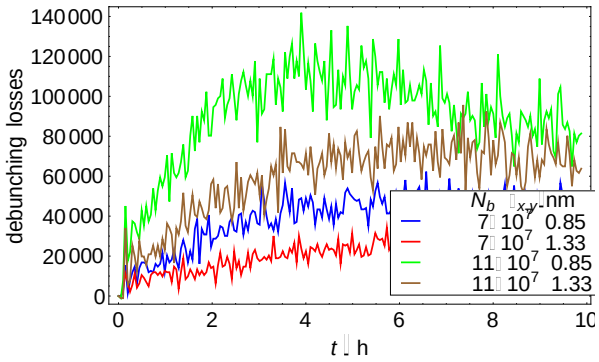
Filling scheme, choice since Chamonix 2011

- "Nominal" (similar Design Report)
  - bunch-splitting in PS
  - 100 ns min spacing
  - Tends to require larger crossing angles
  - About Nominal bunch intensity (7×10^7 Pb/bunch)
  - Smaller emittance
  - Not clear that we can inject enough intensity into PS (source, Linac3, LEIR limits at present)
- "Intermediate" (improved "Early")
  - no splitting in PS
  - 200 ns min spacing
    - (conditional on recent developments in injectors, see D. Manglunki's talk)
  - Smaller crossing angles
  - Higher bunch intensity (10-13$\times10^7$ Pb/bunch)

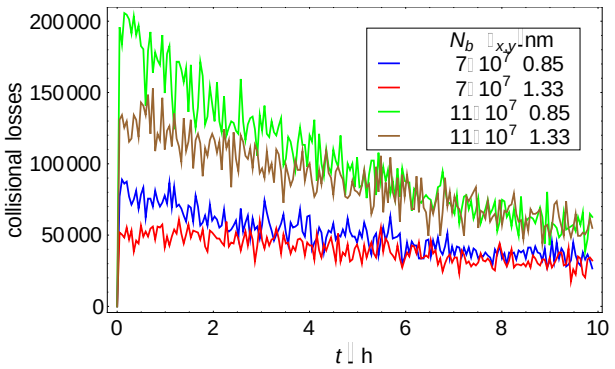
2011 Luminosity evolution



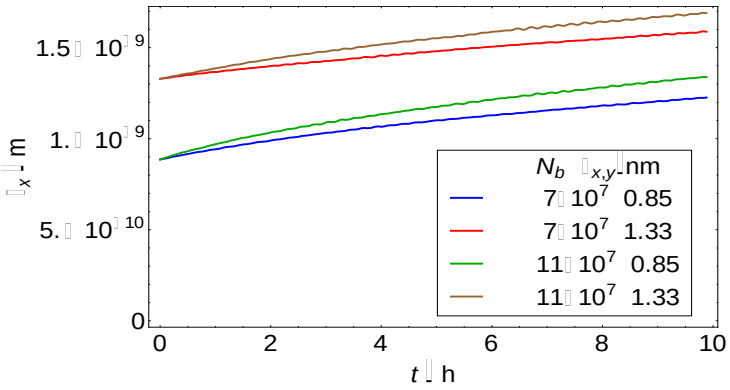
Single bunch intensity



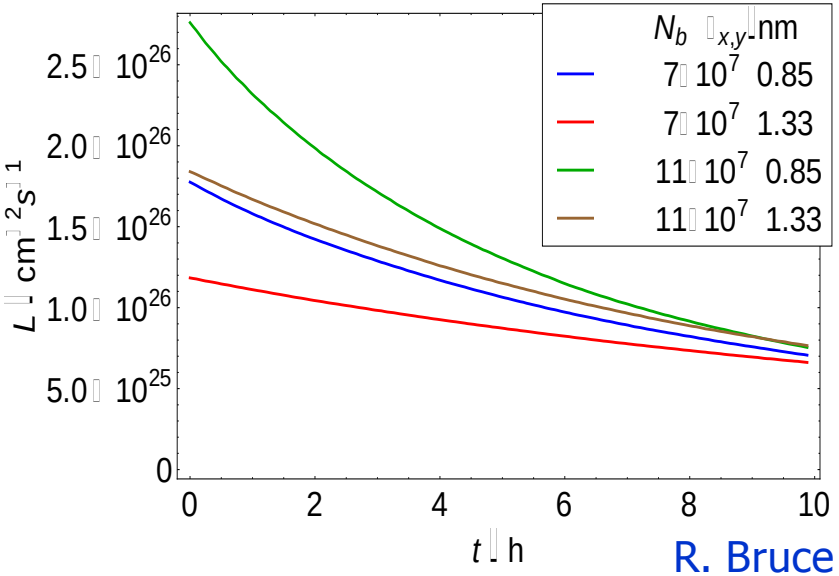
Debunching from IBS



Luminosity burn-off



Emittance



R. Bruce

Realistic choice between blue (Nominal) and brown (Intermediate) filling cases. Blow-up may be worse than this.

Tentative 200 ns scheme, 24 bunch batch

200ns_360b_192_264_0_24bpi15inj_IONS			
B1		B2	
BUCKET	BUNCHES	BUCKET	BUNCHES
1	24	1	24
2211	24	2211	24
4421	24	4421	24
6631	24	6631	24
8841	24	8911	24
11051	24	11121	24
13261	24	13331	24
15471	24	15541	24
17681	24	17751	24
19891	24	19961	24
22101	24	22171	24
24311	24	24381	24
26591	24	26591	24
28801	24	28801	24
31011	24	31011	24

Long SPS injection plateau

Non-colliding bunches for each experiment
264 collisions in ALICE,
192 collisions in ATLAS, CMS

M. Solfaroli-Camilocci

Tentative 200 ns scheme, 12 bunch batch

200ns_301b_169_216_0_12bpi25inj_IONS			
B1		B2	
BUCKET	BUNCHES	BUCKET	BUNCHES
1	1	501	1
871	12	871	12
2121	12	2121	12
3371	12	3371	12
4621	12	4621	12
5871	12	5871	12
7121	12	7121	12
8371	12	8371	12
8911	12	9781	12
10161	12	11031	12
11411	12	12281	12
12661	12	13531	12
13911	12	14781	12
15161	12	16031	12
16411	12	17281	12
17821	12	18531	12
19071	12	19781	12
20321	12	21031	12
21571	12	22281	12
23531	12	23531	12
24781	12	24781	12
26031	12	26031	12
27281	12	27281	12
28531	12	28531	12
29781	12	29781	12
31031	12	31031	12

Shorter SPS injection plateau
Non-colliding bunches for each experiment.

No bunch in Beam2 bucket 1 (?)

301 bunches
216 collisions in ALICE,
169 collisions in ATLAS, CMS

M. Solfaroli-Camilocci

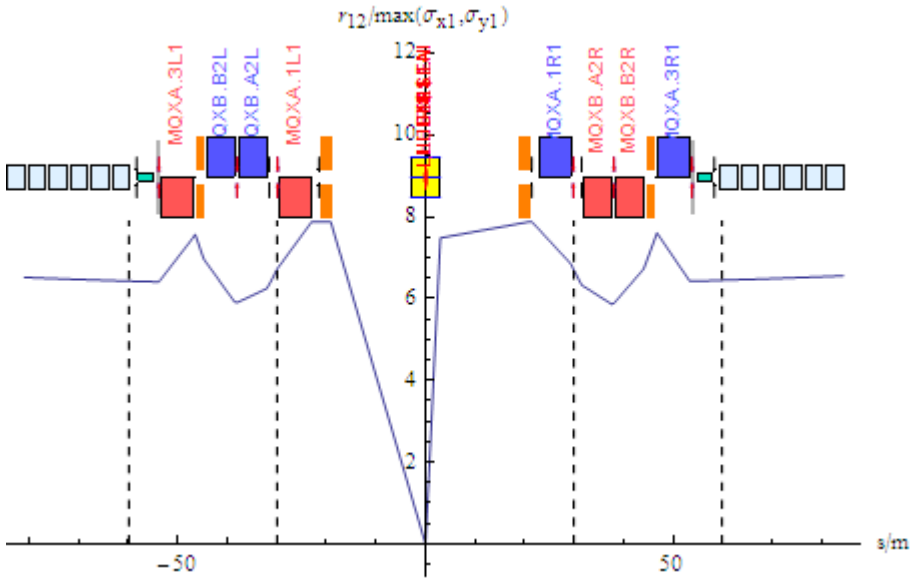
Remaining uncertainties in filling scheme

- Long injection plateau in SPS may cause blow-up and/or intensity loss
  - Could force us to shorten injected batches from SPS, reducing number of bunches in LHC and increasing filling time
    - (Also potential problem for Nominal)
  - Should be resolved in MD 29 September 2011
- Satellite population ?
  - Shorter injection and less "hump": we can hope for somewhat less than in 2010, to be verified during setup
- ATLAS does not need bunch in bucket 1 (new …)
  - Scope to optimise distribution of collisions ? CMS?
- Possible schemes (C. Carli) with alternating spacing between adjacent pairs within batches,
  - Eg (150,200)ns, (150,225)=(2×75,3×75)ns
  - Worth considering for 10-20% more luminosity ?

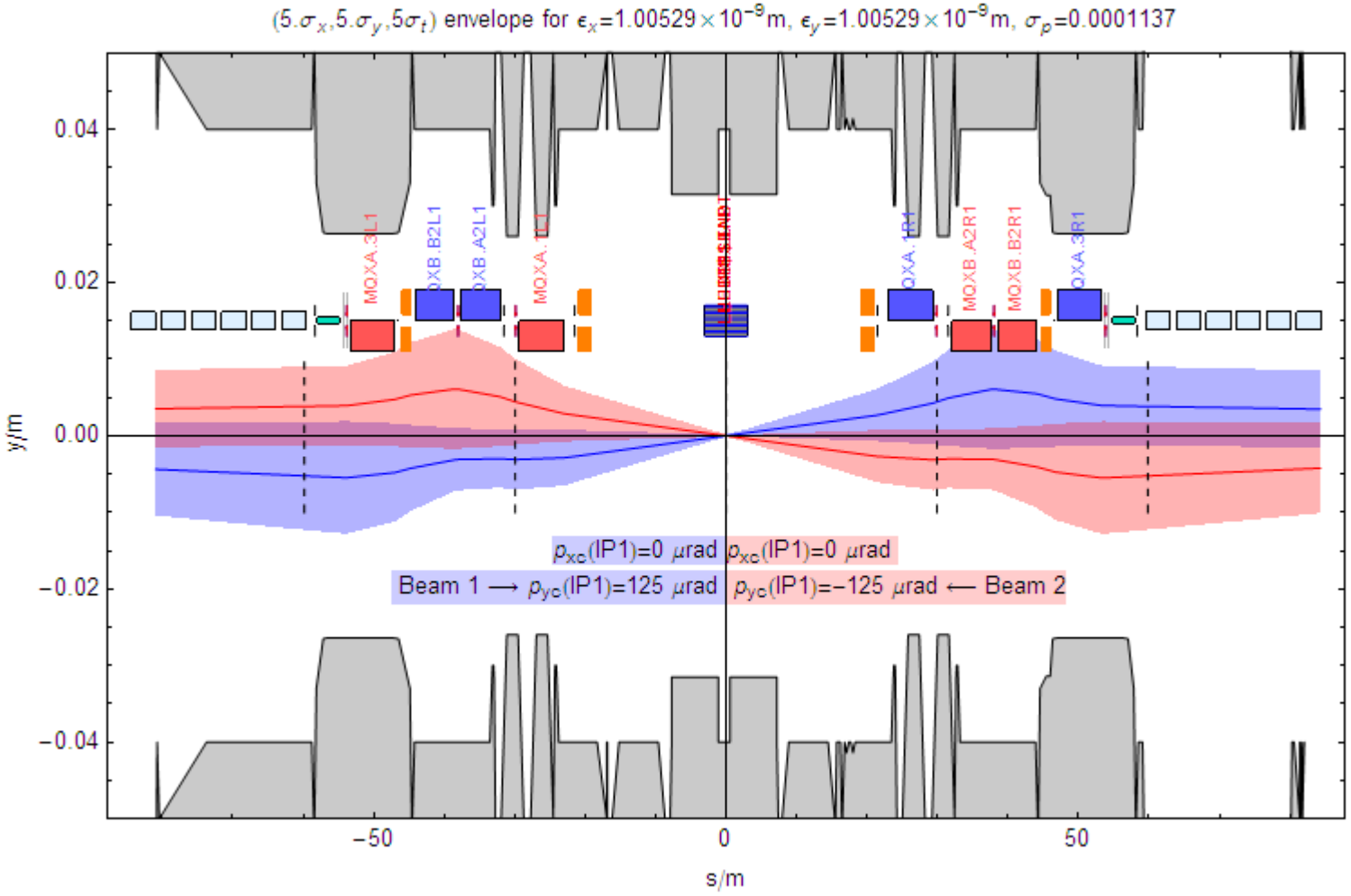
ATLAS and CMS

- Zero crossing angle impossible (unless we go back to 2010 filling scheme, 500 ns,137 bunches)
- Low-β optics already commissioned for p-p
- Proposal: use same crossing angles as p-p
  - Already commissioned, saves time
  - Caveat: beam sizes may be larger with Pb

$\beta^* = 1$ m should be OK



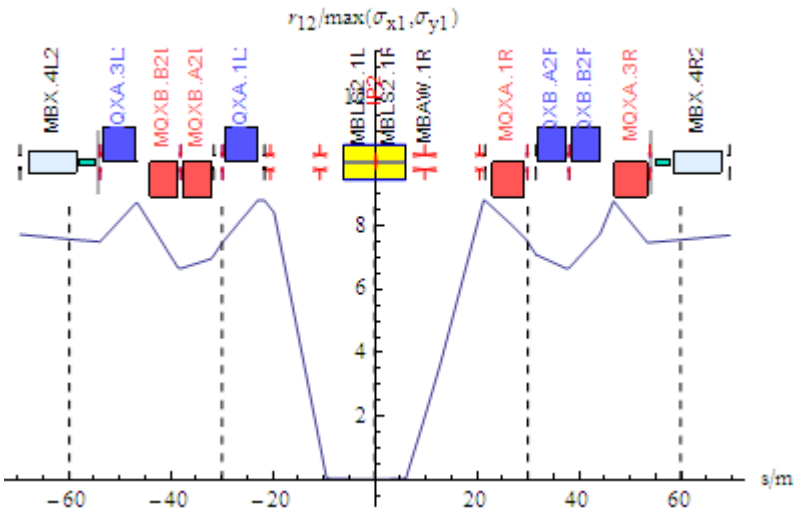
Vertical beam envelopes in ATLAS



Works for p-p, might be difficult to reduce it.
Acceptable to ATLAS? CMS similar ?

ALICE

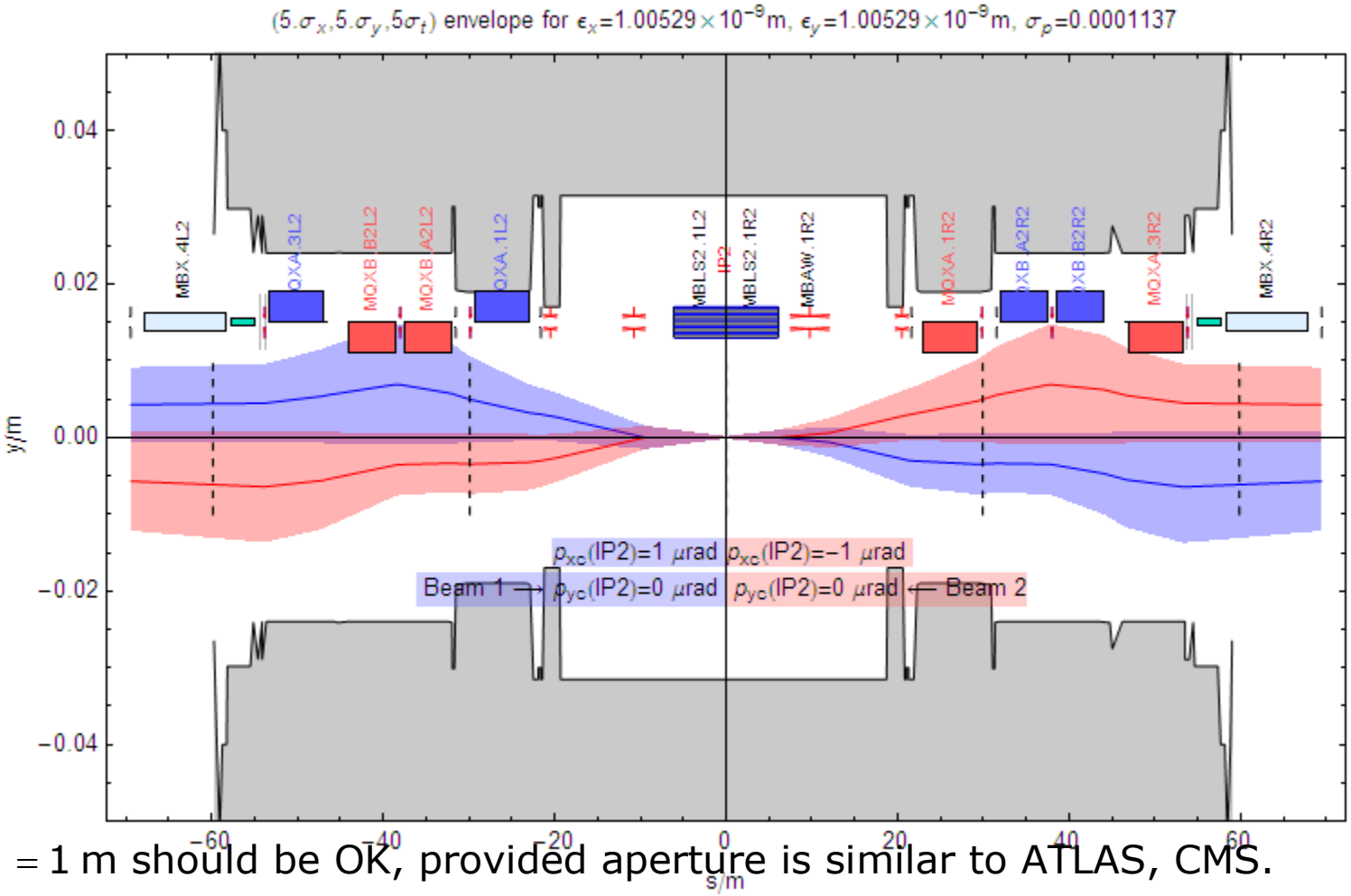
- Polarity change during run (?)
- Try to have zero crossing angle
- TCTVs, machine protection issues
  - Not formally approved
- Larger *external* crossing angle to compensate spectrometer



Assuming spectrometer at full field,
the half-crossing angle is:

$$p_{yc}(\text{IP2}) = \frac{490\ \mu\text{rad}}{E\ /\ (Z\ \text{TeV})} + p_{yext} = 140\mu\text{rad} + p_{yext}$$

Vertical beam envelopes in ALICE



$\beta^* = 1$ m should be OK, provided aperture is similar to ATLAS, CMS.

Will measure during squeeze setup.

Fall-back to 20 μrad would be closer.

Caveat: Pb beams tend to be large than p.

ZDC shadowing constraints

Collimator	Max full gap (mm)	Distance from IP (mm)	Half angle of shadow free region (uRad)	ZDC acceptance half angle (uRad)	Resulting max crossing angle (uRad)
TDI	110	83533	658.4	307	351.4
TCDD	84	71728	585.5	307	278.5
TCTVB	56	74488	375.9	307	68.9
TCLIA	56	76508	366.0	307	59.0
	Minimum needed full gap (mm)				
TDI	63	83533	377.1	307	70.1
TCDD	54	71728	376.4	307	69.4

W. Riegler

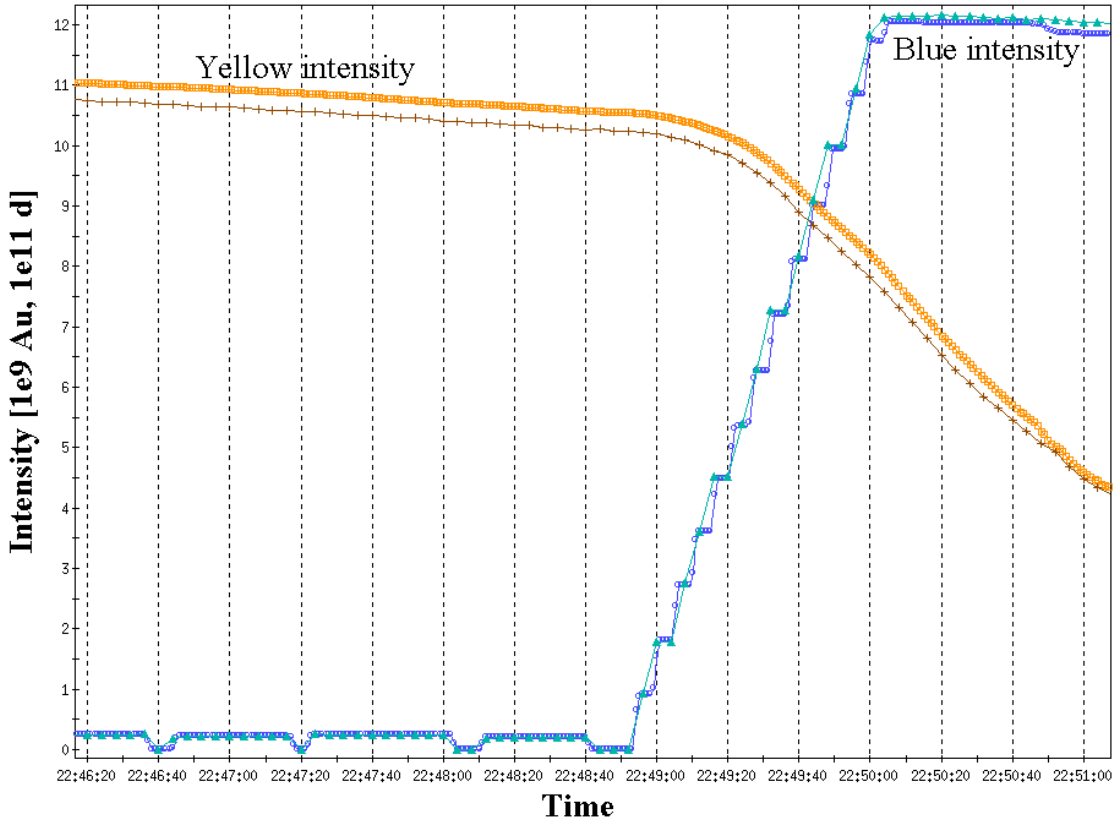
Source refill

- Average 30 h
- At end of technical stop before run
- Again about 2 weeks later (after putting in a good fill … OR in shadow of any other down time that occurs)

Proton-lead feasibility study

- Remarks:
  - This is a new way to operate LHC, very little previous experience in other hadron colliders
  - We do not know if it will work!
    - Could be strongly limited in intensity/luminosity
    - No resources for study (will change on 15/10/2011)
    - Latest discussion at CERN Machine Advisory Committee
      https://indico.cern.ch/contributionDisplay.py?contribId=12&confId=149070
- Aims:
  - Inject and ramp with unequal RF frequencies
- Possible bonus, *if all goes extremely well*:
  - Re-phase RF to collide beams at proper IPs and make a few collisions

RHIC Example – beam lifetimes with $(B\rho)_d = (B\rho)_{Au}$ 2003



beam-beam effect during injection, d and Au with same rigidity, $\Delta f_{rf} = 44$ kHz, vertical separation=10mm

[W. Fischer, et al., "Observation of Coherent Beam-Beam Modes in RHIC", BNL C-A/AP/75 (2002)]

p-Pb filling

- Beam 1: 100 ns proton beam, ~10^{10} p/bunch
  - Should be something close to Nominal Pb scheme
- Beam 2: start with a few (probably 2) Pb bunches for MP reasons
  - If we succeed in ramping and manually re-phasing the RF, this could give 1 (or 0) collision/turn in each experiment
  - More than this is unlikely but not impossible
  - Need to clarify conditions for declaring Stable Beams

$L \approx 10^{23}$ cm^{-2}s^{-1}

$\sigma \approx 1.8$ barn (Barashenkov formula, Chamonix 2004)

$\approx 10^{3}$ events/h ?

Commissioning and run schedule

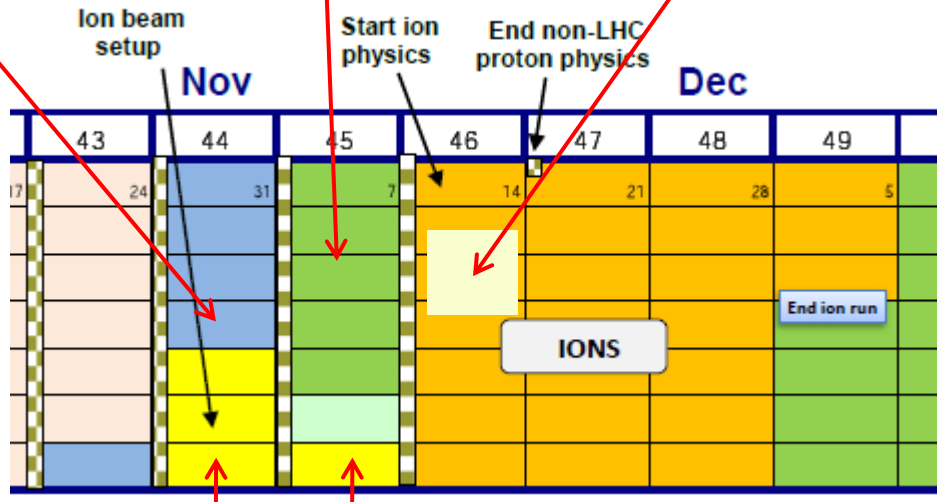
- Cannot be a copy-paste of 2010
  - Must commission ALICE squeeze
  - Interruption by Technical Stop
    - Delays not impossible …
  - Commissioning and p-Pb feasibility test are interleaved of necessity (beam availability)
  - Need to schedule collimation quench limit measurement
  - Start with 2 bunches/beam, move quickly to full scheme
  - Detailed schedule will appear on Web as 2010

Schedule in 2011

Set up p beam, Pb injection, test injection of Pb on p (2 shifts designated MD)

Time to think … review p-Pb

Test ramp of p-Pb, while p still available from injectors, possible collisions



Use of physics time for MD will of course be minimised, but this is a very tight schedule.

Set up ALICE squeeze with protons, then Pb beam, ramp, squeeze, crossing angles, collimation in two instalments

Technical Stop
Recommisssoning with beam
Machine development
Ion run
Ion setup
Injectors - proton physics
Special runs (TOTEM etc.) to be s

Collimation quench limit with Pb beams

- Strong recommendation from Collimation Review
  - Vital to know Pb intensity limit after 2014 to evaluate need for DS collimator upgrade
  - Measurement done for p, not yet for Pb
- About 12 h but … it could induce a real quench this time
  - Optimum time, 6/11/2011 just before Technical Stop, minimise lost physics time
  - Otherwise later, during physics time
  - Can risk of doing it on the last day?
    - Less risk of lost physics for quench recovery
    - More risk that we never know …

BACKUP SLIDES