Experiments during HWC, beam tests and initial commissioning

- What are the experiments going to do from March to the first collisions?
- Can they live with controlled access in the experimental areas in parallel with Hardware Commissioning and Cold-Check Out?
- Impact of a sector test
- How interested are the experiments in a run at intermediate energy?

What are the experiments going to do from March to the first collisions?

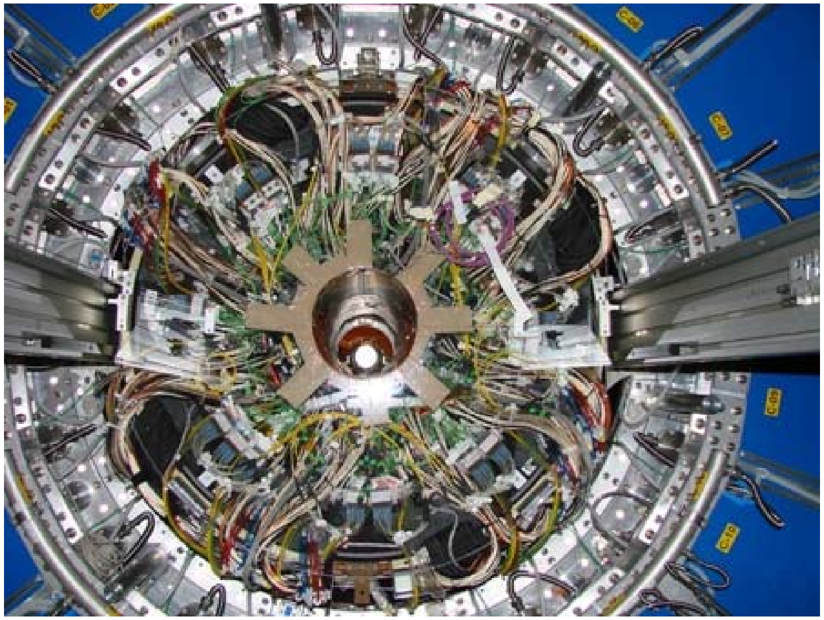
Overview of currently ongoing activities

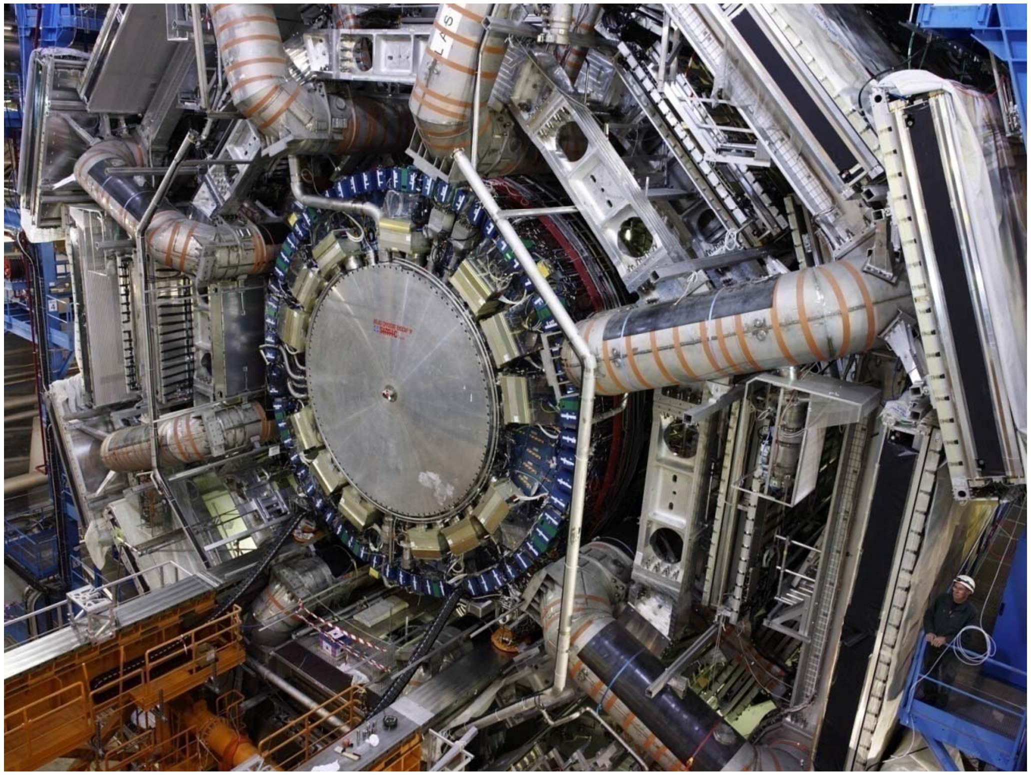
- Completing installation of initial detectors
  - All heavy elements are in the caverns
  - Main activities: cable up, check out
- Commissioning of sub-detectors, going on in parallel
- Regular global commissioning runs

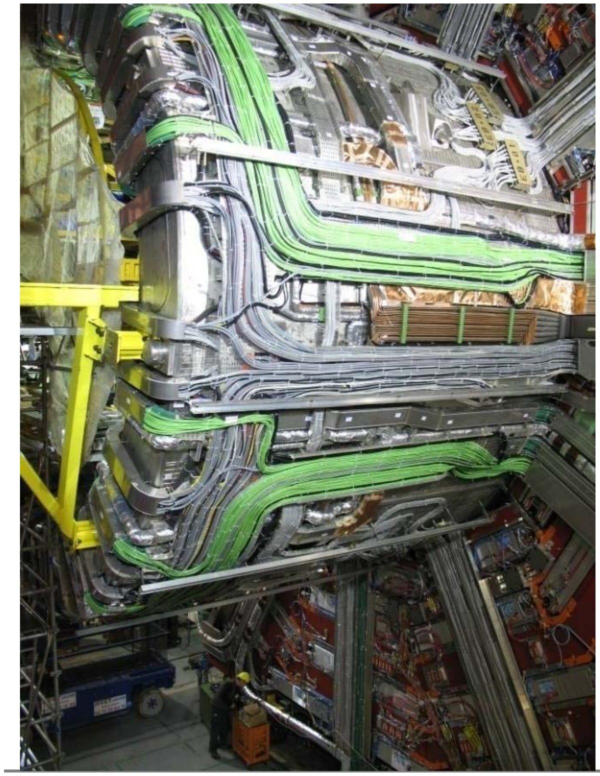
All experiments are already taking data

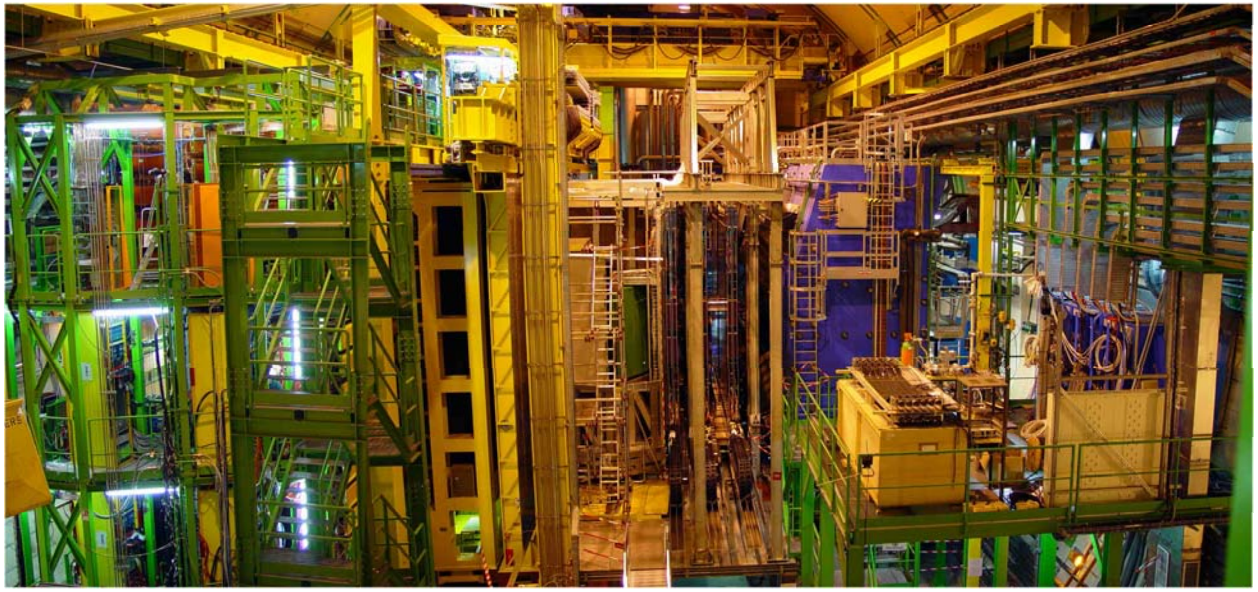
- See for example:
  - ALICE: open session 20/2/08 92nd LHCC
  - ATLAS: Jenni+Wengler in 2/08 ATLAS week,18/2/08 mini-review LHCC
  - CMS: open session 20/2/08 92nd LHCC , Virdee in 2/08 CMS week
  - LHCb: 18/2/08 mini-review LHCC

All will have an initial detector ready for doing physics with first high energy collisions

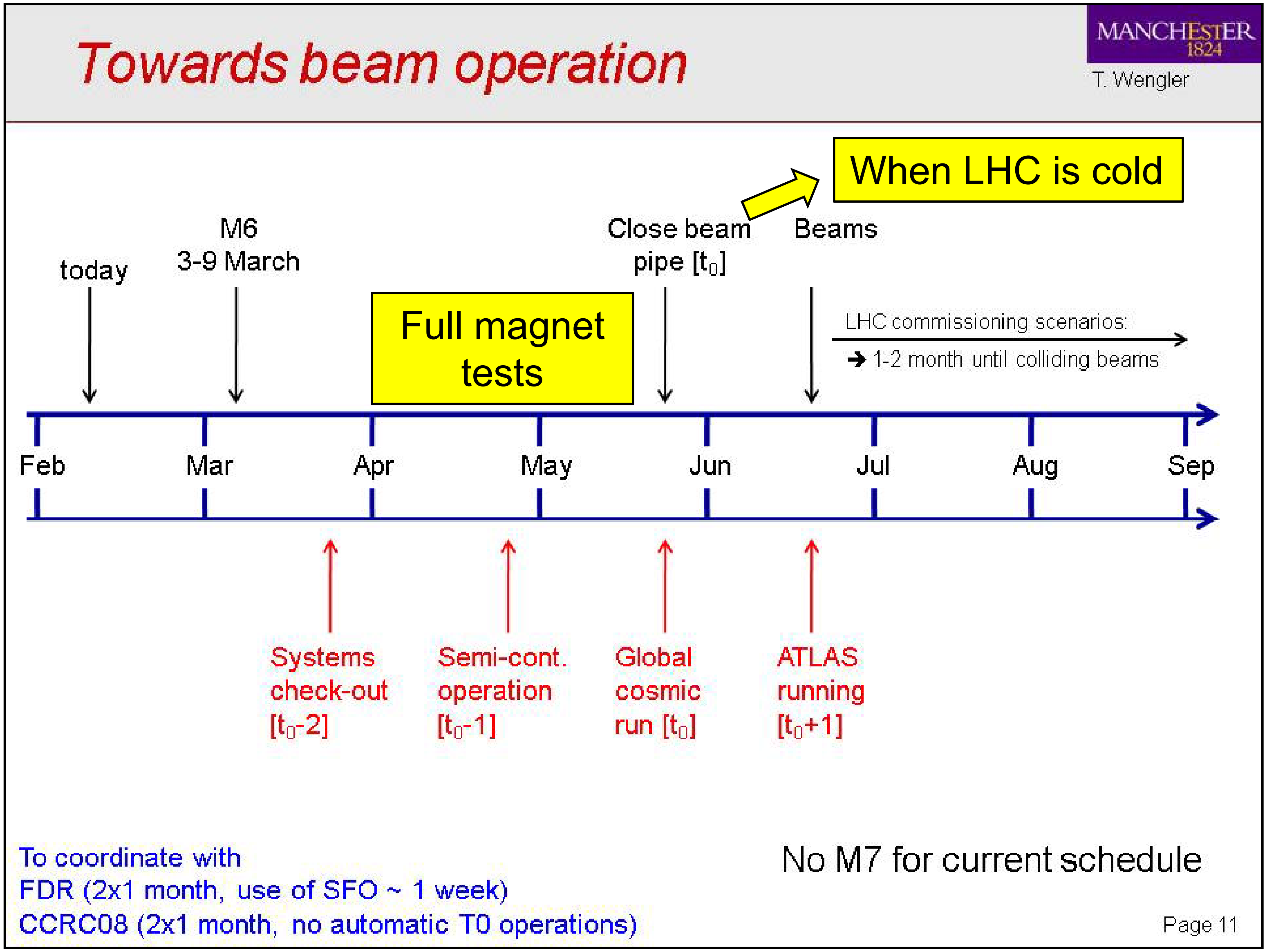








Example: ATLAS (1)



Example: ATLAS (2)

Towards beam operation cont.

MANCHESTER 1824

T. Wengler

- t0 - 2 months: Systems check-out
  - SLIMOS manned 24/7
  - System Assessment periods (in groups, ~1 week each)
    - Calorimeters & L1Calo, Muons & Muon L1 trigger, Full ID, DAQ+HLT
- t0 - 1 month: semi-continuous operation
  - Mon morning to Wed evening free for debugging and detector stand alone
  - Wed night to Mon morning: GCR: 2 shifts (+ night if during full magnet test)
- t0 : Global Cosmic Run [GCR – linked to beam pipe closure]
  - 1 weeks GCR 24/7 shifts – 1 week debugging – 2 weeks GCR 24/7 shifts
- t0 + 1 month: continuous operations (Atlas running): beam in the LHC
  - Commissioning WPs w/ beams: BCM, interlocks, Timing
  - Otherwise: AR 24/7: System w/ problem: out in debug mode
  - First collisions, setup, timing

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Example: CMS (1)

Schedule: Overview

Target

Cosmics Run @4T: Initial CMS Closed - End May'08.

Critical Path up to May goes through:

Tracker connections (separate periods of 1or 2 weeks contingency for each end)

Beam-pipe: no contingency - work mostly responsibility of AT/VAC group (CMS has added trained technicians into the team)

At least one EE Dee rfi

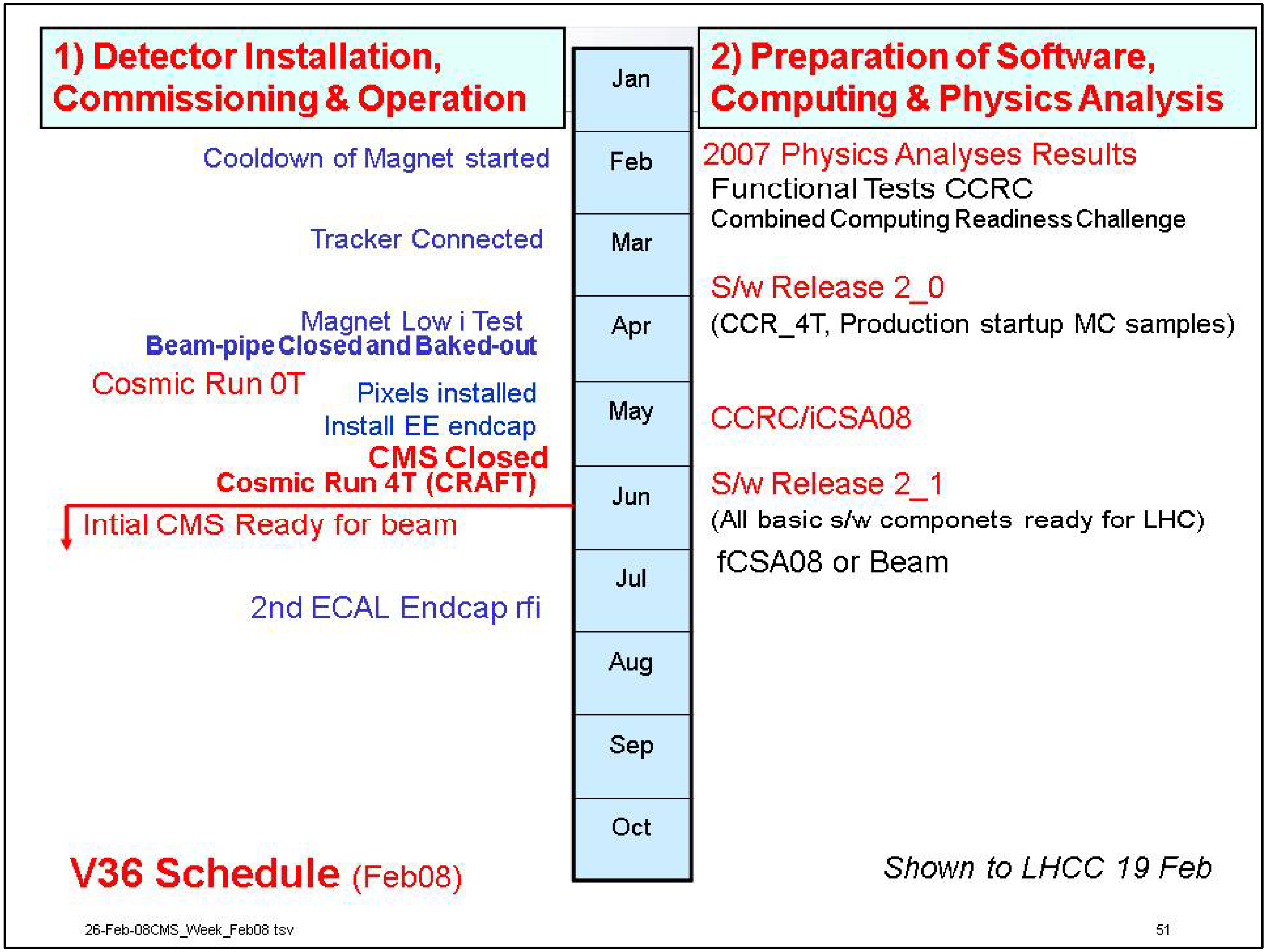
CMS Closure has priority.

From mid-June onwards: if beam not imminent then open for any repair and complete the installation of endcap ECAL. Low lumi CMS ready 1st week of August. Will then need a warning of 1 mo before beam.

Aim is to retain **flexibility in the schedule** to be able to take maximum advantage of unfolding circumstances.

26-Feb-08CMS_Week_Feb08 tsv 50

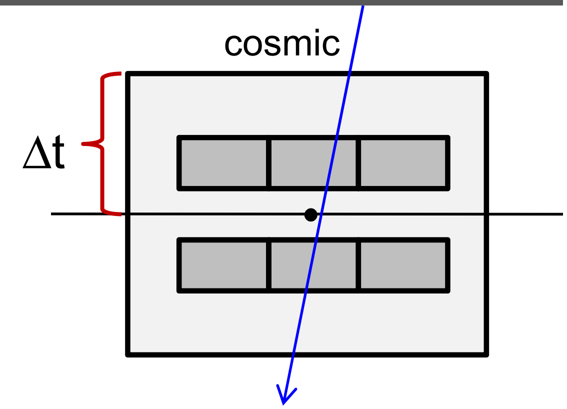
Example: CMS (2)

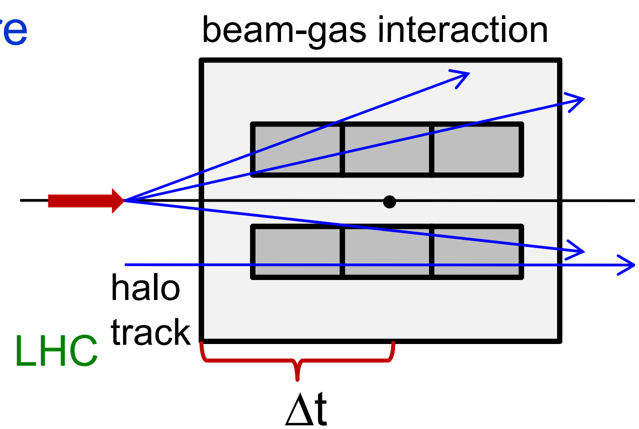


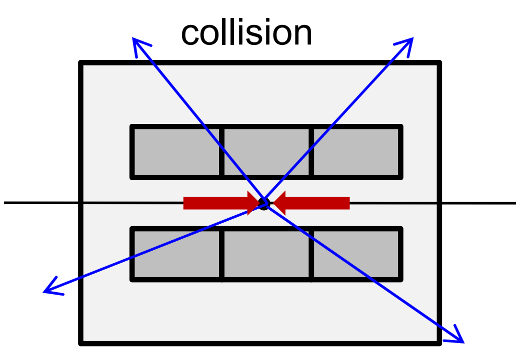
From global commissioning to first collisions

- Commissioning without beam:
  - Dry runs, test pulses, cosmics
    - Spatial alignment, internal synchronization
  - Magnets operation
  - Verification of experiment protection without beam
  - Involve full computing and software infrastructure
    - LCG: Common Computing Readiness Challenge (CCRC)
- Commissioning with single beams
  - Beam-gas tracks, halo tracks
    - Spatial alignment, some first synchronization with LHC
  - Verification of experiment protection with beam
- Commissioning with collisions
  - Final synchronization with LHC
    - high stats and no time “gymnastics” required
  - Understanding of full detector

Then physics !!!







Magnets in the experiments

ATLAS:	toroids and solenoid	superconducting
CMS:	solenoid	superconducting
ALICE:	dipole + 3 correctors, solenoid	warm
LHCb:	dipole + 3 correctors	warm

Commissioning magnets with beam: the experiments are interested to carry it out as soon as possible, though without impeding LHC commissioning.

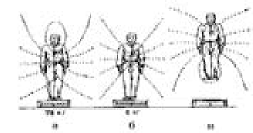
- Toroids:
  - can be turned on/off any time (no effect on machine)
- Solenoids:
  - small effect at 450 GeV (XY coupling), decreases with increasing energy
  - effect needs to be measured and corrected
  - can be done at the earliest after Phase A.4 (“450 GeV Optics”)
  - then would have to be turned off at least once (during the first ramp or Phase A.8).
- Dipoles:
  - largest effects on beams (orbit distortion), correction needed, ramped with ring
  - Commission with beam after Phase A.9 (top energy checks)
- After Phase A.9, it is expected that solenoids and toroids can stay on all the time.
- Dipoles will have to be ramped with the ring magnets and perhaps temporarily turned off during certain subsequent phases of commissioning (e.g. A.11, "Squeeze").

Stage A and magnets in the experiments

Work in progress

Stage A

Pilot physics run



LHC Beam Commissioning

Home

Phase A.1	**First turn:** injection commissioning; threading, commissioning beam instrumentation. Ring 1, ring 2.
Phase A.2	**Circulating pilot:** establish circulating beam, closed orbit, tunes, RF capture, ...
Phase A.3	**450 GeV initial commissioning:** system commissioning: instrumentation, beam dump,...
Phase A.4	**450 GeV optics:** beta beating, dispersion, coupling, non-linear field quality, aperture,...
Phase A.5	**450 GeV, increasing intensity:** prepare the LHC for unsafe beam
Phase A.6	**450 GeV, two beam operation**
Phase A.7	**450 GeV, collisions** To be seen…
Phase A.8	**Snap-back and ramp:** single beam/two beams
Phase A.9	**Top energy checks**
Phase A.10	**Top energy, collisions**
Phase A.11	**Squeeze:** Commission the betatron squeeze in all IP's
Phase A.12	**Beam commissioning with experimental magnets**

Toroids can be turned on (check with beam) → Phase A.1

Solenoids commissioning with beam → Phase A.5

Solenoids off the 1st time, then on → Phase A.8

Dipoles commissioning with beam → Phase A.9

Phase A.12 → Dipoles commissioning with beam

Can the experiments live with controlled access in the experimental areas in parallel with Hardware Commissioning and Cold-Check Out ?

Going to controlled access

- Currently: 1st April all areas go to controlled access
- Some worries for the experiments:
  a) Availability and distribution of badges
  b) Access to machine areas containing equipment of the experiments (e.g. US15 in point 1)
  c) Use of PM lifts by the experiments (during sector HWC)
  d) Minor issue: doors throughput, maximum 2 persons / minute

To be clarified:
Dosimeters needed in service areas ?
If yes, starting from when ?

- All these are surmountable issues, if proper discussion forum is in place
- For example, solutions have already been proposed:

  Point a) : use “tokens” (dosimeterless badges) till DSO acceptance test

  Point b) : progressive closure, taking advantage of sectorisation ?
  - Start 1st April in some machine areas, finish by end April in experimental zones ?
- Experiments agree that some run-in time for the access system is needed, but would like to discuss the planning and find the right balance

⇒ Set up meetings with HWC Coord, TC’s and Access System responsibles

Impact of a sector test ?

Sector test ?

- Experiments can hardly make any use of a sector test
- Would cause some disturbances:
  - Closed machine, no access for duration of sector test (how long ?)
  - LHCb: radiation in IP8 (idem for ALICE, if IP2 also considered)
    - in what radiological state after the sector test ?
    - will it prohibit usage of "tokens" ?
    - will it imply INB tracing of equipment ?
  - General:
    - how does this affect the Access System state and options after the sector test ?
    - Can one still go back to "General Access" with biometry turned off ?

- Yet, if deemed very useful for the LHC commissioning, a low-intensity sector test of 1 or 2 weeks seems acceptable and will have minor impact on the experiments

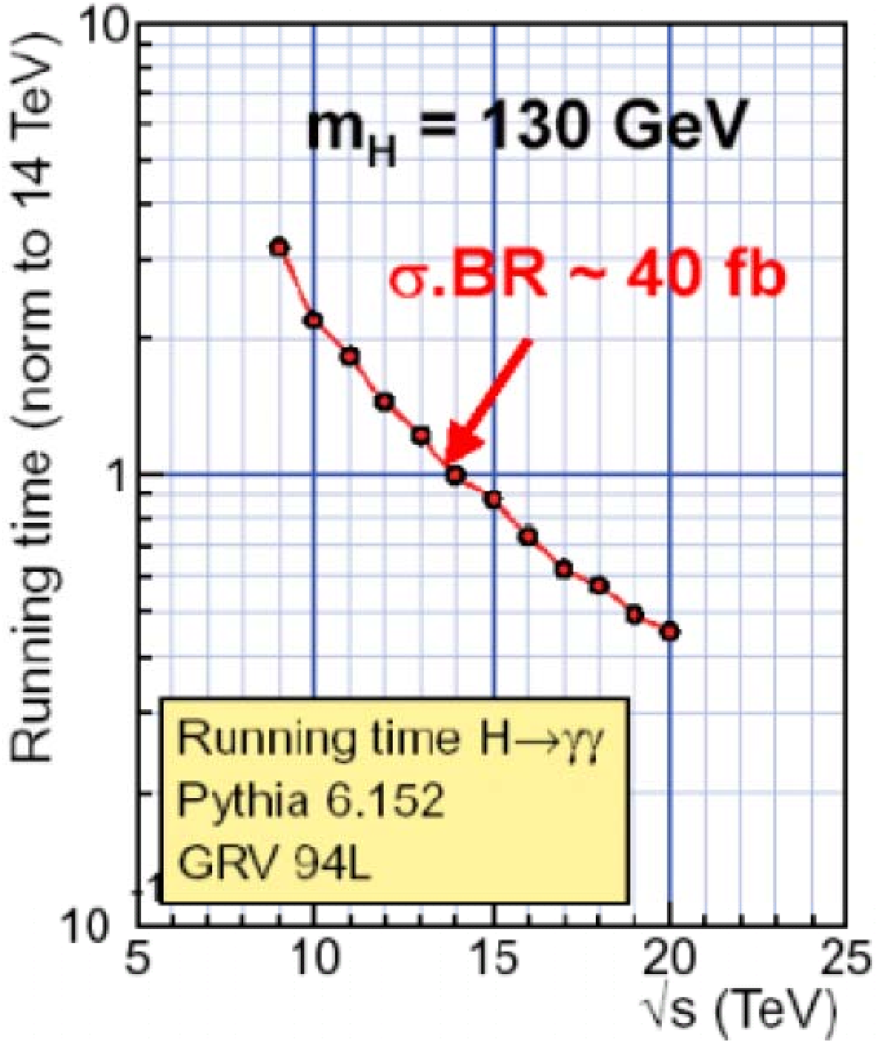
→ see you in SESSION 3

How interested are the experiments in a run at intermediate energy?

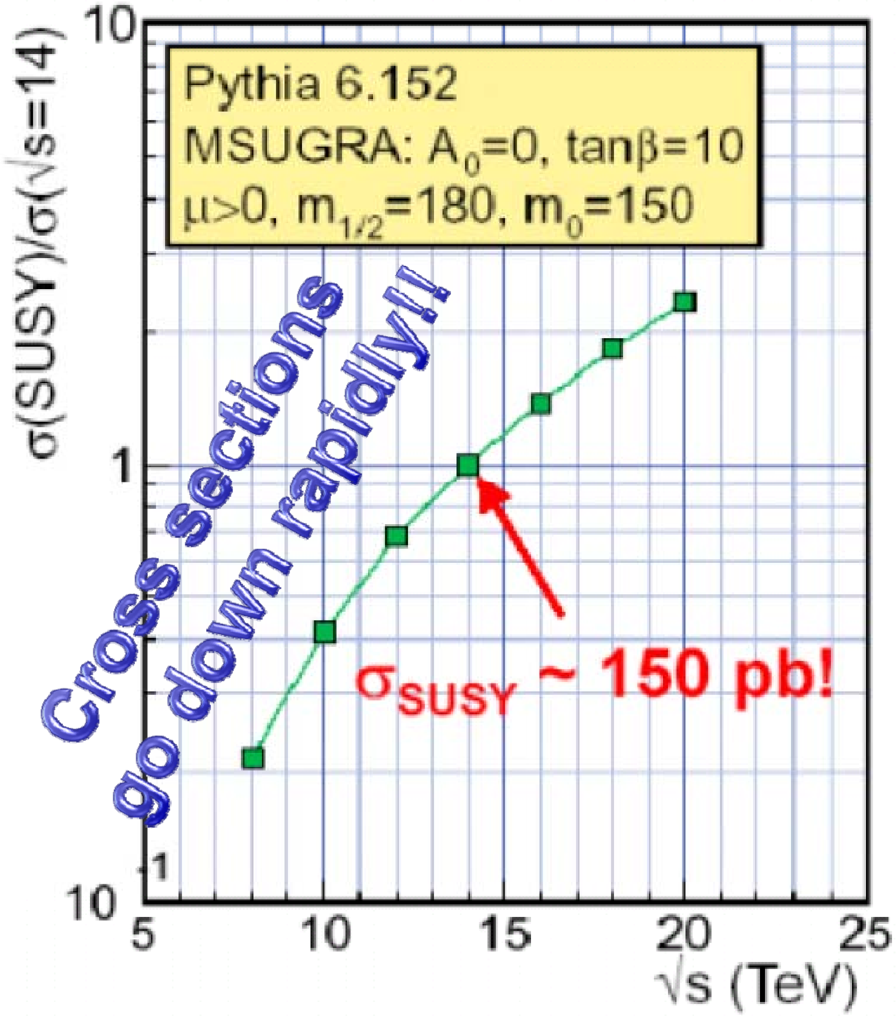
Physics production cross sections versus energy

Normalized variation with energy: (from Virdee in Chamonix XII, p. 257)

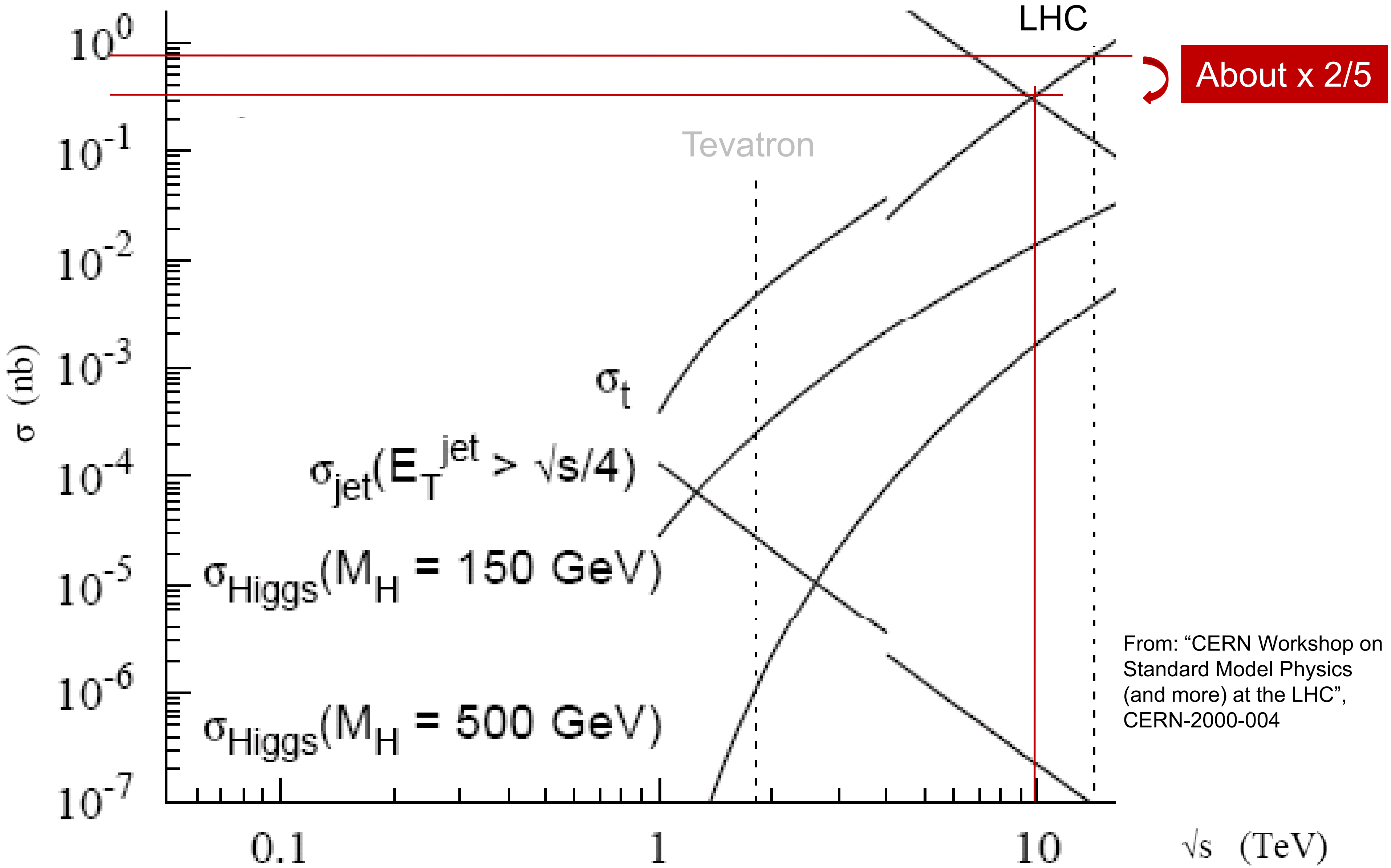
$\sigma \times BR$ for $H \rightarrow \gamma\gamma$



σ^{SUSY}



Physics production cross sections versus energy



From: "CERN Workshop on Standard Model Physics (and more) at the LHC", CERN-2000-004

Intermediate energy ?

See Jim Virdee in Chamonix XII, p. 257:

" Some discoveries can be made with a few weeks of running at 10^{33} cm^{-2} s^{-1}. Therefore doubling this running time is still not too long. Hence a lower rate due to lower cross-sections at lower centre of mass energies does not much affect such discovery potential at startup.

Therefore the requirement from the experiments to start at the design energy is not a strong one, i.e. startup can take place at a lower energy. Clearly, running must start as soon as possible and the move to the design energy should take place as soon as possible. In order not to have to combine data from too many different energies the experiments would wish to move to design energy in one step."

… and physics hasn't changed much since Chamonix XII !

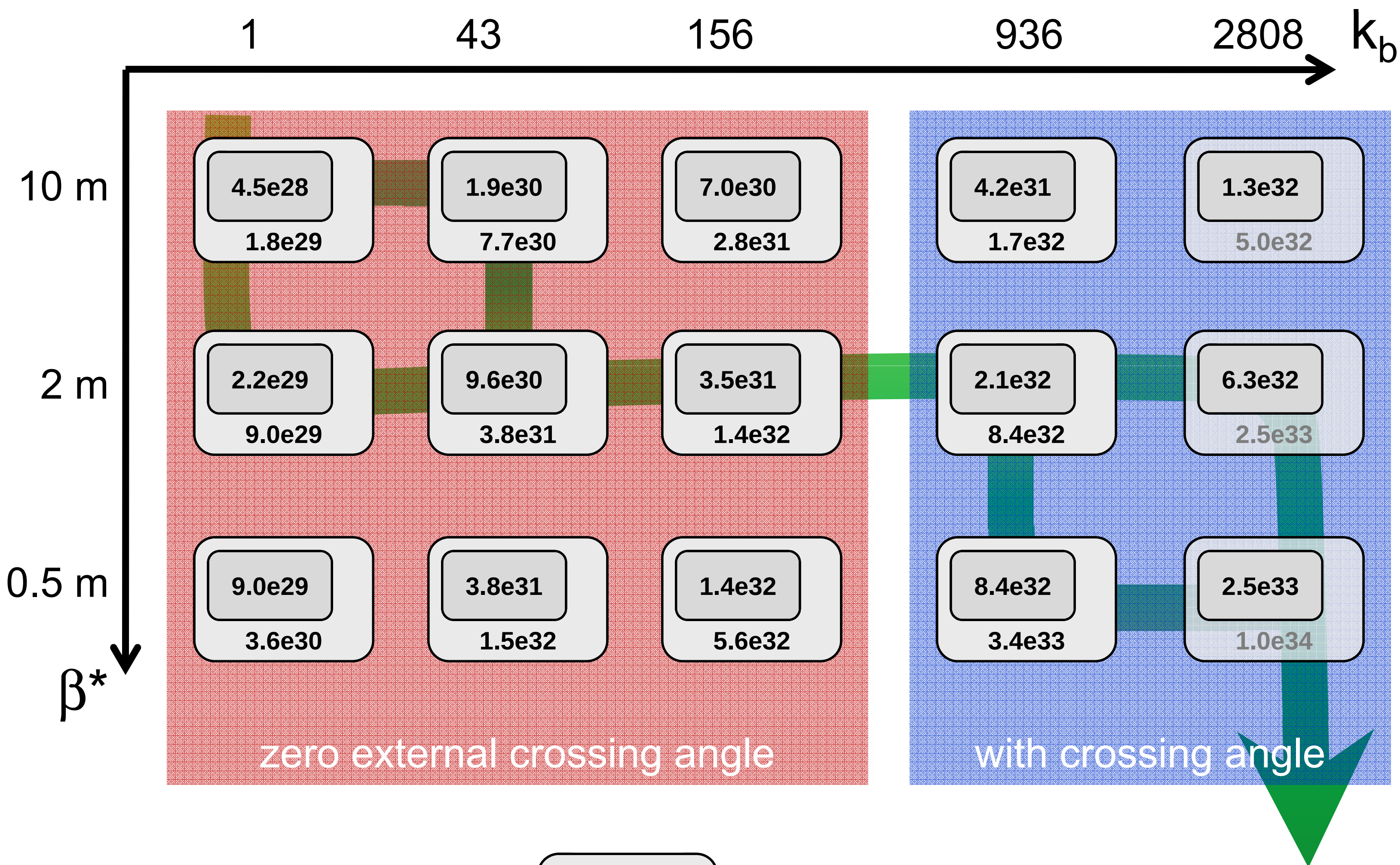
HOWEVER…

…

- run at what intermediate energy ?

- what integrated luminosity ?
  - what "Stage" of commissioning before running ?
  - what beta*, how many bunches ?
  - how long ?

Luminosity



2808x1e11 only with phase II collimators

Bunch charge N = 5e10 / 1e11

crossing angle factor not applied ranges from 0.84 to 0.96 depending on k_b, N, β^*

A first run at less than 14 TeV ?

- The experiments want 14 TeV !
- Yet, they also eagerly want to do physics! They want to get collisions!
- If there are clear advantages from the machine to run at a reduced energy, the experiments are interested to participate in the exercise of finding an “optimal” energy for this initial run
- This energy should be chosen in the light of an overall optimization which takes into account
  - the physics vs energy,
  - the estimated time to completion of the LHC HWC vs energy
  - achievable luminosity vs energy ?
  - the experiments adaptability to a given energy,
  - the expected running efficiency vs energy, etc.

Emittance linear with E
Total storable intensity linear with E, but limited to 2808×10^{11}
$\Rightarrow$ If E< 3.5 TeV, start loosing on max lumi ?

- The choice of strategy may affect the way the experiments will complete their detectors and commissioning

Conclusions

Activities from now to collisions:

- Finish installation of initial detector, wrap up and commission
- The experiments will be ready to do physics this summer

Controlled access:

- Experiments can cope with controlled access,
- but wish to discuss and adjust the planning

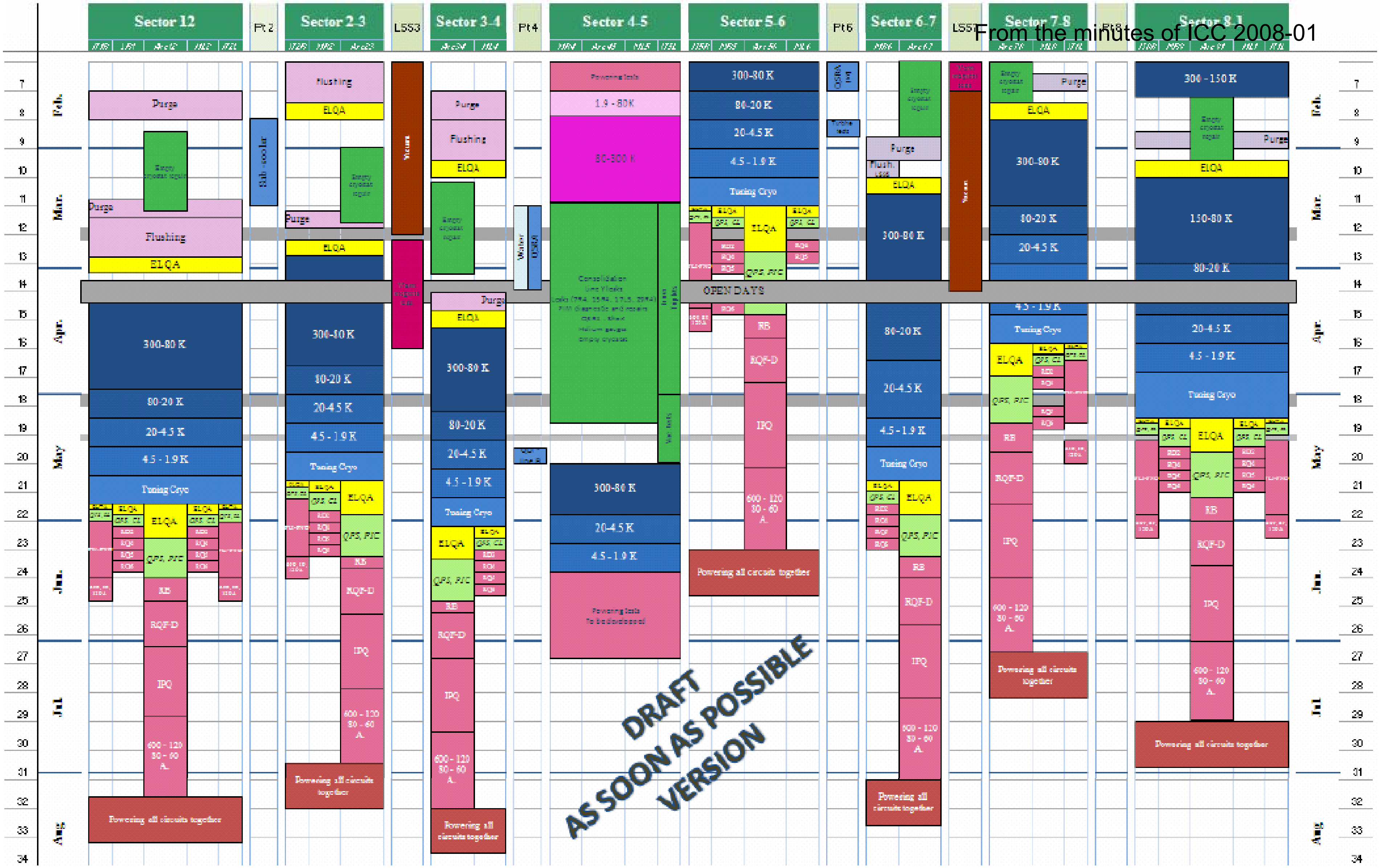
A 2008 run at intermediate energy:

- yes, certainly very useful, but
- what is "intermediate" ?
- what integrated luminosity aimed for ?

SPARE SLIDES

LHC General Schedule

From the minutes of ICC 2008-01



900 GeV Collisions

900 GeV Collisions: feed back from Expts (2)

<u>Outcome:</u>

- Common view of the experiments emerged:
  - a. Such a run is **not required nor requested by the experiments**.
  - b. However, collisions at 900 GeV would be useful, mostly for time alignment.
  - c. A short period with such beam conditions is interesting (**up to a few shifts, i.e. in the noise of the commissioning schedule**),
  - d. Provided the **beam conditions are safe** (no compromise on machine & experiment protection) and **stable beam** conditions declared.
  - e. The experiments do not require their magnets to be ON, though they would benefit from it if they were able to turn them ON.
- Special:
  - – LHCb would require and request a few displaced bunches and would probably request the experimental dipole to be OFF to allow (partially) closing the VELO.
- Keep option for such a short 900 GeV run in the LHC commissioning plan.

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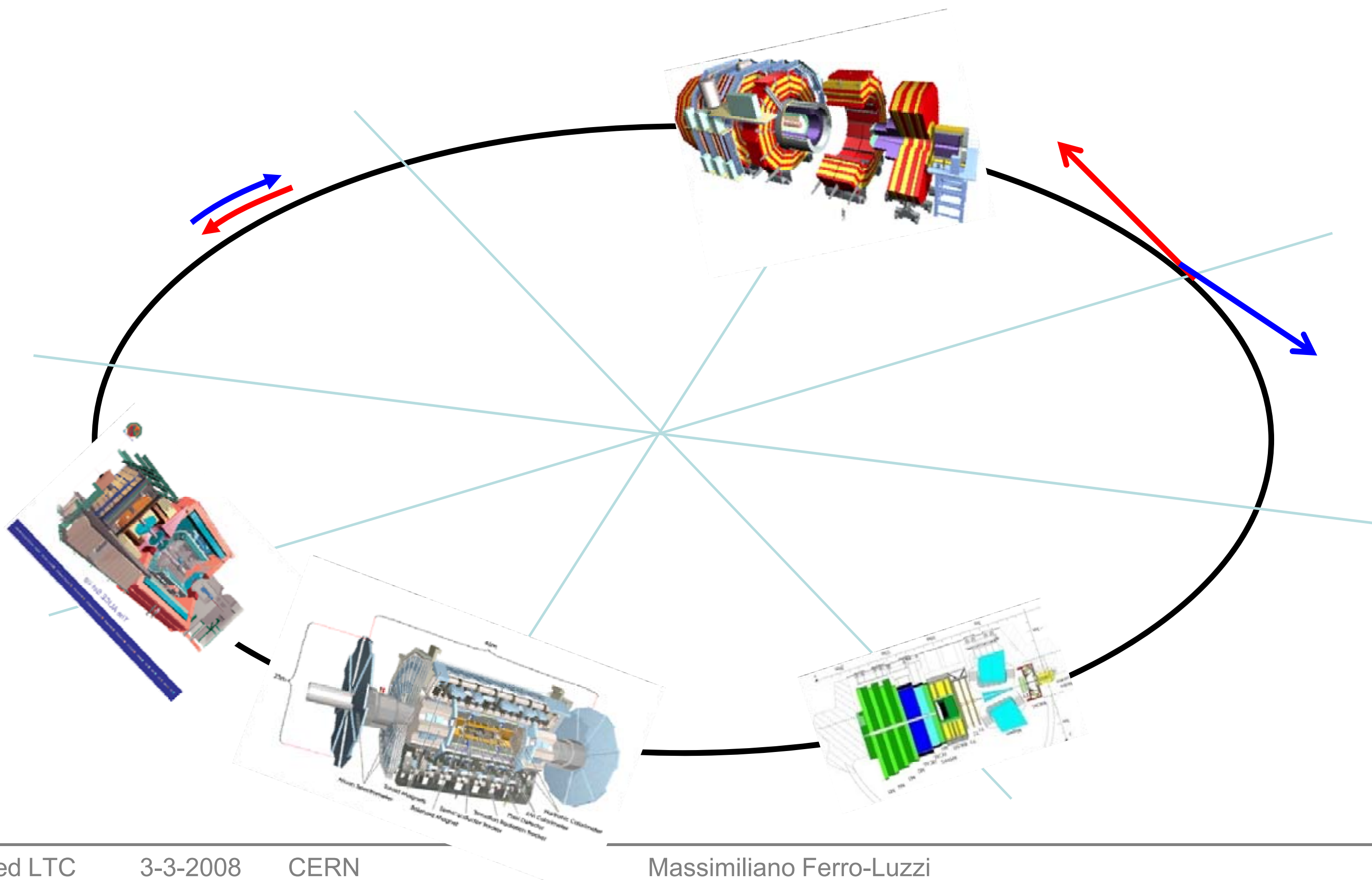
Which beam first ?

- Both Alice and LHCb have an asymmetric setup, with preference for beam1 (beam-gas interactions boosted in the right direction)
- CMS potentially exposed to kicker misfire of beam2



Filling schemes (see LHC-Project Note 323_Revised)

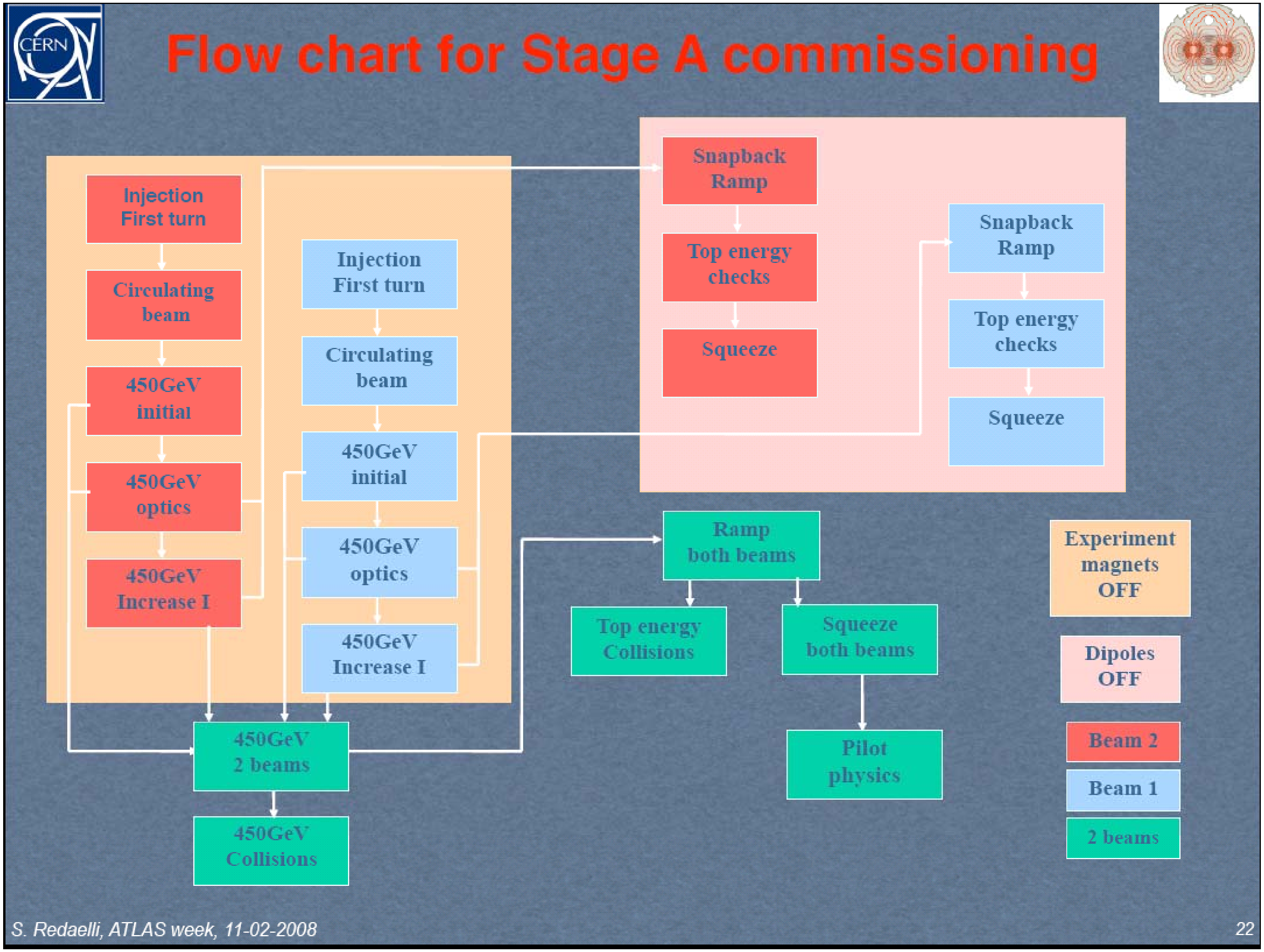
Stage A	**Pilot physics run:** physics aim 43 x 43 bunches; maximum 156 x 156 bunches.
Stage B	**Intermediate physics run:** physics aim 75 ns bunch spacing; possible initial physics aim 96 x 96 bunches (bunch intensity 1 x 10^{10}), maximum aim 936 x 936 bunches (maximum 9 x 10^{10}).
Stage C	**25 ns run I:** intensity per bunch 5 x 10^{10} protons (initial 1 x 10^{10}); physics aim 2808 x 2808 bunches
Stage D	**25 ns run II:** push towards nominal performance

up to here limited by $I < 0.5 \times I_{nominal}$

Different filling schemes

Machine parameters		450GeV		Stage A		Stage B		Stage C			Stage D	
		Target		Target	Limit	Target	Limit	Target	Limit		Target	Limit
spacing	ns	2021		2021	566	75	75	25	25		25	25
bunch length	m	0.1124		0.0755	0.0755	0.0755	0.0755	0.0755	0.0755		0.0755	0.0755
crossing angle	urad	0		0	0	250	250	285	285		285	285
bunch intensity		4.00E+10		4.00E+10	9.00E+10	4.00E+10	9.00E+10	5.00E+10	5.00E+10		9.00E+10	1.15E+11
bunches		43		43	156	936	936	2808	2808		2808	2808
energy	eV	4.50E+11	Commission hardware for high energy operation	7.00E+12	7.00E+12	7.00E+12	7.00E+12	7.00E+12	7.00E+12	Installation of phase II collimators and full beam dump diluters	7.00E+12	7.00E+12
F		1.00		1.00	1.00	0.96	0.92	0.90	0.84		0.90	0.84
normalised emittance	cm	3.75E-04		3.75E-04	3.75E-04	3.75E-04	3.75E-04	3.75E-04	3.75E-04		3.75E-04	3.75E-04
beta*	cm	1100		200	200	200	100	100	55		100	55
luminosity	/cm2s	7.16E+28		6.12E+30	1.12E+32	1.28E+32	1.24E+33	1.13E+33	1.91E+33		3.65E+33	1.01E+34
total inel cross section	cm2	6.00E-26		6.00E-26	6.00E-26	6.00E-26	6.00E-26	6.00E-26	6.00E-26		6.00E-26	6.00E-26
event rate per cross		0.01		0.76	3.85	0.73	7.09	2.14	3.63		6.94	19.18
protons per beam		1.72E+12		1.72E+12	1.40E+13	3.74E+13	8.42E+13	1.40E+14	1.40E+14		2.53E+14	3.23E+14
current per beam	mA	3.09E+00		3.09E+00	2.53E+01	6.74E+01	1.52E+02	2.53E+02	2.53E+02		4.55E+02	5.81E+02
energy per beam	Joules	1.24E+05		1.93E+06	1.57E+07	4.19E+07	9.43E+07	1.57E+08	1.57E+08		2.83E+08	3.62E+08
beam size	um	293.3		31.7	31.7	31.7	22.4	22.4	16.6		22.4	16.6

Stage A commissioning



Beam commissioning

Time scale

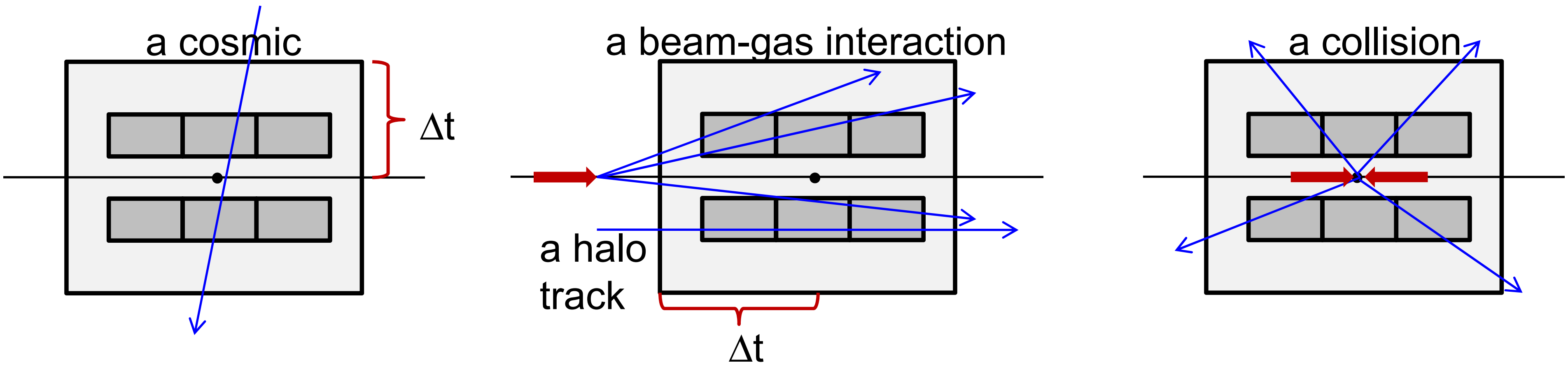
(beam time is given, assuming 100% availability)

	Activity	Rings	Beam Time [day]
1	Injection and first turn	2	4
2	Circulating beam	2	3
3	450 GeV – initial commissioning	2	4
4	450 GeV – detailed optics studies	2	5
5	*450 GeV increase intensity*	*2*	*6*
6	450 GeV - two beams	1	1
7	*450 GeV - collisions*	*1*	*2*
8a	Ramp - single beam	2	8
8b	Ramp - both beams	1	2
9	7 TeV – top energy checks	2	2
10a	Top energy collisions	1	1
	TOTAL TO FIRST COLLISIONS at 7 TeV ($1.1 \times 10^{30} cm^{-2}s^{-1}$)		30
11	*Commission squeeze*	*2*	*6*
10b	*Set-up physics - partially squeezed*	*1*	*2*
	TOTAL TO PILOT PHYSICS RUN ($\sim 1.1 \times 10^{32} cm^{-2} s^{-1}$)		44

Approx. 2 months of elapsed time (50% effic.)

S. Redaelli, ATLAS week, 11-02-2008 24

Synchronisation without/with collisions



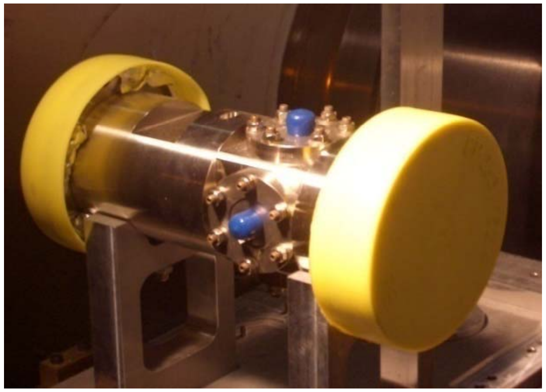
Need to take this Δt into account

Only with collisions:
•No time gymnastics
•High statistics
⇒ explore full detector granularity of timing distribution

Synchronisation tasks

Without beam:

- Test pulses used for internal alignment of a read-out chain
- Cosmics used to time-align various independent detector modules

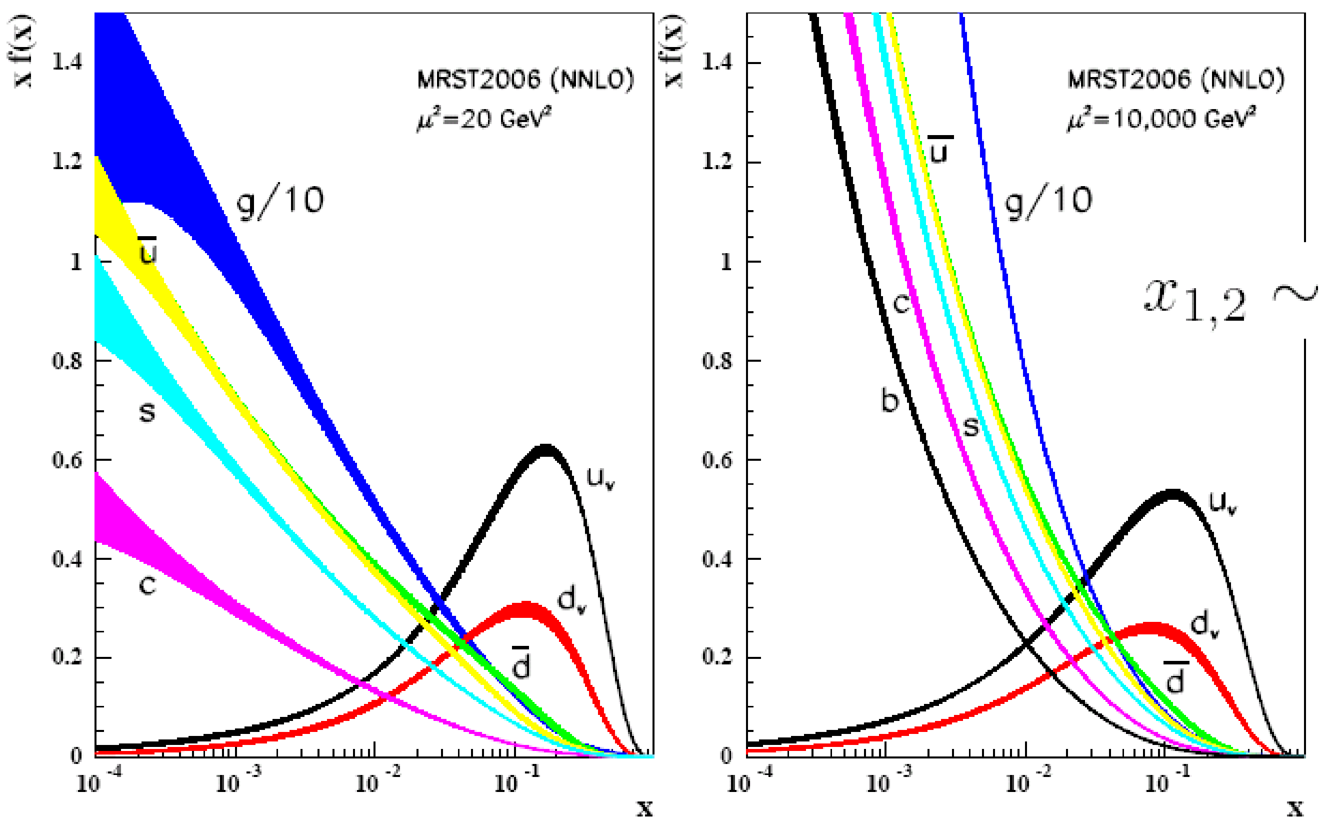


With beam, for each independent detector module:

- Align front-end sampling time with bunch crossing
- Align data in steps of 25 ns
- Use BPTX to narrow down time of bunch arrival
- Starting with large bunch spacing (43x43, 156x156) will facilitate easy identification of the correct 25ns time slot
- Can make use of beam-gas and halo, but collisions are much better (rates and topology)

LHC is a parton collider

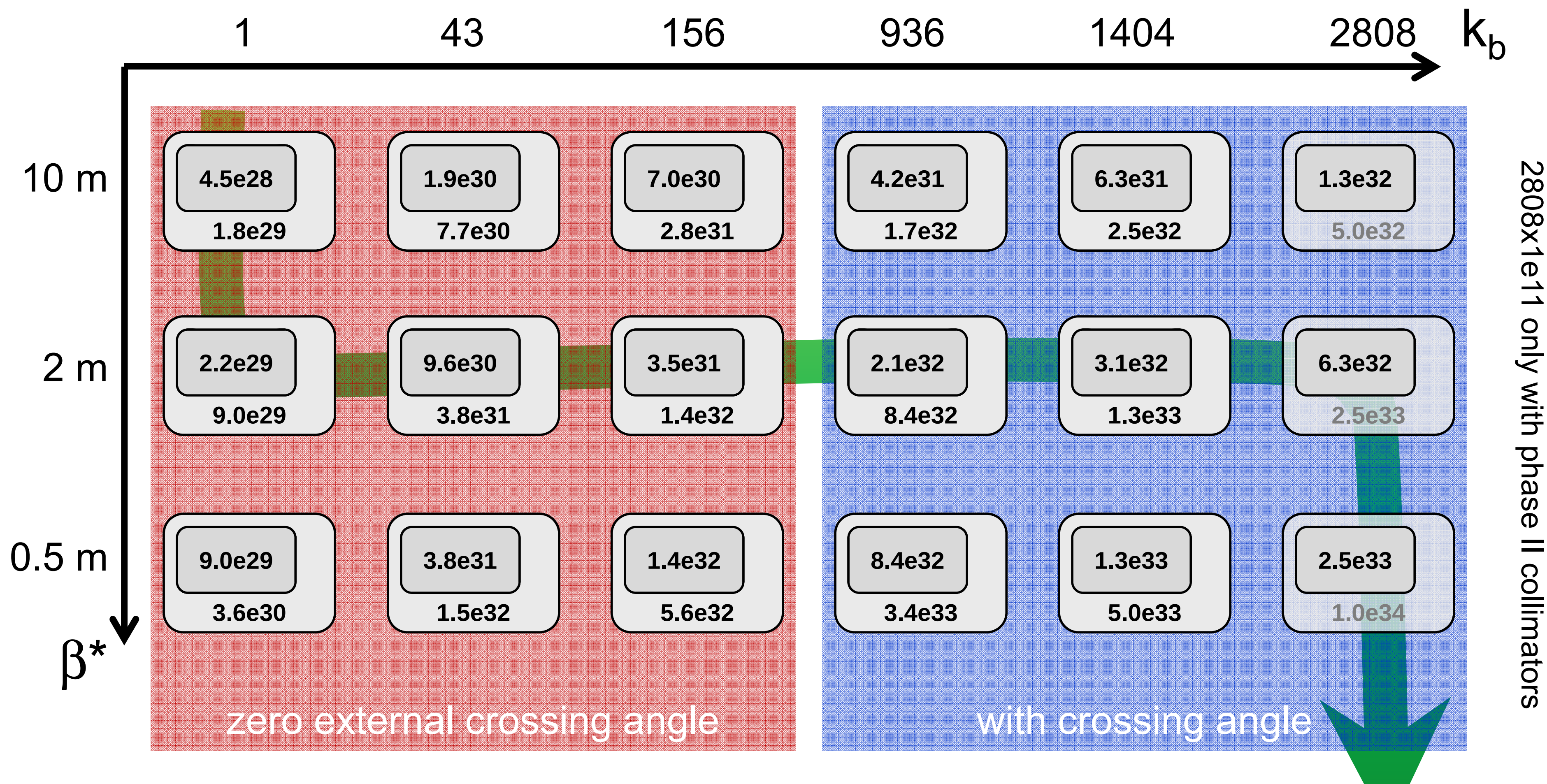
- Energy dependence of particle production at hadron collider driven by parton distributions



$$x_{1,2} \sim (Me^{\pm y})/\sqrt{s}$$

Figure 16.4: Distributions of x times the unpolarized parton distributions $f(x)$ (where $f = u_v, d_v, \overline{u}, \overline{d}, s, c, b, g$) and their associated uncertainties using the NNLO MRST2006 parameterization [13] at a scale $\mu^2 = 20\ \mathrm{GeV}^2$ and $\mu^2 = 10,000\ \mathrm{GeV}^2$.

Luminosity



Bunch charge N = 5e10 / 1e11

crossing angle factor not applied
ranges from 0.84 to 0.96
depending on k_b, N, β*