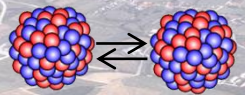
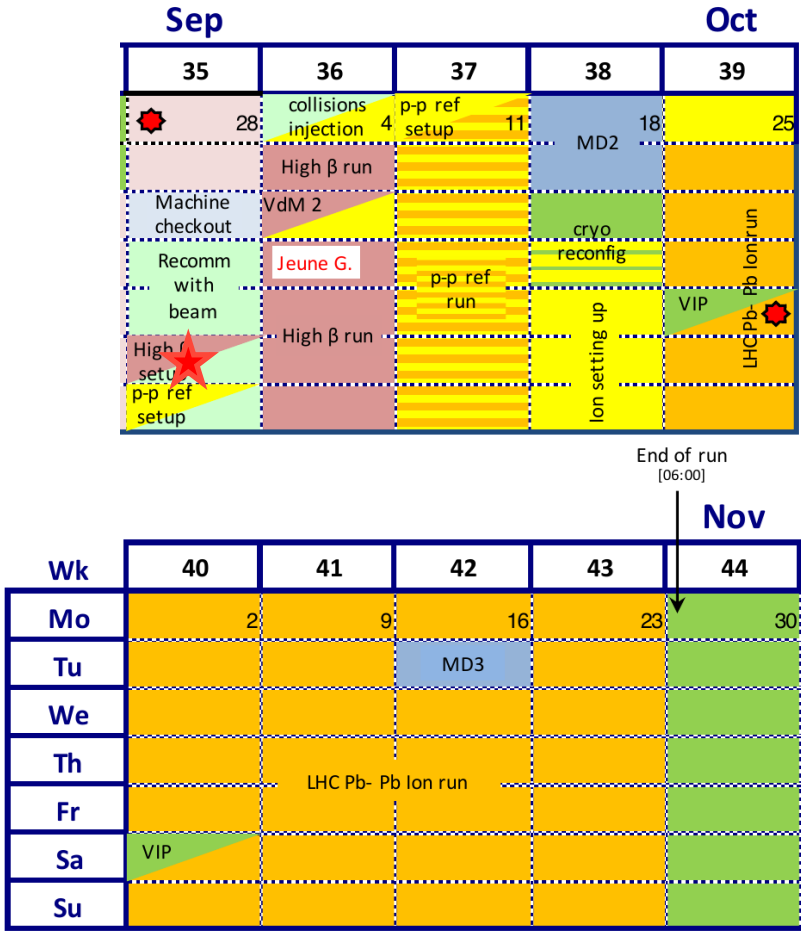
2023 Pb-Pb run: Scenarios for beam and machine parameters



R. Bruce
With essential inputs from many colleagues

Introduction

- **Re-scheduling after IT8 incident**
  - Foreseen now to start ion physics on Sept 25-26
  - 1 week earlier and 1 week more than in schedule pre IT-8
- **LHC 2023 schedule:**
  - 1 week pp reference run
  - 4 days Pb commissioning
  - 32 days of Pb-Pb physics operation
  - 1 day of MD
- **Ion run relies on several new concepts**
  - Slip-stacked 50-ns beams
  - Crystal collimation
  - New DS collimators in IR2
  - Faster ramp&squeeze, reaching directly final β* at top energy
- **Run preparations ongoing**



Physics goals

- **Run 3+4 Pb-Pb physics goal: 13 nb^{-1} for ATLAS, ALICE, CMS**
  - Same goal as before 20% cut in physics time and cancellation of 2022 ion run
  - Needed 2.6 nb^{-1} per one-month run, assuming five runs in total, as before cancellation of 2022 runs
- **2023 physics goals**
  - input from experiments, see F. Moortgat @ Chamonix 2023
  - 3.25 nb^{-1} at ALICE
    - would give 13 nb^{-1} in four runs, as assumed after cut of 2022 ion run
  - 3 nb^{-1} at ATLAS/CMS
  - 0.4 nb^{-1} at LHCb
- **The goals are ambitious – see next slide**

Projected 2023 performance, Pb-Pb

Simulated integrated luminosity over **27 days in nb^{-1}**

6.8 Z TeV, 50%	IP1/5	IP2	IP8
1240_1200_1240_0	2.8	3.	0.
1144_1144_1144_239	2.7	3.	0.2
1088_1088_1088_398	**2.6**	**2.9**	**0.33**
1032_1032_1032_557	2.5	2.8	0.43
976_976_976_716	2.5	2.8	0.52
733_702_733_468	1.9	2.1	0.39

6.8 Z TeV, 62%	IP1/5	IP2	IP8
1240_1200_1240_0	3.5	3.7	0.
1144_1144_1144_239	3.3	3.7	0.24
1088_1088_1088_398	**3.2**	**3.6**	**0.4**
1032_1032_1032_557	3.1	3.5	0.54
976_976_976_716	3.	3.4	0.64
733_702_733_468	2.4	2.6	0.48

Physics goals are met with 62% OP efficiency, but not with 50%

(3.25 nb-1 at ALICE; 3 nb-1 at ATLAS/CMS; 0.4 nb-1 at LHCb)

Beam parameters and filling schemes

- **Baseline: rely on 50 ns slip-stacked beams**
  - **Range of schemes available with different sharing between experiments**
  - 1240b_1088_1088_398 is the baseline

Filling scheme	n.o. bunches	n.o. collisions at IP1/5	IP2	IP8	spacing
1240b_1240_1200_0	1240	1240	1200	0	50 ns
1240b_1144_1144_239	1240	1144	1144	239	50 ns
1240b_1088_1088_398	1240	1088	1088	398	50 ns
1240b_1032_1032_557	1240	1032	1032	557	50 ns
1240b_976_976_716	1240	976	976	716	50 ns
733b_733_702_468	733	733	702	468	75 ns

- **Projected Pb beam parameters in collision**
  - Based on LIU target for injection, with some degradation before reaching collision

	LHC design	2018	Run 3
Beam energy (Z TeV)	7	6.37	6.8
Bunch spacing (ns)	100	75	50
Total n.o. bunches	592	733	1240
Bunch intensity (10^7 Pb ions)	7	21	18
Normalized transverse emittance (μm)	1.5	2.3	1.65

2023 ion machine configuration

- **Optics: very similar to 2018**
  - Prepared in 2022 by S. Fartoukh
  - β*=0.5 m at IP1/2/5, 1.5 m at IP8

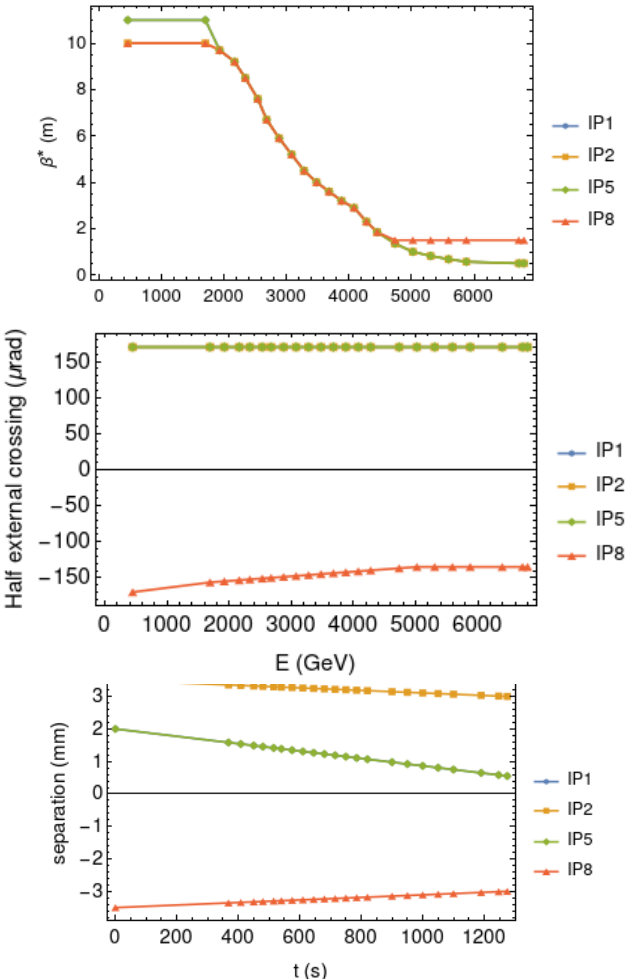
	IP1	IP2	IP5	IP8
β^* (m)	0.5	0.5	0.5	1.5
crossing plane	V	V	H	H
spectrometer half crossing (μrad)	0	$\mp$72	0	-139
external half crossing (μrad)	170	$\pm$170	170	-135
net half crossing (μrad)	170	$\pm$ 98	170	-274
spectrometer polarity	-	pos/neg	-	pos

- **Will do ALICE polarity reversal in the middle of the run**
  - As in 2018, reverse crossing angle during physics beam process → Need large 3.5 mm parallel separation for beam-beam

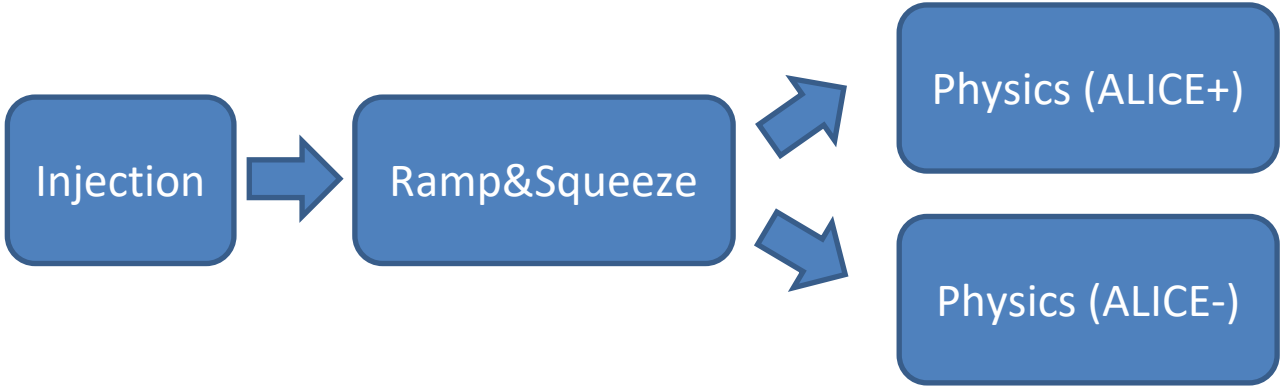
- **Luminosity levelling targets:**
  - L=6.4×10^{27} cm^{-2} s^{-1} for IP1/2/5
    - Could potentially be higher for IP1/5
  - L=1.0×10^{27} cm^{-2} s^{-1} at IP8
    - Kept at this value in 2018 to be safe from quenches due to BFPP
    - Could potentially be a bit higher
  - Assuming separation levelling at all IPs, no β*-levelling

2023 Ion cycle

- **Use shorter cycle, doing the full squeeze to 0.5m in the ramp**
  - Skips squeeze at flat top
  - OK for power converters and aperture - to respect 15 σ in IR8, decrease external crossing to 135 urad at FT
  - See LBOC talk
- **Most optics commissioning already done during the proton period**
  - About 1 shift remains



Overview of ion cycle



	Injection	Flat top	Physics
Energy (Z TeV)	0.45	6.8	6.8
β* (m) IP1,2,5,8	11, 10, 11, 10	0.5, 0.5, 0.5, 1.5	0.5, 0.5, 0.5, 1.5
Half external crossing (µrad) IP1,2,5,8	170, 170, 170, -170	170, 170, 170, -135	170, ±170, 170, -135
Parallel separation (mm) IP1,2,5,8	-2, 3, 2, -3	-0.55, 3, 0.55, -3	Separation levelling

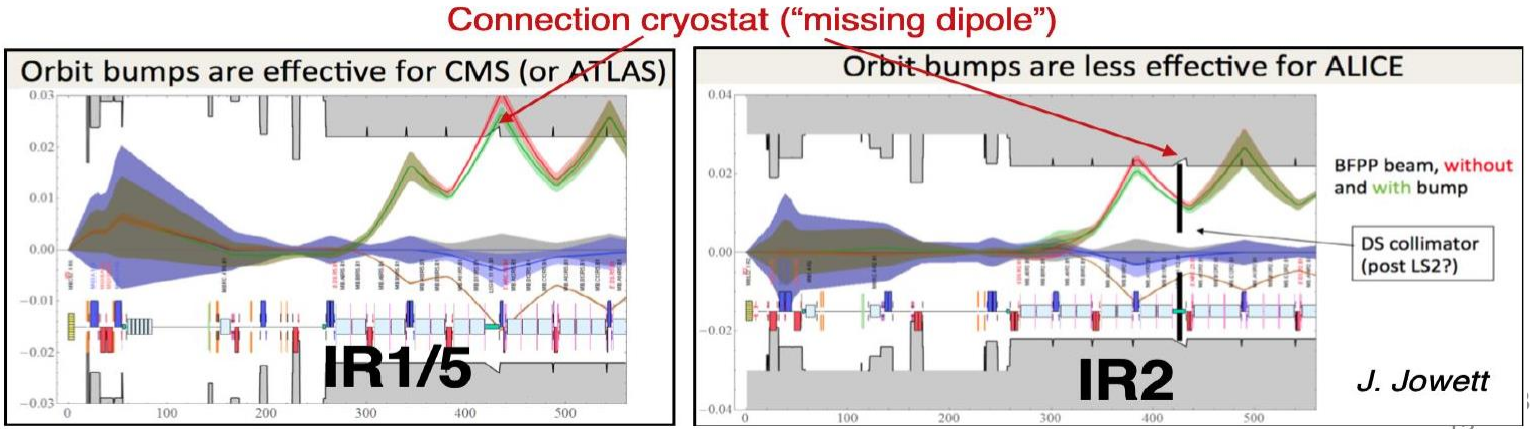
Collimation

- **2023 ion run will rely on collimators not used in standard proton operation**
  - **crystal collimation to be used throughout the cycle** – need improved cleaning to deal with lifetime drops (10 Hz events?) in combination with significantly increased intensity
  - **New IR2 TCLD** collimators - needed to alleviate BFPP losses and avoid quenches at nominal luminosity for new upgraded ALICE detector
- **All crystals collimators from Run 2 exchanged with new improved design**
  - Settings shown in dedicated talk
- **Involved calculations of BLM thresholds with crystals** – see dedicated talks

Alleviation of collisional losses

- Ultra-peripheral electromagnetic interactions create **secondary beams with changed charge-to-mass ratio**
  - Bound-Free pair production, source of one-electron ions → magnet quench below operational luminosity

- **Alleviation techniques**
  - **IR1/5: Orbit bumps** successfully deployed already in Run 2 to steer losses into empty connection cryostat
  - **IR2: bumps alone do not work – need bumps + new dispersion suppressor collimator (TCLDs) → new in 2023**
  - **IR8: use bumps to steer losses from cell 10 to cell 12**, where they are more spread out and BLM threshold is higher **→ new in 2023**



Conclusions

- Ion commissioning to start in about 3 weeks, ion physics 4 days later
- 2023 run relying on several new concepts and hardware: slip-stacked beams, crystal collimation, TCLD collimators, full squeeze in ramp
- Important to prepare everything well…