Session 9 : What will we do with beam in 2009/10 ?

What would we like to do ?	
Experiments desiderata	M. Ferro-Luzzi
Protons in LHC	W. Herr
Ions in LHC	J. Jowett
Are we ready to do it ?	
Beams in the injectors	E. Metral
Commissioning plan	S. Redaelli
Organization	G. Arduini

450 GeV running

Is it useful ?

- Yes! Contrary to a year ago: Experiments request a 900 GeV runlet
- All Experiments wish to make use of 2 or 3 shifts of stable colliding beams, still in the noise of the beam commissioning schedule

When ?

- As soon as possible
- Solenoids on
- No need to wait for high intensities
  - happy with $k_b = 2$, β^* = injection value, $N = \sim 9\times10^{10}$

for info: about 10^{28}cm^{-2} s^{-1}
$\times10^5$ s = ~ 1 nb^{-1}
(~5×10^7 inelastic interactions)

Why ?

- Mainly: time alignment, space alignment
- Also: physics cross check (a few basic distributions, cross section)

if luminosity measured
(fast separation scan?)

Discovery channels for General Purpose Detectors

- **With 50-100 pb^{-1} <u>good data</u> at 10-8 TeV $\Rightarrow$ many new limits set on hypothetical particles (some more stringent than Tevatron), or even discoveries possible!**

- **With 200-300 pb^{-1} <u>good data</u> at 10-8 TeV $\Rightarrow$ start competing with Tevatron for Higgs masses around 160 GeV**

- **With 1 fb^{-1} <u>good data</u> at 10 TeV $\Rightarrow$ find Higgs if around 160 GeV**

- **The higher the energy, the faster it goes...**

- **Note: below ~20-40 pb^{-1} at 10-8 TeV, or at any lower energy, one would probably start talking about an "engineering run"**

  (can still be very useful, but perhaps not in terms of immediate physics results)

Non GPD

- LHCb
  - B cross section does not vary as drastically as for high mass objects. Thus, the request to go to highest possible energy is milder
  - Need 0.3-0.5 fb^{-1} at $s^{1/2} \geq 8$ TeV to surpass Tevatron in B physics
  - Need at least 5 pb^{-1} at $s^{1/2} \geq 4$ TeV to collect good sample of J/psi

- ALICE with *pp*
  - Not as strongly interested as GPDs in reaching the highest possible energy for *pp*
  - What about $s^{1/2} = 5.5$ TeV ? (the *NN* equivalent in PbPb@14TeV)
    - not so crucial at this stage, but yes, would request to choose E=2.75 TeV if a beam energy between 2 and 3 TeV was being considered
  - Will collect data at ~10^{29} cm^{-2} s^{-1} (opt) or 3×10^{30} cm^{-2} s^{-1} (max)
  - Runs with smallest possible β^* (while remaining at desired luminosity, and with full B_{spectr})
  - Particularly interested in “symmetric shift” filling schemes and in 50ns (as opposed to 25ns)

TOTEM and LHCf

- TOTEM (IP5)
  - T1, T2, all RP220 and some RP147 will be ready
  - TOTEM will operate under all running conditions
  - Early optics ($\beta^* = 3$ m): large |t| elastic scattering, central diffraction
  - As soon as technically feasible: request $\beta^* = 90$ m optics (or a gradual unsqueezing from $\beta^* = 3$ m to higher values)

- LHCf (IP1)
  - Lumi limitation: degradation of non rad-hard components after few pb^{-1} in data taking position
    - move out by 10 cm when $L>10^{30}$ cm^{-2} s^{-1}
    - dismount & remove detector when $L>10^{3?}$ cm^{-2} s^{-1}
  - Preferred operating conditions:
    - 2x2 and 43x43, $L= 10^{29}$ cm^{-2} s^{-1} , crossing angle 0 and 140 urad (enhanced acceptance)
    - 156x156 introduce pile-up (2us electronics)

LHC performance

$$L = \frac{N^2 k_b f \gamma}{4\pi \varepsilon_n \beta^*} F$$

$$Eventrate/Cross = \frac{L\sigma_{TOT}}{k_b f}$$

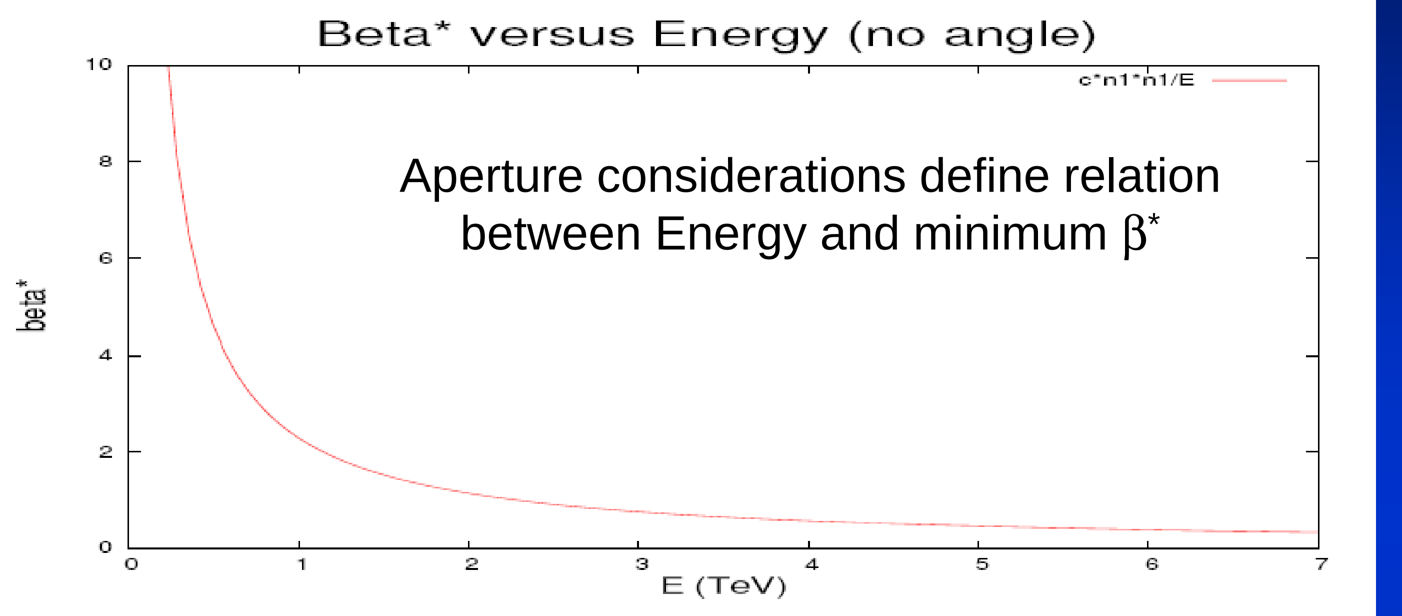
Key parameters are γ N k_b β^* and they are strongly correlated

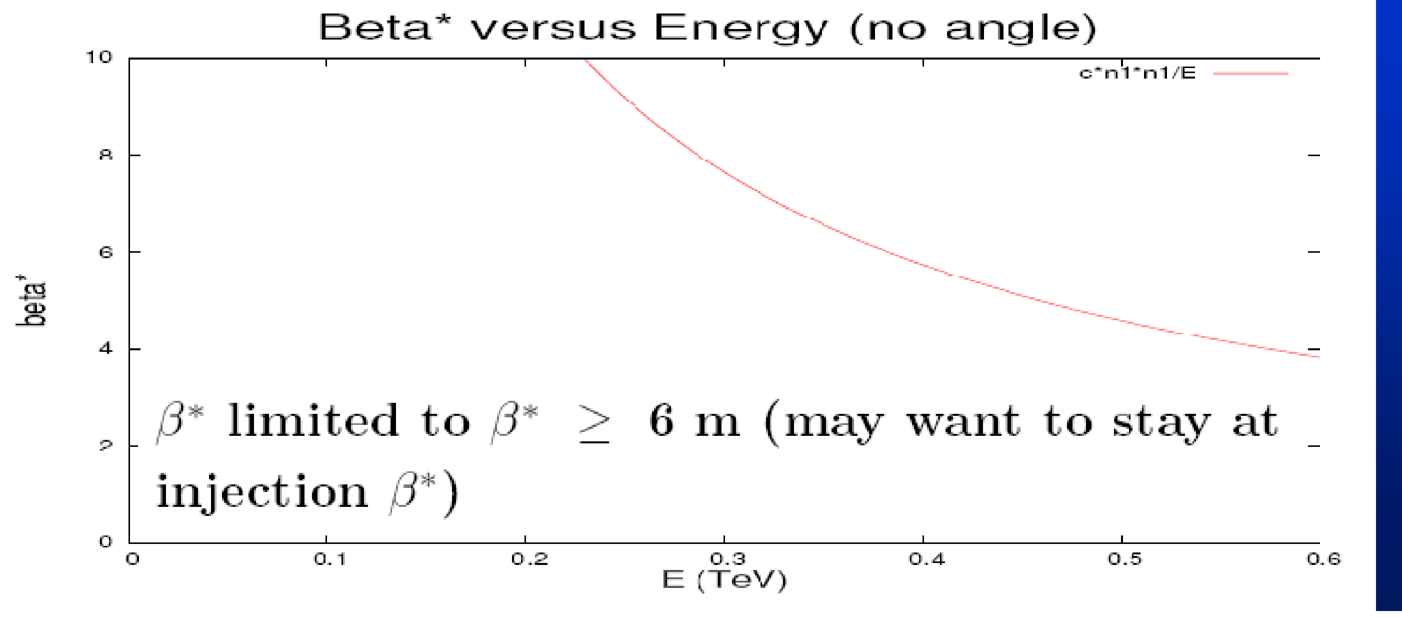
γ	Energy not a free choice but has consequences for F N β^*
N	Number of bunches has consequences for F β^* and machine protection
k_b	Bunch intensity has consequences for beam-beam and pileup
β^*	Has consequences for N F and aperture

Smaller emittances ? Could be problems

$$\Delta Q \propto \xi = \frac{N \cdot r_o \cdot \beta^*}{4\pi\gamma\sigma^2} = \frac{N \cdot r_o}{4\pi\epsilon_n}$$

Energy and β^*





43 and 156 bunch schemes (no crossing angle)

43 bunch operation

displaced	0	4	11	19
IP1	43	43	43	43
IP2	42	34	21	4
IP5	43	43	43	43
IP8	0	4	11	19

156 bunch operation

	no bunches displaced	option 1	option 2
IP1	156	156	156
IP2	152	76	16
IP5	156	156	156
IP8	0	36	68

Assuming N $= 0.4\ 10^{11}$, $\epsilon_n = 3.75\ \mu$m

Energy (TeV)	β^* (m)	$\mathcal{L}_{43}$ ($cm^{-2}s^{-1}$)	$\mathcal{L}_{156}$ ($cm^{-2}s^{-1}$)
0.45	6	$0.13 \cdot 10^{30}$	$0.47 \cdot 10^{30}$
2.75	1	$4.30 \cdot 10^{30}$	$15.6 \cdot 10^{30}$
5.00	0.6	$13.0 \cdot 10^{30}$	$47.0 \cdot 10^{30}$

All compatible with aperture, consider as limit

Multibunch operation (crossing angle)

Requires crossing angle α to avoid parasitic interactions

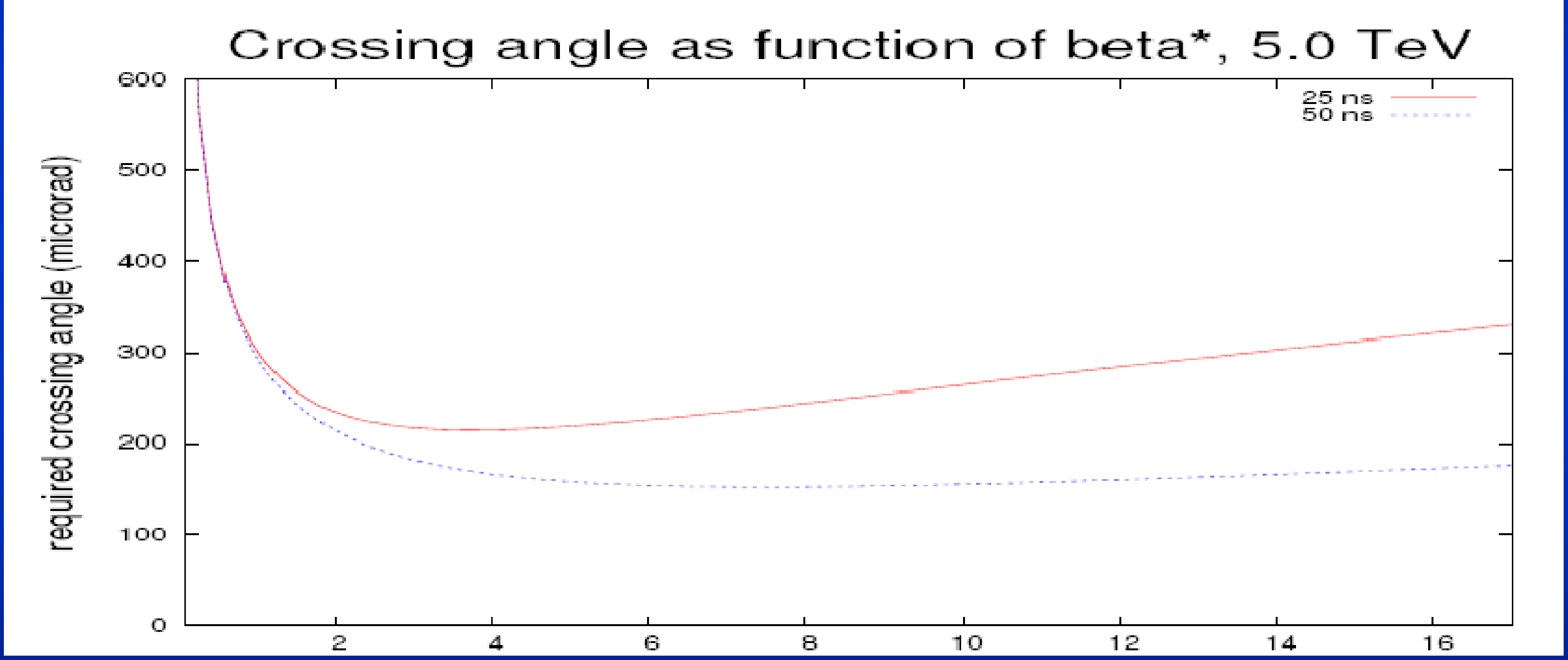
Bunch spacing	Δs	# long range encounters (per IP)
25 ns	3.75 m	32
50 ns	7.50 m	16
75 ns	11.25 m	12

Spacing	IP1	IP2	IP5	IP8
25 ns	2808	2736	2808	2622
50 ns	1404	1368	1404	0
75 ns	936	912	936	874

	a	b	c	d	e
IP1	1404	1404	1404	1404	1333
IP2	1368	684	0	72	2
IP5	1404	1404	1404	1404	1333
IP8	0	655	1311	1242	1173

Crossing angle

$$\alpha = \frac{d_{sep} \cdot \sqrt{\frac{\epsilon_n}{\gamma}}}{\sqrt{\beta^*}}$$



Operation with β^* between 1 m and 4 m very promising

Multibunch operation

Assume 0.5 10^{11} per bunch, and crossing angle ≈ 300 μrad

Luminosity (in IP1 and IP5) in units of 10^{32} $cm^{-2}s^{-1}$

Energy (TeV)	β^* (m)	$\mathcal{L}_{936}$ ($cm^{-2}s^{-1}$)	$\mathcal{L}_{1404}$ ($cm^{-2}s^{-1}$)	$\mathcal{L}_{2808}$ ($cm^{-2}s^{-1}$)
5.0	3.0	0.9	1.4	2.8
5.0	2.0	1.4	2.1	4.2
5.0	1.0	2.6	4.0	8.0
7.0	3.0	1.3	2.00	4.0
7.0	2.0	2.0	3.00	6.0
7.0	1.0	4.0	6.00	12.0

Delivered luminosities

(10^6 seconds @ <L> of 10^{33} cm^{-2} s^{-1} → 1 fb^{-1})

- **Without crossing angle**

Could hit few 10^{31} cm^{-2} s^{-1} say <L> of 10^{31} cm^{-2} s^{-1}

40% efficiency for physics → 10^6 seconds collisions per month

Integrated luminosity per month = 10 pb^{-1}

- **With crossing angle**

Could hit few 10^{32} cm^{-2} s^{-1} say <L> of 10^{32} cm^{-2} s^{-1}

40% efficiency for physics → 10^6 seconds collisions per month

Integrated luminosity per month = 100 pb^{-1}

Heavy Ion Run

- Keep option open
  - Injectors and LHC should be compatible with the possibility of a HI run
  - Note that even 1 day @ early scheme is enough to surpass RHIC

Parameter	Units	Early Beam	Nominal
Energy per nucleon	**TeV**	**2.76**	**2.76**
Initial ion-ion Luminosity L_0	**cm^{-2} s^{-1}**	**~ 5×10^{25}**	**1×10^{27}**
No. bunches, k_b		**62**	**592**
Minimum bunch spacing	**ns**	**1350**	**99.8**
β^*	**m**	**1.0**	**0.5 /0.55**
Number of Pb ions/bunch		$7\ 10^7$	$7\ 10^7$
Transv. norm. RMS emittance	**µm**	**1.5**	**1.5**
Longitudinal emittance	**eV s/charge**	**2.5**	**2.5**
Luminosity half-life (1,2,3 expts.)	**h**	**14, 7.5, 5.5**	**8, 4.5, 3**

Only possibility for 2009 or early 2010

Heavy Ion Run

- Systems checked for readiness
  - RF
  - BI
  - Collimators
  - Vacuum
  - Machine protection
  - Optics (essentially identical magnetic machine)
  - Controls (watch out for hard coded protons)

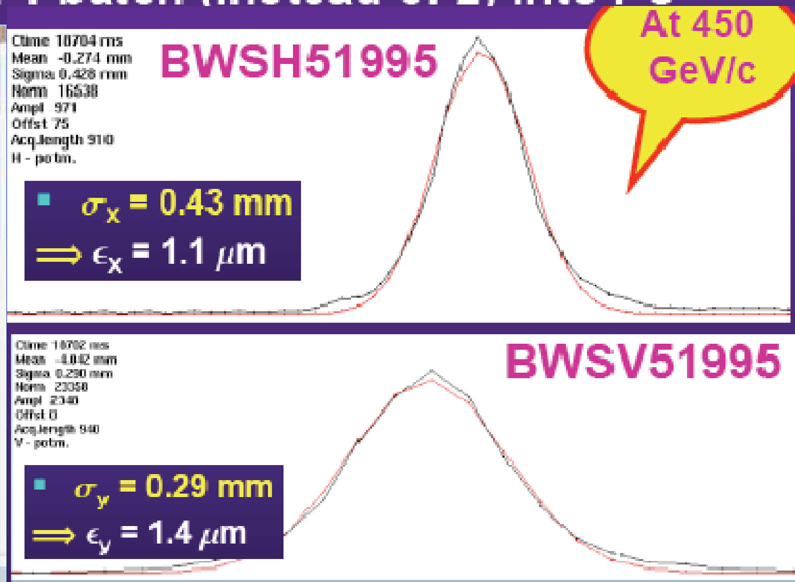
- Hot switch strategy
  - Working LHC with protons
  - Ions available from SPS

Web based procedures being put in place

Stage I	Initial commissioning Early Ion Beam (DRAFT)	Ring factor	Total Time [days]	Comments
I1	Injection and first turn	2	0.25	Magnetically identical to protons; 1 bunch/beam.
I2	Circulating beam	2	0.25	Magnetically identical to protons. Synchronisation of transfer lines and RF capture at -4.7 kHz frequency shift. Check lifetime in particular (IBS?).
I3	450 Z GeV initial commissioning	2	0.25	Beam instrumentation slightly different. Optics OK.
I4	450 Z GeV optics measurements	2	.5	Magnetically identical to protons but do minimal check.
I6	450 Z GeV - two beams	1	.5	>0.4 nominal bunch intensity, otherwise magnetically identical to protons.
I7	Collisions at 450 Z GeV	1	0	Not interesting.
I8	Snapback and ramp	2	0.5	Single and then two beams, Magnetically identical to protons. Check beam dump at various energies.
I9	7 Z TeV flat top checks	2	0.5	Single beam initially, performed following successful ramp
I12	Commission experimental magnets			Included already since done for protons.
I10	Setup for collisions - 7 Z TeV	1	0.5	
	Physics un-squeezed	1	?	Zero crossing angle in ALICE, leave as-is in CMS & ATLAS. LHCb separated.
	TOTAL to first collisions		6	
I11	Commission squeeze	2	2	Commission squeeze of ALICE to same as presently achieved with CMS and ATLAS (with ATLAS and CMS unsqueezed). May have been started with protons. Check separation. Include CMS & ATLAS squeeze depending on time.
I5	Increase intensity	2	1	Increase bunch number to 62 (Early Scheme).
	Set-up physics - partially squeezed.	1	2	
	Pilot physics run			Parasitic measurements during physics (BLMs, ...) of great interest.

Injectors - protons

- PROTONS: news in 2008
  - Rephasing SPS-LHC ➔ Possibility to extract p beams to LHC
  - Low intensity probe beam: 2E9 p/b (instead of 5E9)
  - 25 ns (LHC25) and 75 ns (LHC75) beams with intermediate intensities
  - Controlled transverse emittance blow-up in SPS
  - 2 requests from the LHCCWG held on 13/02/08
    - 1 LHCINDIV + 1 LHCPILOT (at the same time) in SPS
    - 50 ns beam (LHC50)
  - Production of the LHC75(50) in 1 batch (instead of 2) into PS



Injectors - ions

- IONS: news in 2007 and 2008
  - Early beam ➔ SPS commissioning in 2007
  - New 18 GHz source in 2008 (instead of 14.5 GHz)

- **EARLY BEAM**: Several weeks of setting-up and MD time are necessary to make a first LHC ion run possible (~ end of September)

- **NOMINAL BEAM**
  - Only LEIR made some progress in 2007
  - PS HW needs rebuilding, testing, setting up
  - Alternative filling schemes (to minimize IBS and SC) need to be tested in SPS
  - LHC crystal collimation studies ➔ Many MDs foreseen in 2009

- *No ions in rings since November 2007 ➔ Recommissioning needed (controls, RF, power supplies, etc.)*

Commissioning – 2008 experience – 3 days of beam

Beam 1

Beam 2

First turn (A.1)

- *Commissioning of the last 100 m of the transfer line and the injection*
- *First commissioning of key beam instrumentation*
- *Commissioning of the trajectory acquisition and correction*
- *Threading the beam around the two rings (first turn)*
- *Closing the orbit*

Circulating beam (A.2)

- *Establishing closed orbit*
- *Commissioning of additional instrumentation: BPM intensity acquisition*
- *Preliminary orbit, tune, coupling and chromaticity adjustments*
- *Obtaining circulating beam (few thousand turns)*
- *SPS-LHC energy matching*
- *Commissioning of RF capture*

Initial commissioning at 450 GeV (A.3)

- *Commissioning of beam instrumentation*
- *Improving lifetime*
- *Rough optics checks*
- *Initial commissioning of beam dumping system*

Detailed measurements at 450 GeV (A.4)

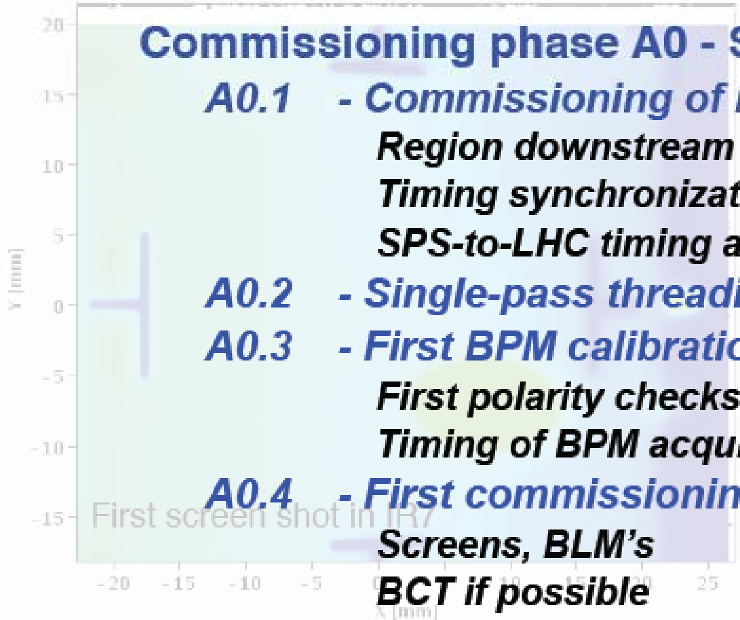
.... Beta-beat measurements; initial commissioning of beam dump, ...

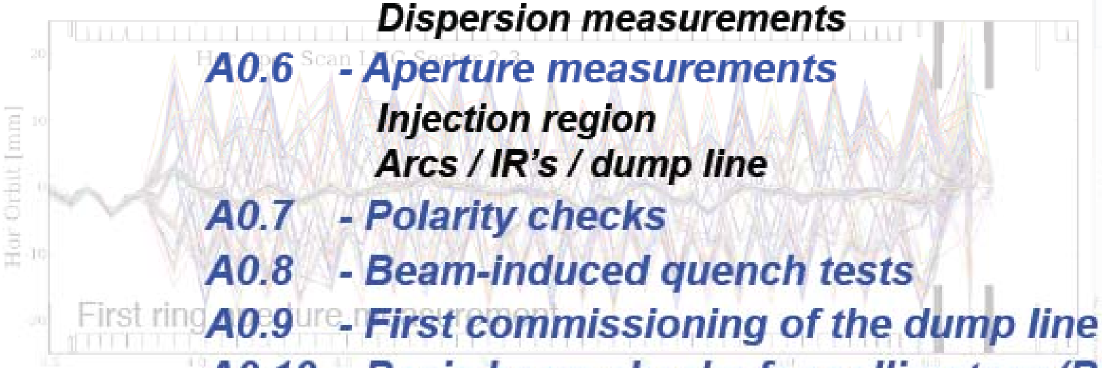
Commissioning – 2008 experience – sector tests

Commissioning phase A0 - Sector tests

- ***A0.1 - Commissioning of injection region***
  - *Region downstream of TED with TDI closed*
  - *Timing synchronization of MKI*
  - *SPS-to-LHC timing aspects*
- ***A0.2 - Single-pass threading in the LHC***
- ***A0.3 - First BPM calibration and optics response matrices***
  - *First polarity checks of BPM's and COD's*
  - *Timing of BPM acquisitions*
- ***A0.4 - First commissioning of additional BI***
  - *Screens, BLM's*
  - *BCT if possible*
- ***A0.5 - SPS/LHC energy synchronization (LHC master)***
  - *Dispersion measurements*
- ***A0.6 - Aperture measurements***
  - *Injection region*
  - *Arcs / IR's / dump line*
- ***A0.7 - Polarity checks***
- ***A0.8 - Beam-induced quench tests***
- ***A0.9 - First commissioning of the dump line (Beam 2)***
- ***A0.10 - Basic beam checks for collimators (BLM calibr., VAC, temperature, ...)***

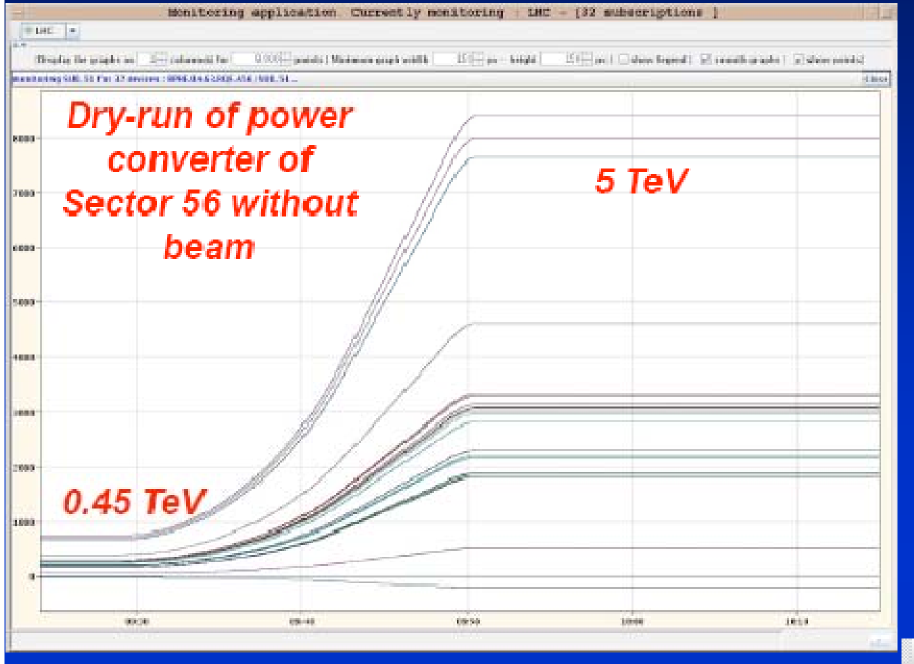
September 10^{th} would have been VERY different without the sector tests. Beam commissioning speeded up!

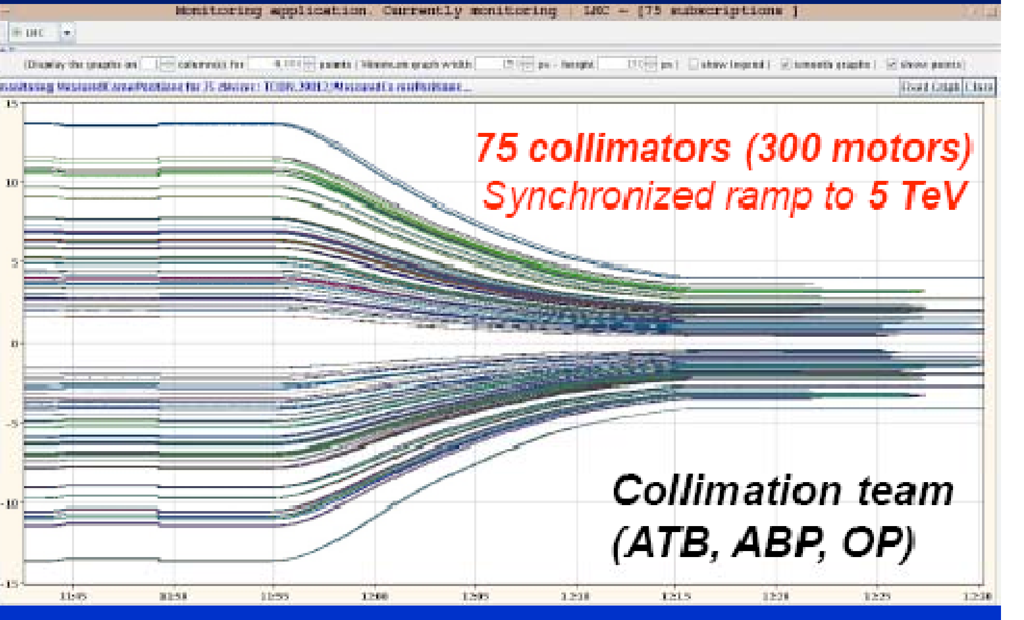


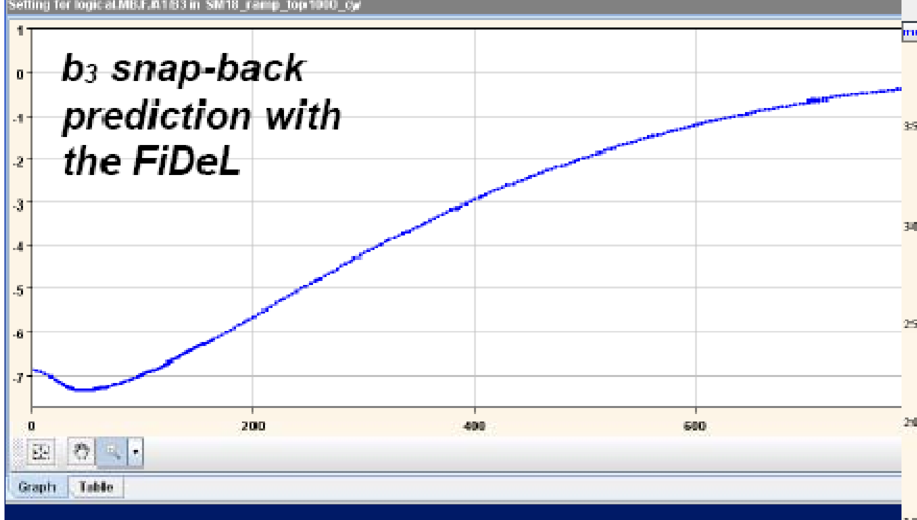


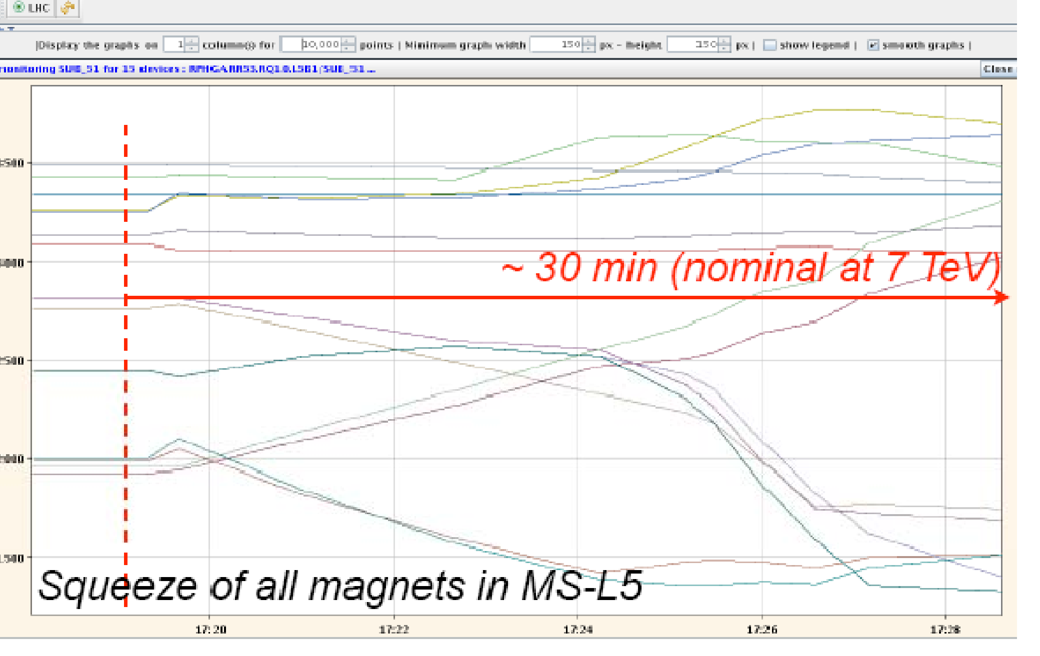
We propose to collect these procedures in a dedicated "A0" phase.

Commissioning – 2008 experience – dry runs









Commissioning – 2009

- **Path to 7 TeV well thought of**

  First version of procedures finalized before 2008 operation

  Used for the (limited) commissioning steps covered by beam operation

  *Need to be updated to match the **new baseline commissioning strategy***

- **We believe that we are ready for the 2009 operation**

  We know - on paper - how to do what we need to do...

  We are more confident than 1 year ago that the tools will be available (dry-tests!)

- **The machine protection procedures have to be systematically built into the existing procedures**

- **We need to know the scenario for 2009+ operation**

  Collision energy, β^*, desired bunch filling scheme, collisions at injection, ...

- **Will start dry-tests as soon as possible to be ready**

  ... then the beam will tell!

Organisation – 2008 experience

- Numerous activities
  - Installation
  - Cool down
  - System integration
  - Dry runs
  - Machine checkout
  - Injection tests
  - Beam commissioning
- It worked
  - Thanks to all concerned
- It was not always easy
  - Interference between activities
  - Sharing of resources
  - Time pressure

} Activities not always done in optimal order

Organisation – 2009

- Lessons can and will be learned
- New things will have to be accommodated
  - Personnel changes
  - Access and powering restrictions
  - Machine protection largely untested
    - single bunch at injection energy in 2008
  - New magnet protection systems
    - have to work, have to allow operation
- Availability of experts
  - Machine protection (definition of safe envelope)
  - Magnet protection
    - On shift or on call ?
- Commissioning team should be involved early on
  - \+ Plenty to do before beam
  - – Same people in the CCC for a year