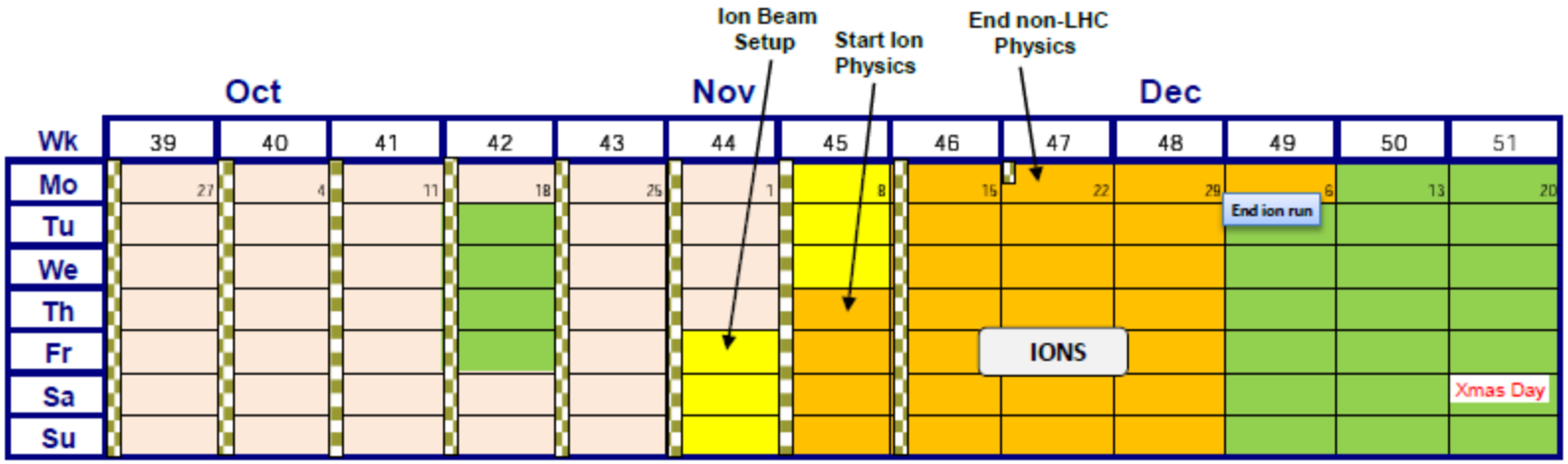
Preparation for ions in the LHC



From discussions with and with contributions from :

J Jowett, S Redaelli, M Solfaroli, W Venturini

Beam parameters

		Early++ (2010/11)	Nominal
$\sqrt{s_{NN}}$ (per colliding nucleon pair)	TeV	2.76	5.5
Number of bunches		60→128 (124,112 coll.)	592
Bunch spacing	ns	1350	99.8
β^*	m	3.5	0.5
Pb ions/bunch		7×10^7	7×10^7
Transverse norm. emittance	μm	1.5	1.5
Initial Luminosity (L_0)	$cm^{-2}s^{-1}$	(0.7→ 1.26) 10^{25}	10^{27}
Stored energy (W)	MJ	0.2→ 0.4	3.8
Luminosity half life (1,2,3 expts.)	h	τ_{IBS}=7-30	8, 4.5, 3

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Initial settings

First setup with 2 bunches/beam : still safe beam @3.5TeV
Nominal filling scheme still being finalised. Factor of **2.5 SBF reduction** agreed upon.

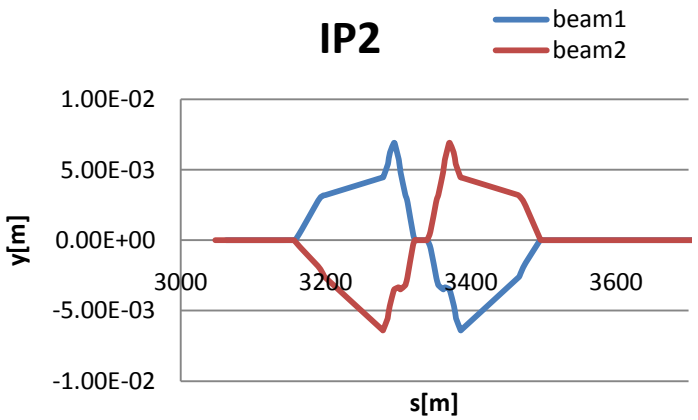
• Ramp and Squeeze functions are ready in a dedicated Hypercycle (**EARLY-IONS_3.5TeV**)

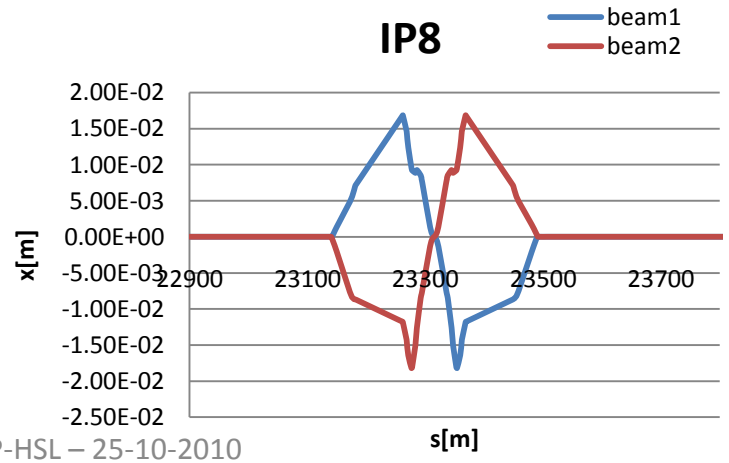
• Most settings to be kept identical to protons except for: RF, X-ings and collimation.

• Xing angle settings to be maintained as for protons through injection, ramp and squeeze. Change to ion settings at the end of the squeeze.

<u>IP setttings for IONS:</u>

- LHCb, ALICE spectrometers ON (on_lhcb=on_alice=2)
- 0 μrad for IP1/IP5. 140 μrad for IP2, 100μrad for IP8





Orbit checks

- Cross calibration of orbit reading with protons:
    1. Inject high intensity p bunch (LOW BPM sensitivity)
    2. Correct against reference orbit
    3. Inject low intensity p bunch and record orbit (HIGH BPM sensitivity)
    4. Inject an Ion bunch and check that orbit is the same
    5. Define it as Ions reference orbit

- Test ramp with safe ion beam (2bunches), collimators at injection settings and OFB on to establish reference orbit up to high energy

- During squeeze use same orbit reference as for protons and measure the optics

Venturini/Solfaroli, - LHC BBCWG 12/10/2010

Collimation settings

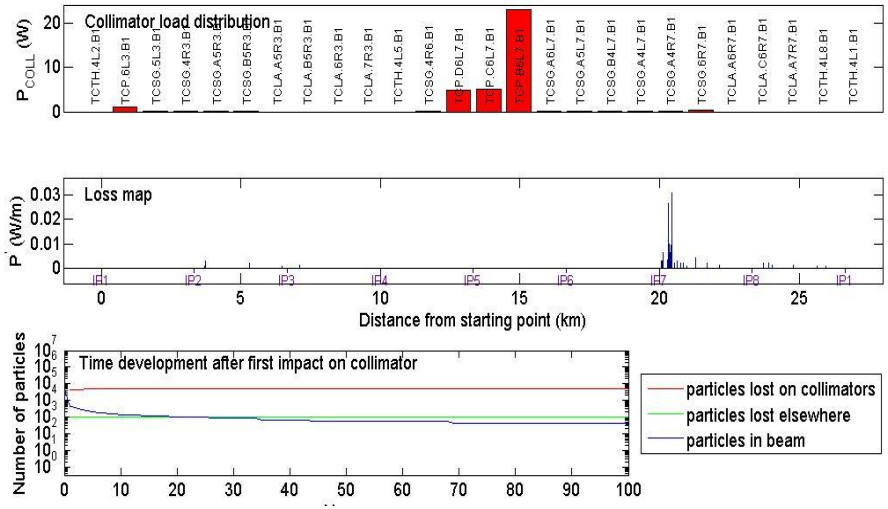
1. Ramp with the same collimator settings as for p until the end of the squeeze, then

2. change X-ing angles at IPs and set up TCTs around new collision orbit
   - Only one collimator setup at top energy
   - Shadowing of ALICE ZDCs : TCTVBs at 23 mm (up from 11/15mm)

3. Loss maps to be taken at 3 critical points (both IR3 and IR7), 3-4 fills:
   - injection,
   - end of squeeze
   - collision

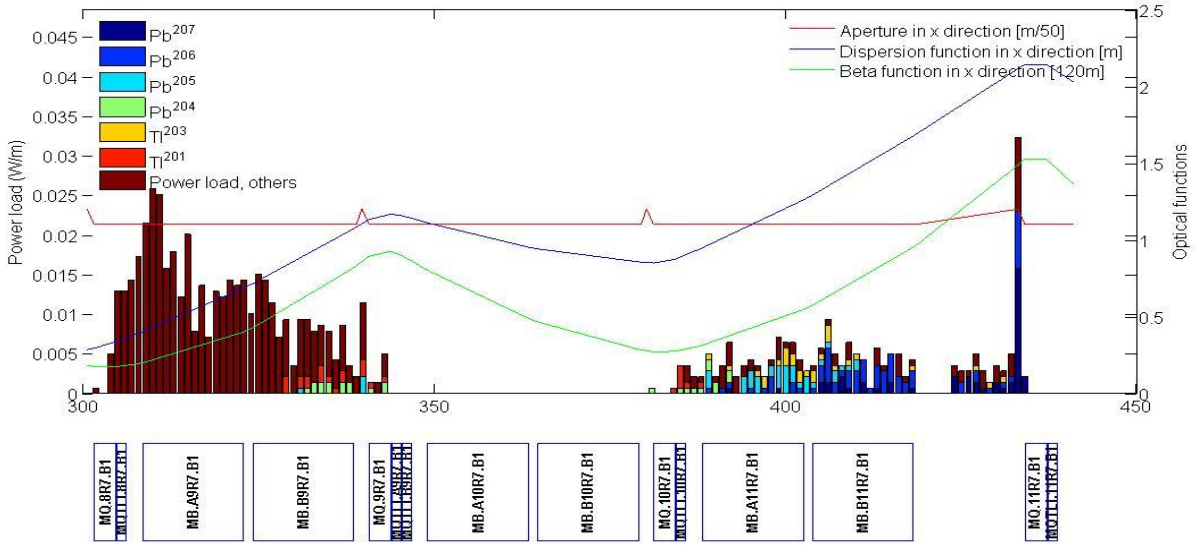
Loss maps: injection, beam1, IR7

62 bunches, 12min lifetime



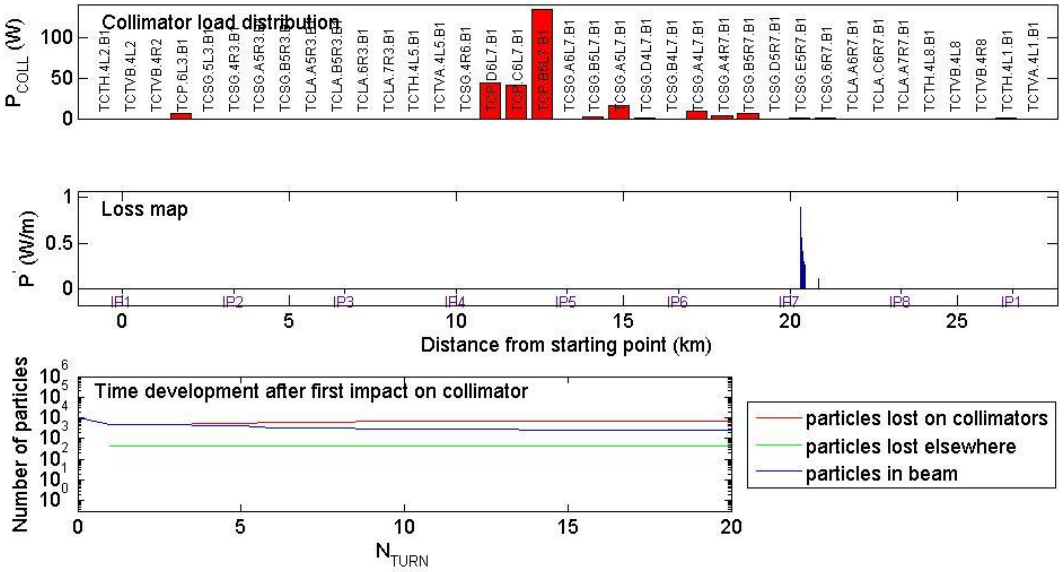
TCP IR7	5.7 σ	TCP IR3	8 σ
TCSG IR7	6.7 σ	TCSG IR3	9.3 σ
TCLA IR7	10 σ	TCLA IR3	10 σ
		TCTs	15/25 σ

Aperture losses < 0.04 W/m



Loss maps collision: β*=3.5m

62 bunches, 12min lifetime



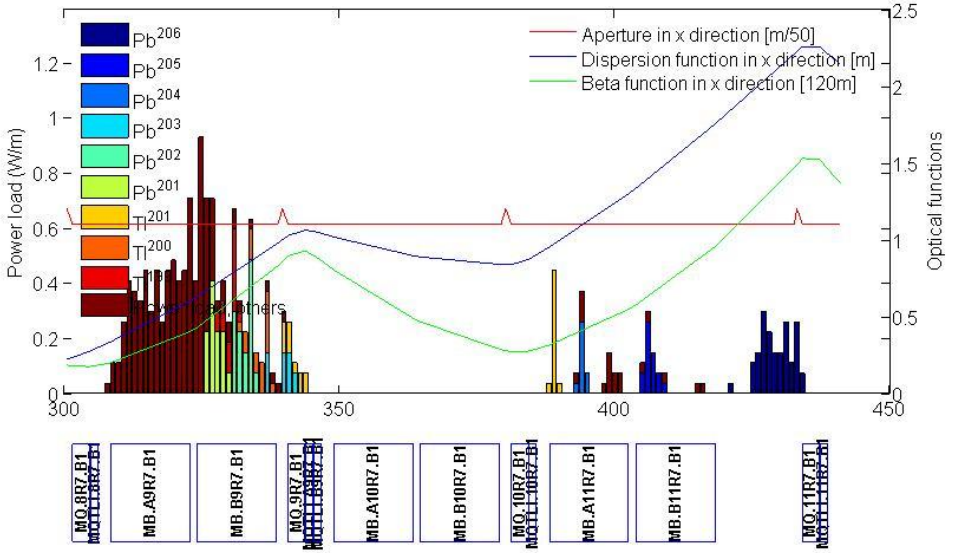
Beam1, IR7

Aperture losses <1 W/m

Σ aperture hits/Σ collimator hits= η= 0.065

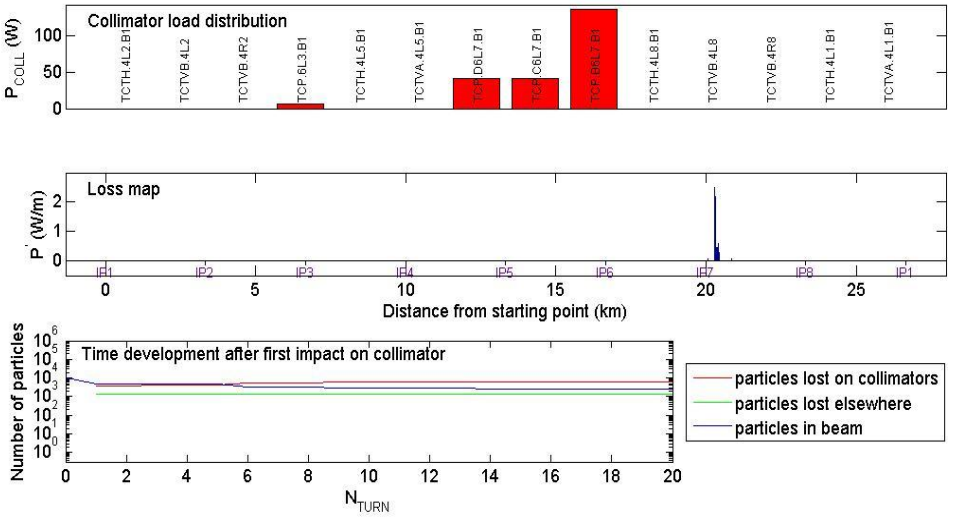
p collision settings

TCP IR7	5.7 σ	TCP IR3	12 σ
TCSG IR7	8.5 σ	TCSG IR3	15.6σ
TCLA IR7	17.7 σ	TCLA IR3	17.6 σ
		TCTs	15 σ



Loss maps collision: β*=3.5m

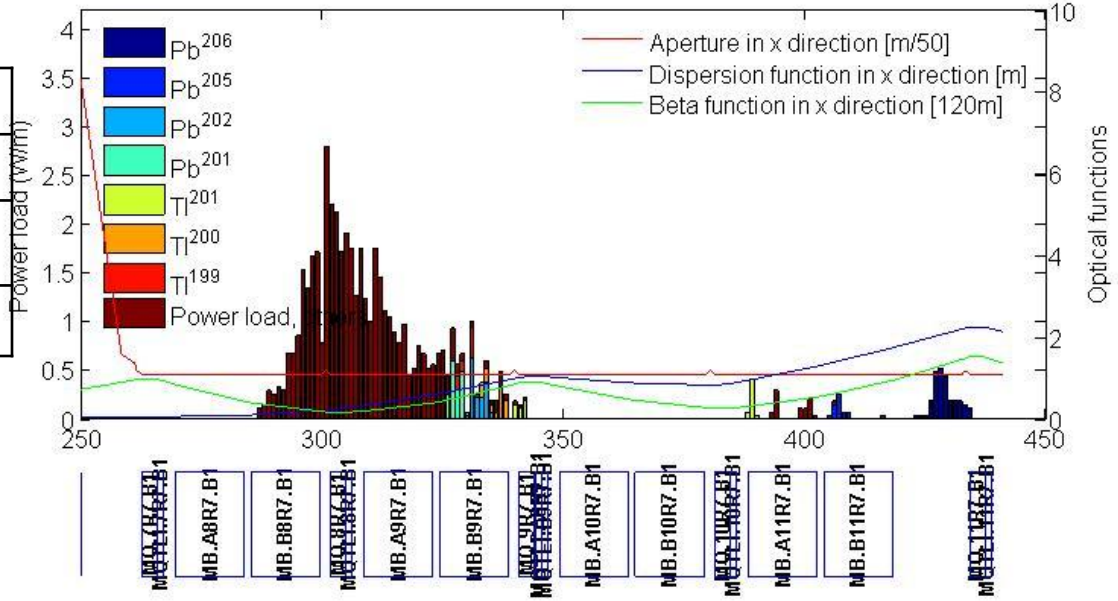
62 bunches, 12min lifetime



Beam1, IR7
TCPs and TCTs only
TCS, TCLA open

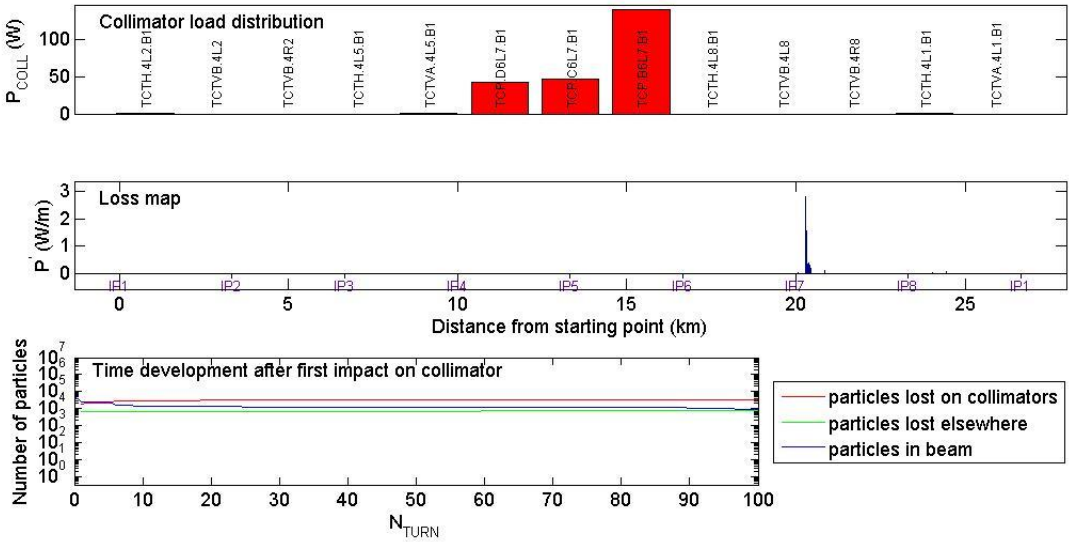
Σ aperture hits/Σ collimator hits=
η= 0.235

TCP IR7	5.7 σ	TCP IR3	12 σ
TCSG IR7	open	TCSG IR3	open
TCLA IR7	open	TCLA IR3	open
		TCTs	15 σ



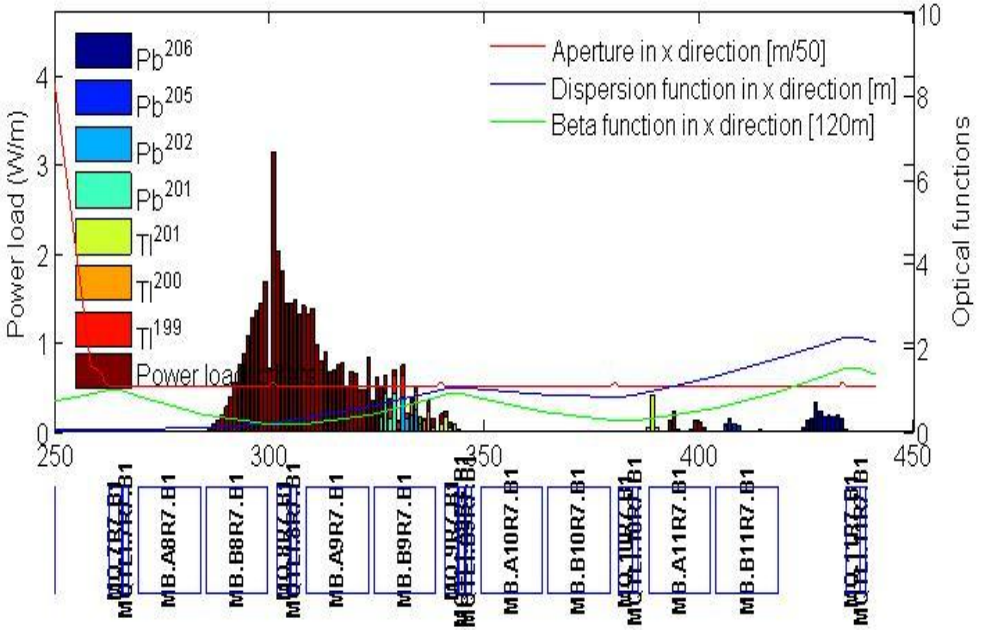
Loss maps: collision, β*=3.5m

62 bunches, 12min lifetime



Beam1, IR7
TCPs and TCTs only,
TCTVBs at 50σ
TCS, TCLA open

TCP IR7	5.7 σ	TCP IR3	Open
TCSG IR7	Open	TCSG IR3	Open
TCLA IR7	open	TCLA IR3	open
TCTVBs	50 σ	TCTHs	15 σ



Commissioning planning

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		Bunches	Total Time [days] both rings	Comments
I0	Re-commission protons	1	1	Following technical stop, establish orbit with low-intensity BPM settings.
I1	Injection and first turn	1	(0.25)	Magnetically identical to protons; 1 bunch/beam.
I2	Circulating beam	1	0.25	Magnetically identical to protons. Synchronisation of transfer lines and RF capture at -5 kHz frequency shift. Check lifetime in particular.
I3	450 Z GeV initial commissioning	1	0.25	Cross-calibration of BPMs from protons. Beam instrumentation setup. Wire-scanner, BGI.
I4	450 Z GeV optics checks with two beams	2	(0.5)	Magnetically identical to protons but do minimal check of energy matching, beta-beating. >0.4 nominal bunch intensity
I5	450 Z GeV - two beams	2	0.5	Otherwise magnetically identical to protons
I6	Collimation	2	0.5	Set-up single stage collimation, loss map to compare with protons.
I7	Ramp	1	0.5	Start with two beams, Magnetically identical to protons. Check beam dump at various energies.
I8	3.5 Z TeV flat top checks	1	0.5	Performed following successful ramp. Collimation setup and loss map.
I9	Setup for collisions - 3.5 Z TeV	1	0.5	Squeeze and transition to zero real crossing angle in ALICE, CMS & ATLAS. LHCb separated, squeezed. Collimation setup.
I10	Loss maps	1	0.5	Measure to verify hierarchy appropriate for ion beams. test predictions. Verify protection.
	Stable beam	1	(0.1)	See machine backgrounds ?

Commissioning planning (II)

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		Bunches	**Total Time [days] both rings**	Comments
	TOTAL to prepare		5+(1)	
I11	First collisions+physics	2	1.5	Ramp with two beams, squeeze, checks
I12	Increase intensity	128	1	Increase bunch number to 128 (Early++ Scheme).
	Physics	128		Parasitic measurements during physics (luminosity evolution, BFPP, etc, ...) to test our models and prepare future runs.