LHC-CC09

3rd LHC Crab Cavity Workshop

European Organization for Nuclear Research, CERN, Geneva, CH

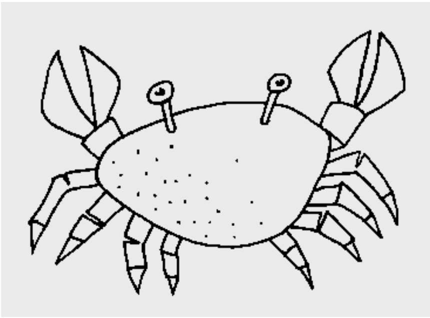
16th-18th September 2009

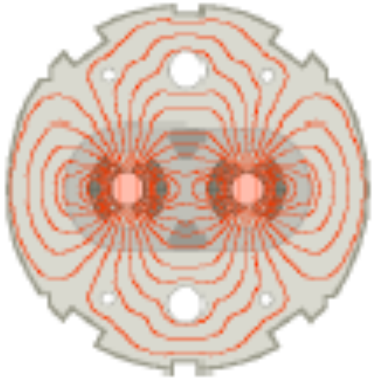
Operational Aspects of the Phase II Crab Cavity System

Stefano Redaelli

Beam Department - Operations Group

Acknowledgments: R. Bailey, J. Tückmantel
R. Calaga, R. Tomás, F. Zimmermann





Outline

- **Introduction**
- **Commissioning baseline**
  - *Strategy*
  - *Procedures*
- **Crab cavity operation aspects**
  - *Integration into LHC procedures*
  - *Safe beam tests*
- **Conclusions**

Scope - Introduction

Scope - Introduction

- **Scope** of this presentation in the context of CC Phase II system:
  - *- Introduce/review beam commissioning procedures*
  - *- Show the framework that the CC commissioning has to comply with*
  - *- Identify main working areas - if possible - to establish safe commissioning procedures for the nominal operation*
  - *- This talk does NOT provide detailed procedures*

Scope - Introduction

- **Scope** of this presentation in the context of CC Phase II system:
  - *- Introduce/review beam commissioning procedures*
  - *- Show the framework that the CC commissioning has to comply with*
  - *- Identify main working areas - if possible - to establish safe commissioning procedures for the nominal operation*
  - *- This talk does NOT provide detailed procedures*

- The procedures for the LHC beam commissioning were established in preparation for the **7 TeV operation**.

  Collective effort of OP team and system experts; first version by mid-2008

Scope - Introduction

- **Scope** of this presentation in the context of CC Phase II system:
  - *Introduce/review beam commissioning procedures*
  - *Show the framework that the CC commissioning has to comply with*
  - *Identify main working areas - if possible - to establish safe commissioning procedures for the nominal operation*
  - *This talk does NOT provide detailed procedures*
- The procedures for the LHC beam commissioning were established in preparation for the **7 TeV operation**.

  Collective effort of OP team and system experts; first version by mid-2008
- Since then, two things have changed:
  - *HWC → MANY quenches are needed to train the dipoles ("training problem")*
  - *Sep. 19th event → Issue with the interconnections ("splice problem")*

⇒ New commissioning baseline for 2009-2010: **3.5 TeV** → ~5 TeV.

Scope - Introduction

☑ **Scope** of this presentation in the context of CC Phase II system:

- *Introduce/review beam commissioning procedures*
- *Show the framework that the CC commissioning has to comply with*
- *Identify main working areas - if possible - to establish safe commissioning procedures for the nominal operation*
- *This talk does NOT provide detailed procedures*

☑ The procedures for the LHC beam commissioning were established in preparation for the **7 TeV operation**.

Collective effort of OP team and system experts; first version by mid-2008

☑ Since then, two things have changed:

- *HWC → MANY quenches are needed to train the dipoles ("training problem")*
- *Sep. 19th event → Issue with the interconnections ("splice problem")*

⇒ New commissioning baseline for 2009-2010: **3.5 TeV** → ~5 TeV.

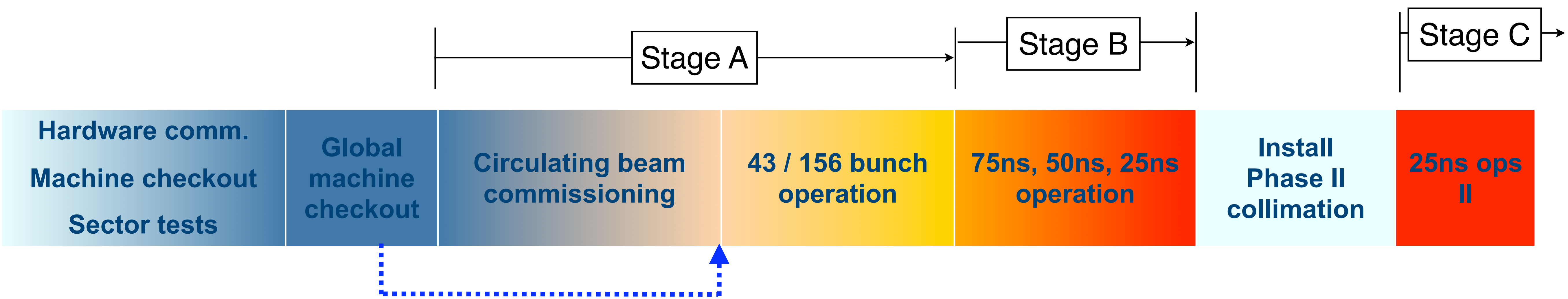
☑ Nevertheless, for the **Phase II system**, the 7 TeV baseline is appropriate:

- *By ~2018 the high energy goal will be achieved.*
- *The operating energy has actually a minor impact on the procedures*

Overall commissioning strategy

LHC beam commissioning **strategy**:

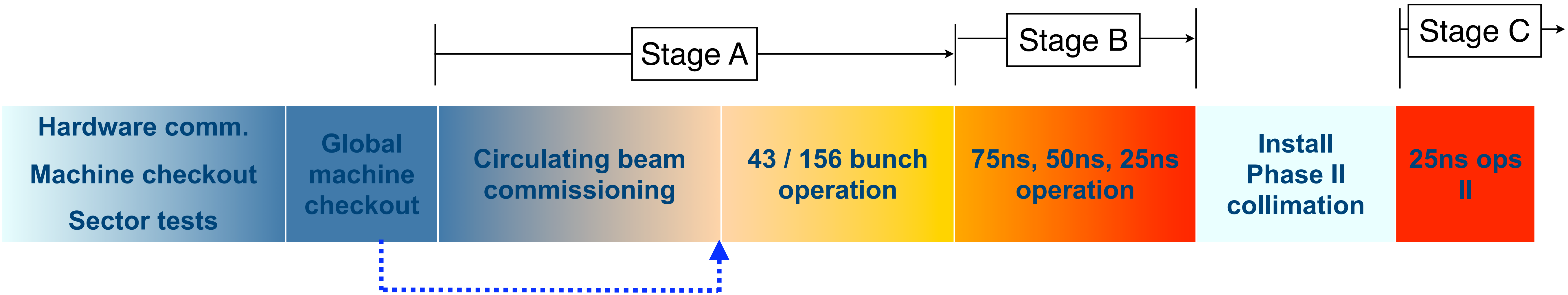
- *Staged approach to address efficiently machine complexity*
- *Physics runs at energy below 7 TeV, imposed by hardware (start with 2x3.5 TeV)*
- *Co-existence of HWC, checkout and sector tests before circulating beam commissioning*
- *Full machine checkout and machine protection commissioning AFTER first beam OP*



Overall commissioning strategy

LHC beam commissioning **strategy**:

- *Staged approach to address efficiently machine complexity*
- *Physics runs at energy below 7 TeV, imposed by hardware (start with 2x3.5 TeV)*
- *Co-existence of HWC, checkout and sector tests before circulating beam commissioning*
- *Full machine checkout and machine protection commissioning AFTER first beam OP*



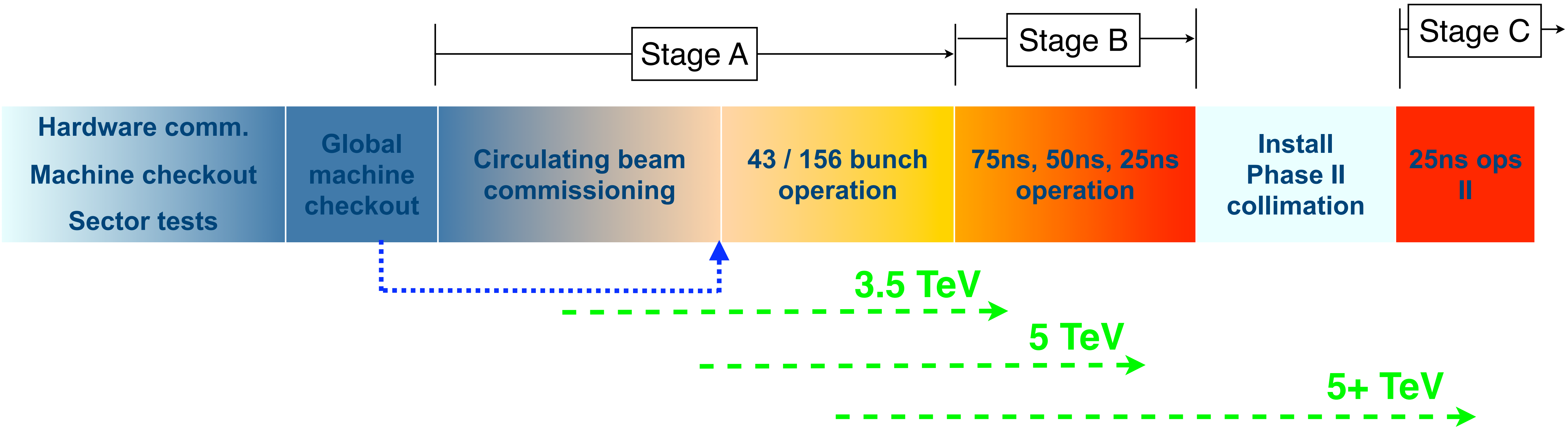
Three beam commissioning stages:

- **Stage A** → Simplest machine configuration (no crossing, moderate squeeze)
- **Stage B** → Up to intensity limit (fill pattern depends on experiment requests)
- **Stage C** → Towards nominal and ultimate performance

Overall commissioning strategy

LHC beam commissioning **strategy**:

- *Staged approach to address efficiently machine complexity*
- *Physics runs at energy below 7 TeV, imposed by hardware (start with 2x3.5 TeV)*
- *Co-existence of HWC, checkout and sector tests before circulating beam commissioning*
- *Full machine checkout and machine protection commissioning AFTER first beam OP*



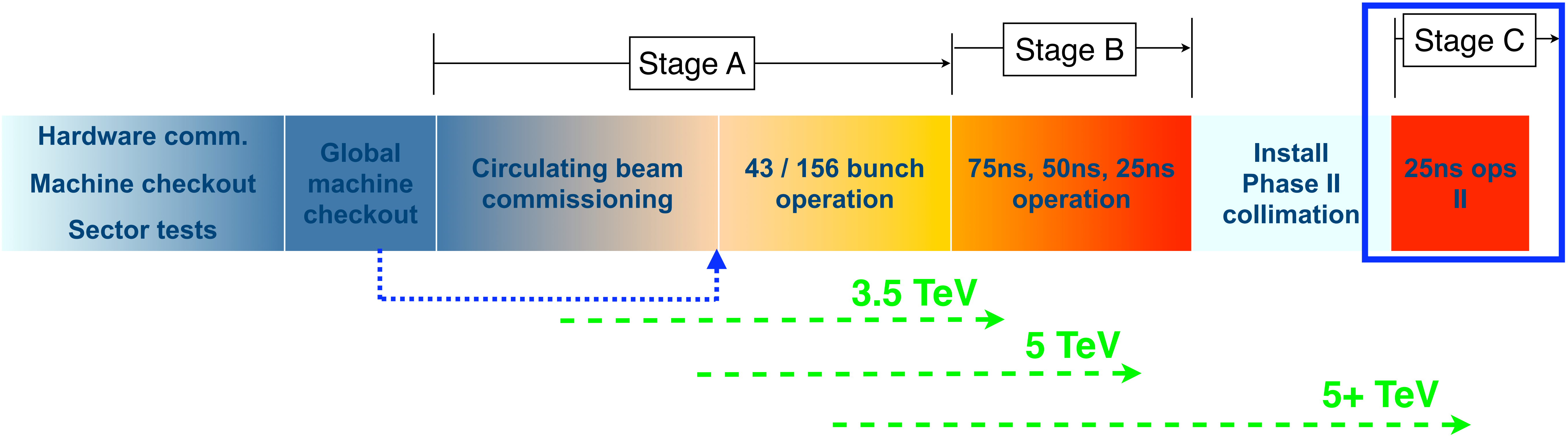
Three beam commissioning stages:

- **Stage A** → Simplest machine configuration (no crossing, moderate squeeze)
- **Stage B** → Up to intensity limit (fill pattern depends on experiment requests)
- **Stage C** → Towards nominal and ultimate performance

Overall commissioning strategy

LHC beam commissioning **strategy**:

- *Staged approach to address efficiently machine complexity*
- *Physics runs at energy below 7 TeV, imposed by hardware (start with 2x3.5 TeV)*
- *Co-existence of HWC, checkout and sector tests before circulating beam commissioning*
- *Full machine checkout and machine protection commissioning AFTER first beam OP*



Three beam commissioning stages:

- **Stage A** → Simplest machine configuration (no crossing, moderate squeeze)
- **Stage B** → Up to intensity limit (fill pattern depends on experiment requests)
- **Stage C** → Towards nominal and ultimate performance

Phase II Crab: well into high performance goal of **Stage C**

Stage A - “early” physics runs

- Procedures for Stage A elaborated within the LHC Commissioning Working Group
  Put together operation team, commissioning team and “owners” of accelerator systems
- LHC Engineers in Charge and Commissioners responsible for the preparation
  Details worked out at the LHCCWG, then approval at the LTC
- Web-based documentation, strict approval of EDMS documents

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**
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**

http://lhccwg.web.cern.ch/lhccwg/

Stage A - "early" physics runs

- Procedures for Stage A elaborated within the LHC Commissioning Working Group
  Put together operation team, commissioning team and "owners" of accelerator systems
- LHC Engineers in Charge and Commissioners responsible for the preparation
  Details worked out at the LHCCWG, then approval at the LTC
- Web-based documentation, strict approval of EDMS documents

Phase A.1	**First turn:** injection commissioning; threading, commiss instrumentation. Ring 1, ring 2.
Phase A.2	**Circulating pilot:** establish circulating beam, closed orb ...
Phase A.3	**450 GeV initial commissioning:** system commissioning beam dump,...
Phase A.4	**450 GeV optics:** beta beating, dispersion, coupling, non aperture,...
Phase A.5	**450 GeV, increasing intensity:** prepare the LHC for un
Phase A.6	**450 GeV, two beam operation**
Phase A.7	**450 GeV, collisions**
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**

CERN
CH-1211 Geneva 23
Switzerland

the **Large Hadron Collider** project

LHC Project Document No.
LHC-OP-BCP-0002 rev 1.0

CERN Div./Group or Supplier/Contractor Document No.
LHCCWG

EDMS Document No.
850423

Date: 2007-10-29

Beam Commissioning Procedure

LHC COMMISSIONING WITH BEAM:
PHASE A.1 (FIRST TURN)

Abstract
This document describes the LHC beam commissioning procedures for the first turn. It covers the entry conditions, the commissioning procedures and exit conditions of this phase. Possible problems and open questions are also listed.

Prepared by :	*Checked by :*	*Approved by:*
R.Alemany Fernandez B.Goddard M.Gruwé V.Kain L.Ponce S.Redaelli W.Venturini On behalf of the LHCCWG	LHCCWG	R.Bailey O.Bruning P.Collier M.Lamont S.Myers

LHCCWG list:
R.Alemany Fernandez, G. Arduini, R. Assmann, R.Bailey, O.Bruning, H.Burkhardt, A.Butterworth, P.Collier, S.Fartoukh, M.Giovannozzi, B.Goddard, J.-J.Gras, M.Gruwé, R.Jones, V.Kain, P.Koutchouk, M.Lamont, A.MacPherson, L.Ponce, S.Redaelli, R.Saban, F.Schmidt, R.Schmidt, R.Steinhagen, E.Todesco, J.Uythoven, W.Venturini Delsolaro, J.Wenninger, T.Wijnands, F.Zimmermann

Approval list:
M.Barnes, F.Bordry, L.Bottura, L.Bruno, T.Camporesi, E.Carlier, P.Ciriani, L.Ducimetiere, K.Eggert, L.Evans, M.Ferro-Luzzi, R.Garoby, M.Gyr, J.-M.Jimenez, Y.Kadi, A.Koschik, J.-T.Kramer, J.Lettry, P.Lebrun, T.Linnecar, D.Macina, S.Maury, V.Mertens, K.-H.Mess, G.Mornacchi, M.Nessi, Y.Papaphilippou, W.Rieger, G.Roy, H.Schmickler, A.Schopper, F.Strubin, G.Tranquille, E.Tsesmelis, R.VanWeelderen

http://lhccwg.web.cern.ch/lhccwg/

Stage A - “early” physics runs

- Procedures for Stage A elaborated within the LHC Commissioning Working Group
  Put together operation team, commissioning team and “owners” of accelerator systems
- LHC Engineers in Charge and Commissioners responsible for the preparation
  Details worked out at the LHCCWG, then approval at the LTC
- Web-based documentation, strict approval of EDMS documents

Phase A.1	**First turn:** injection commissioning; threading, commis instrumentation. Ring 1, ring 2.
Phase A.2	**Circulating pilot:** establish circulating beam, closed orb ...
Phase A.3	**450 GeV initial commissioning:** system commissioning beam dump,...
Phase A.4	**450 GeV optics:** beta beating, dispersion, coupling, non aperture,...
Phase A.5	**450 GeV, increasing intensity:** prepare the LHC for un
Phase A.6	**450 GeV, two beam operation**
Phase A.7	**450 GeV, collisions**
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**

http://lhccwg.web.cern.ch/lhccwg/

CERN
CH-1211 Geneva 23
Switzerland

LHC Project Document No.
LHC-OP-BCP-0002 rev 1.0

CERN
CH-1211 Geneva 23
Switzerland

the Large Hadron Collider project

LHC Project Document No.
LHC-OP-BCP-0005 rev 0.2

CERN Div./Group or Supplier/Contractor Document No.
LHCCWG

EDMS Document No.
876824

Date: 2007-11-30

Beam Commissioning Procedure

LHC COMMISSIONING WITH BEAM: PHASE A.4 (450 GEV OPTICS)

Abstract
This document describes the LHC beam commissioning procedures for the detailed measurements with circulating beams at 450 GeV. It covers the entry conditions, the commissioning procedures and exit conditions of this phase. Possible problems and open questions are also listed.

Prepared by :	*Checked by :*	*Approved by:*
R.Alemany Fernandez M.Gruwé V.Kain L.Ponce S.Redaelli W.Venturini F. Zimmermann On behalf of the LHCCWG	LHCCWG	R.Bailey O.Bruning P.Collier M.Lamont S.Myers

LHCCWG list:
R.Alemany Fernandez, G. Arduini, R. Assmann, R.Bailey, O.Bruning, H.Burkhardt, A.Butterworth, P.Collier, S.Fartoukh, M.Giovannozzi, B.Goddard, J.-J.Gras, M.Gruwé, R.Jones, V.Kain, P.Koutchouk, M.Lamont, A.MacPherson, L.Ponce, S.Redaelli, R.Saban, F.Schmidt, R.Schmidt, R.Steinhagen, E.Todesco, J.Uythoven, W.Venturini Delsolaro, J.Wenninger, T.Wijnands, F.Zimmermann

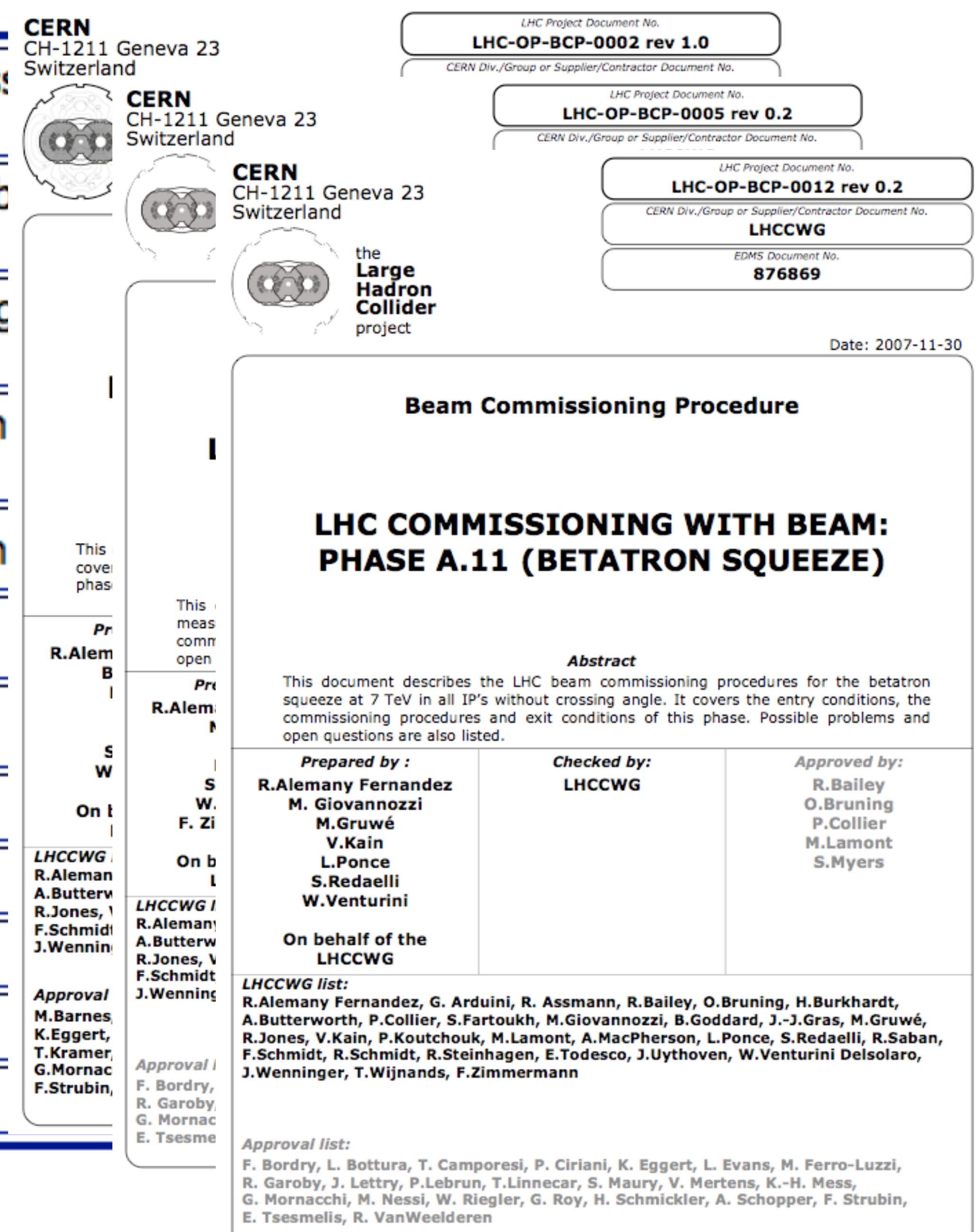
Approval list:
F. Bordry, L. Bottura, T. Camporesi, P. Ciriani, K. Eggert, L. Evans, M. Ferro-Luzzi, R. Garoby, J. Lettry, P.Lebrun, T.Linnecar, S. Maury, V. Mertens, K.-H. Mess, G. Mornacchi, M. Nessi, W. Riegler, G. Roy, H. Schmickler, A. Schopper, F. Strubin, E. Tsesmelis, R. VanWeelderen

Stage A - "early" physics runs

- Procedures for Stage A elaborated within the LHC Commissioning Working Group
  Put together operation team, commissioning team and "owners" of accelerator systems
- LHC Engineers in Charge and Commissioners responsible for the preparation
  Details worked out at the LHCCWG, then approval at the LTC
- Web-based documentation, strict approval of EDMS documents

Phase A.1	**First turn:** injection commissioning; threading, commis instrumentation. Ring 1, ring 2.
Phase A.2	**Circulating pilot:** establish circulating beam, closed orb ...
Phase A.3	**450 GeV initial commissioning:** system commissioninc beam dump,...
Phase A.4	**450 GeV optics:** beta beating, dispersion, coupling, non aperture,...
Phase A.5	**450 GeV, increasing intensity:** prepare the LHC for un
Phase A.6	**450 GeV, two beam operation**
Phase A.7	**450 GeV, collisions**
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**

http://lhccwg.web.cern.ch/lhccwg/


CERN
CH-1211 Geneva 23
Switzerland

the Large Hadron Collider project

LHC Project Document No.
LHC-OP-BCP-0002 rev 1.0

LHC Project Document No.
LHC-OP-BCP-0005 rev 0.2

LHC Project Document No.
LHC-OP-BCP-0012 rev 0.2
CERN Div./Group or Supplier/Contractor Document No.
LHCCWG
EDMS Document No.
876869

Date: 2007-11-30

Beam Commissioning Procedure

LHC COMMISSIONING WITH BEAM: PHASE A.11 (BETATRON SQUEEZE)

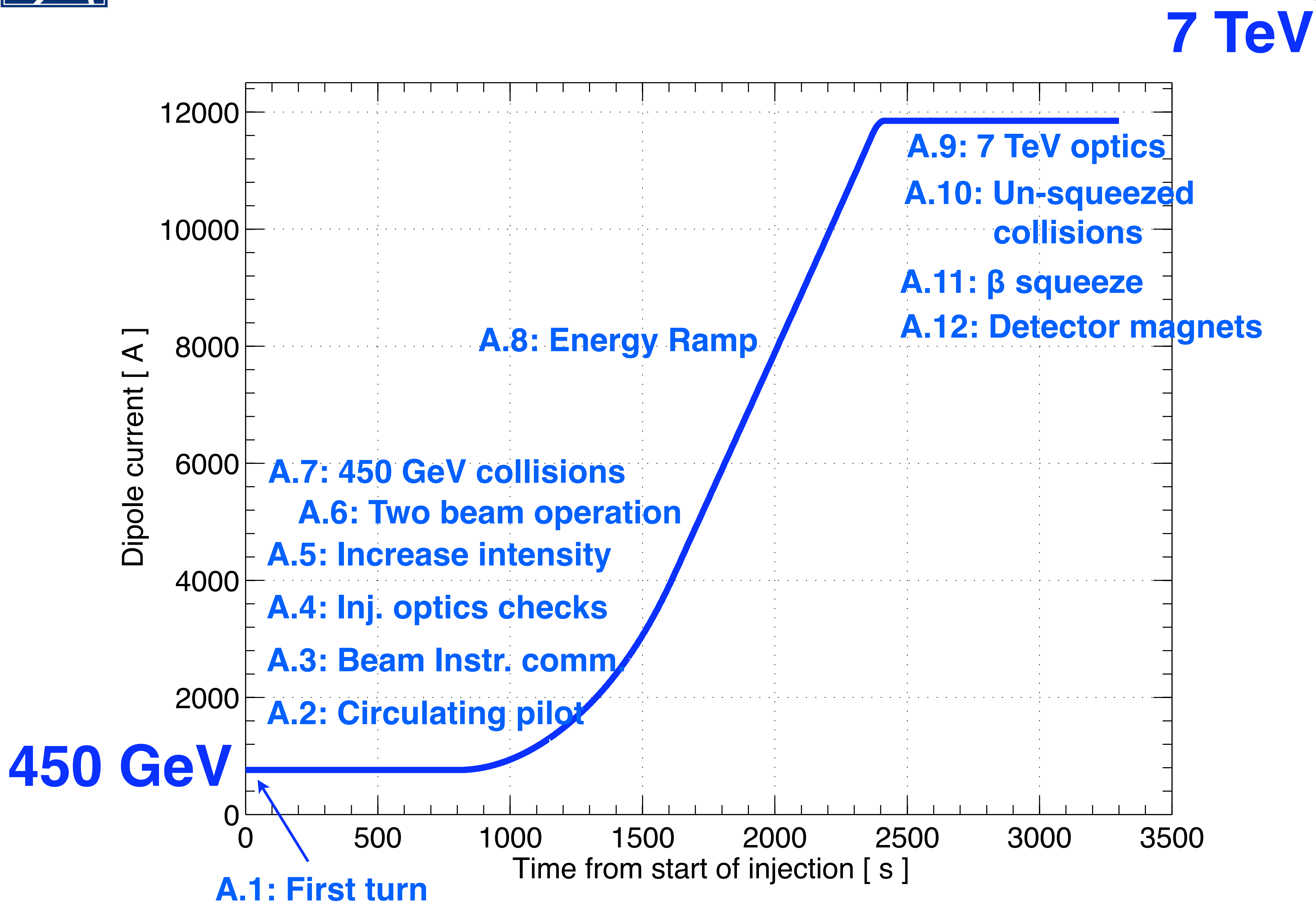
Abstract
This document describes the LHC beam commissioning procedures for the betatron squeeze at 7 TeV in all IP's without crossing angle. It covers the entry conditions, the commissioning procedures and exit conditions of this phase. Possible problems and open questions are also listed.

Prepared by :	Checked by:	Approved by:
R.Alemany Fernandez M. Giovannozzi M.Gruwé V.Kain L.Ponce S.Redaelli W.Venturini On behalf of the LHCCWG	LHCCWG	R.Bailey O.Bruning P.Collier M.Lamont S.Myers

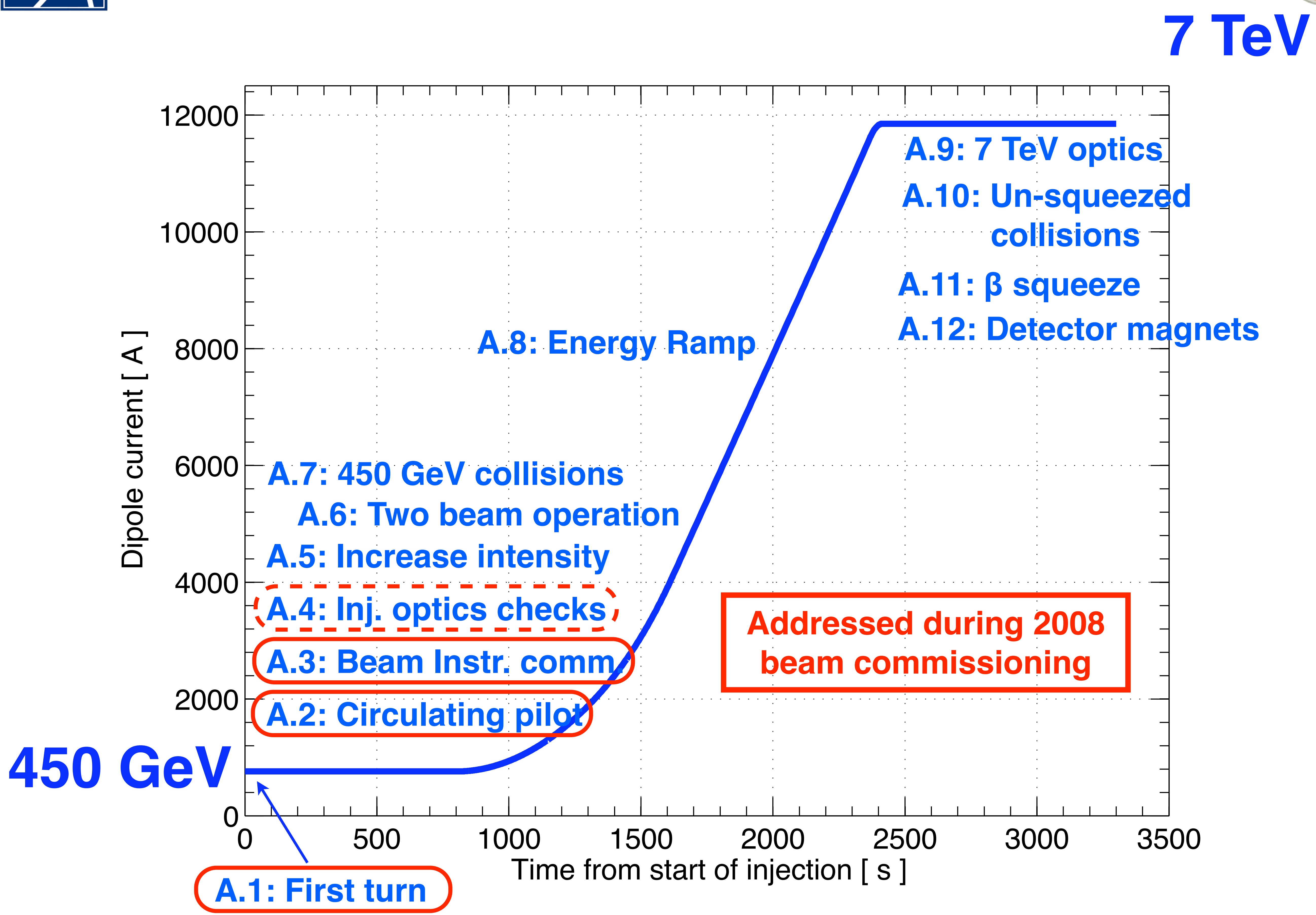
LHCCWG list:
R.Alemany Fernandez, G. Arduini, R. Assmann, R.Bailey, O.Bruning, H.Burkhardt, A.Butterworth, P.Collier, S.Fartoukh, M.Giovannozzi, B.Goddard, J.-J.Gras, M.Gruwé, R.Jones, V.Kain, P.Koutchouk, M.Lamont, A.MacPherson, L.Ponce, S.Redaelli, R.Saban, F.Schmidt, R.Schmidt, R.Steinhagen, E.Todesco, J.Uythoven, W.Venturini Delsolaro, J.Wenninger, T.Wijnands, F.Zimmermann

Approval list:
F. Bordry, L. Bottura, T. Camporesi, P. Ciriani, K. Eggert, L. Evans, M. Ferro-Luzzi, R. Garoby, J. Lettry, P.Lebrun, T.Linnecar, S. Maury, V. Mertens, K.-H. Mess, G. Mornacchi, M. Nessi, W. Riegler, G. Roy, H. Schmickler, A. Schopper, F. Strubin, E. Tsesmelis, R. VanWeelderen

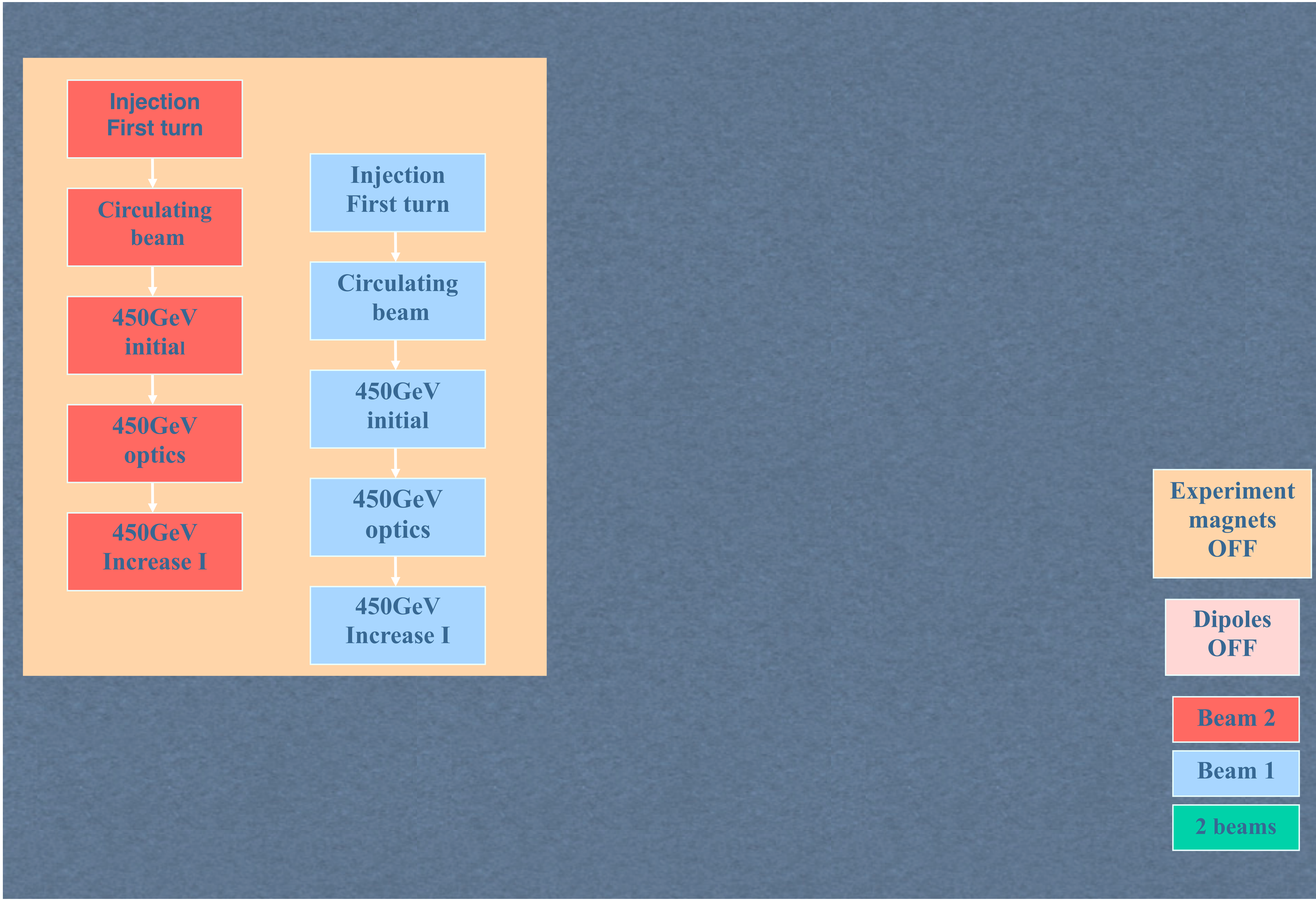
Geography of Stage A phases



Geography of Stage A phases

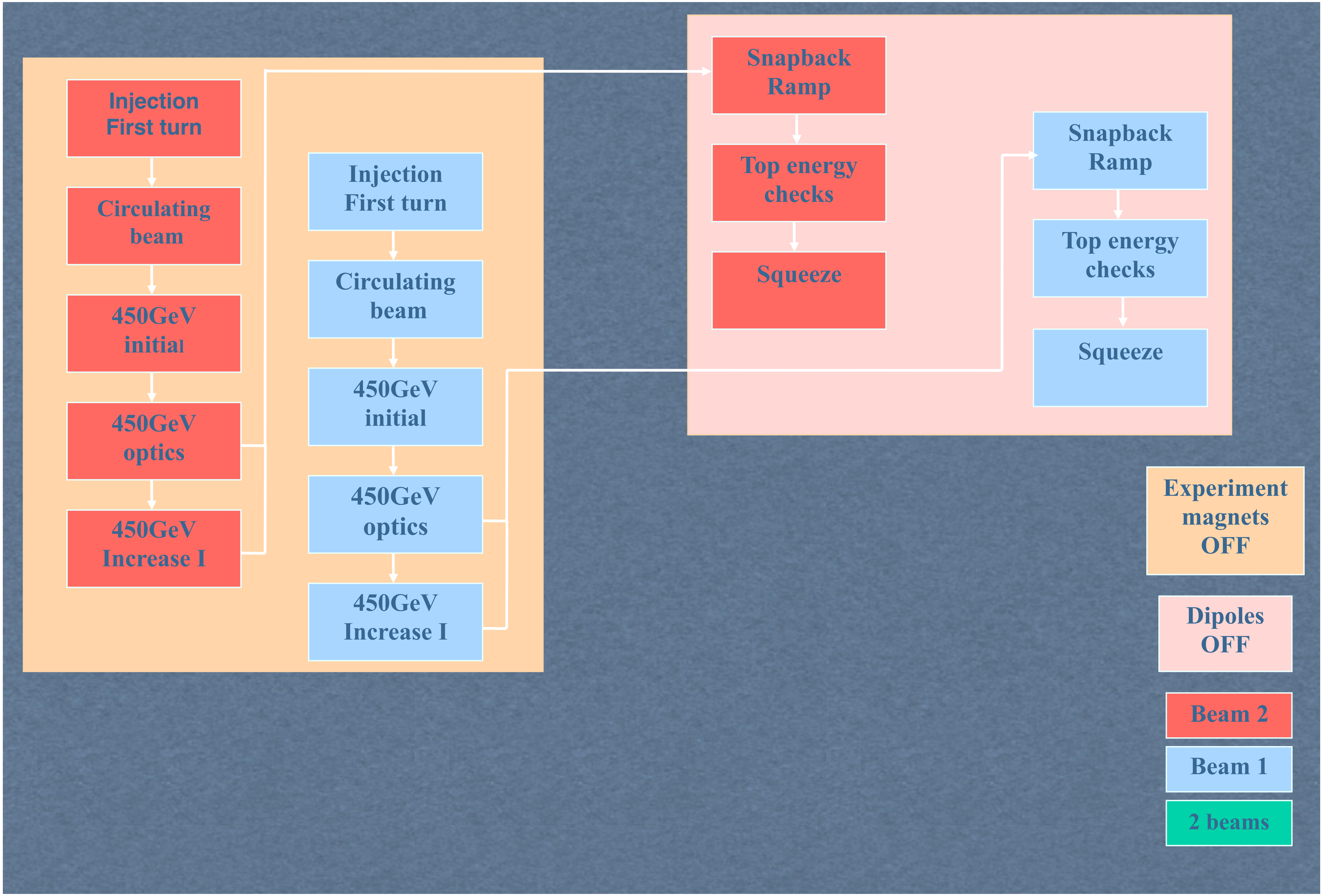


Flow chart



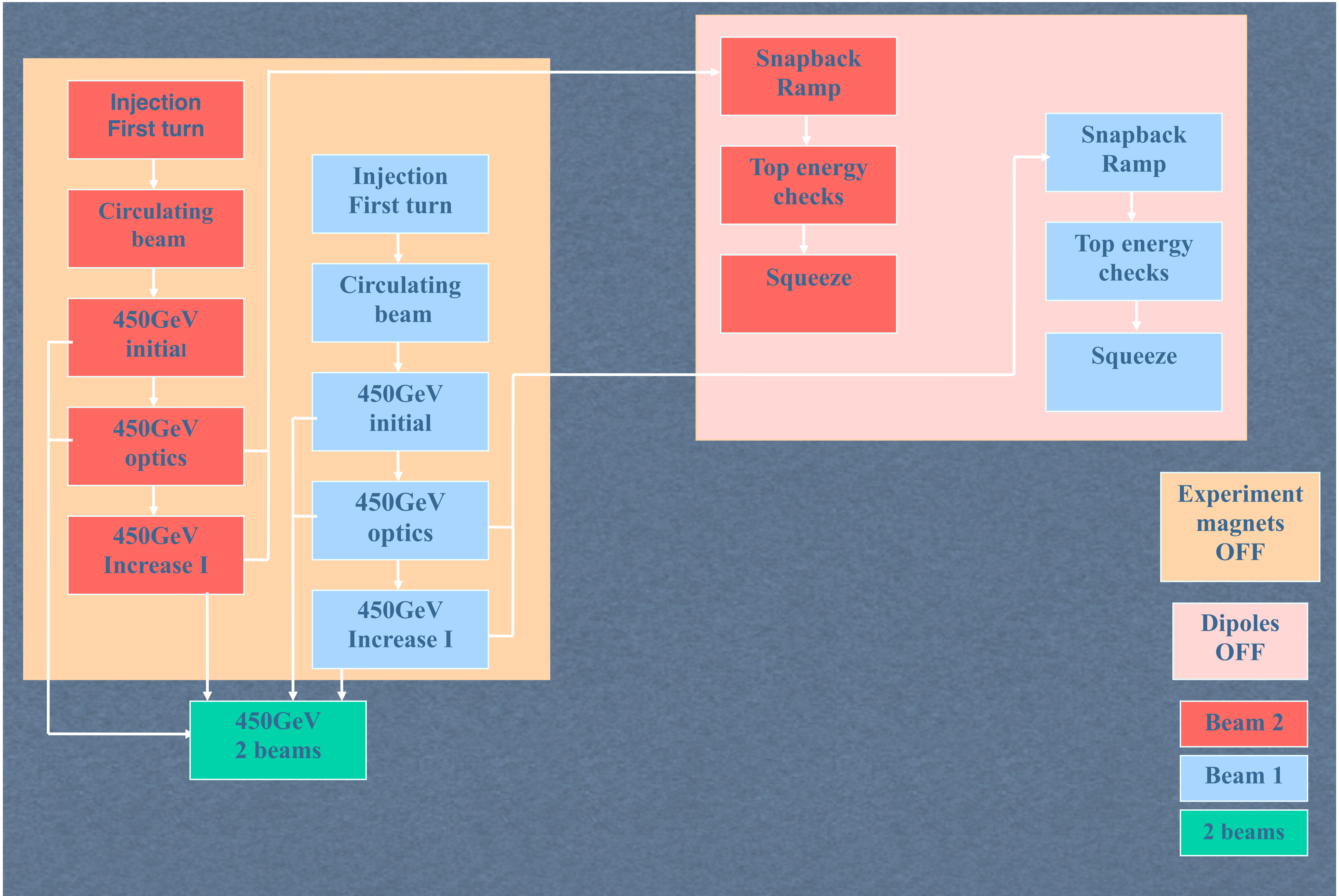
Injection First turn
Circulating beam
450GeV initial
450GeV optics
450GeV Increase I
Injection First turn
Circulating beam
450GeV initial
450GeV optics
450GeV Increase I
Experiment magnets OFF
Dipoles OFF
Beam 2
Beam 1
2 beams

Flow chart



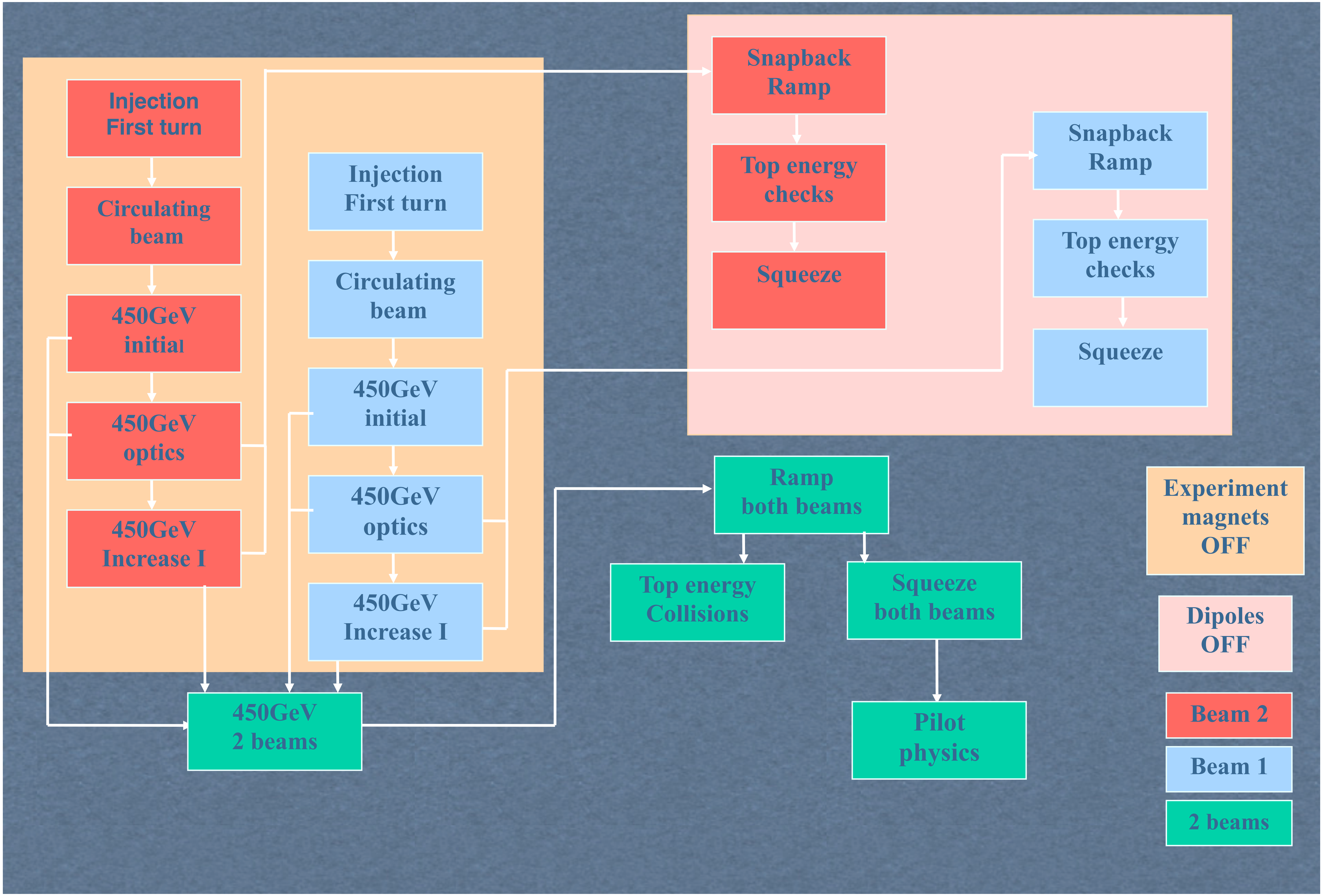
Injection
First turn
Circulating
beam
450GeV
initial
450GeV
optics
450GeV
Increase I
Injection
First turn
Circulating
beam
450GeV
initial
450GeV
optics
450GeV
Increase I
Snapback
Ramp
Top energy
checks
Squeeze
Snapback
Ramp
Top energy
checks
Squeeze
Experiment
magnets
OFF
Dipoles
OFF
Beam 2
Beam 1
2 beams

Flow chart



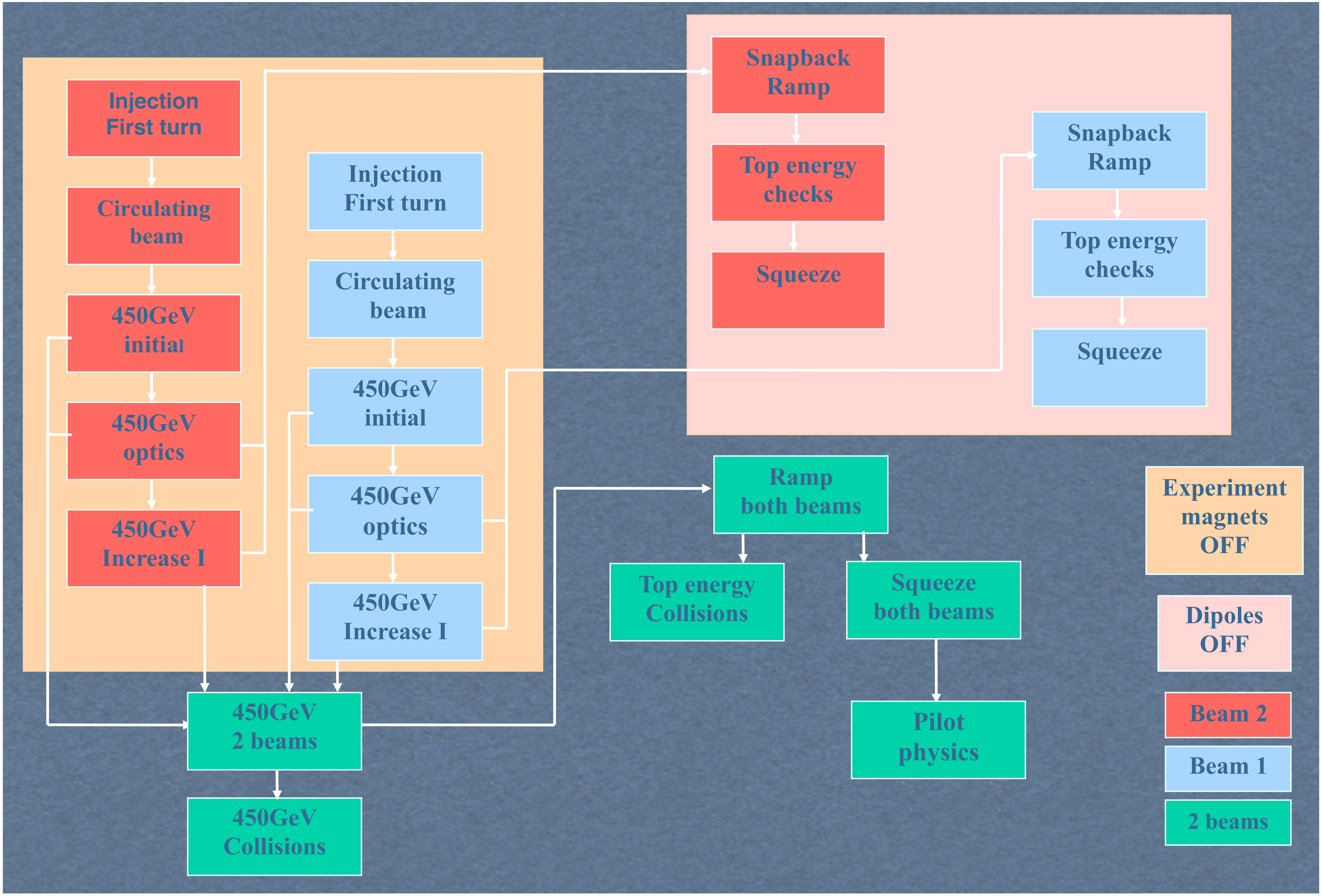
Injection
First turn
Circulating
beam
450GeV
initial
450GeV
optics
450GeV
Increase I
Injection
First turn
Circulating
beam
450GeV
initial
450GeV
optics
450GeV
Increase I
450GeV
2 beams
Snapback
Ramp
Top energy
checks
Squeeze
Snapback
Ramp
Top energy
checks
Squeeze
Experiment
magnets
OFF
Dipoles
OFF
Beam 2
Beam 1
2 beams

Flow chart



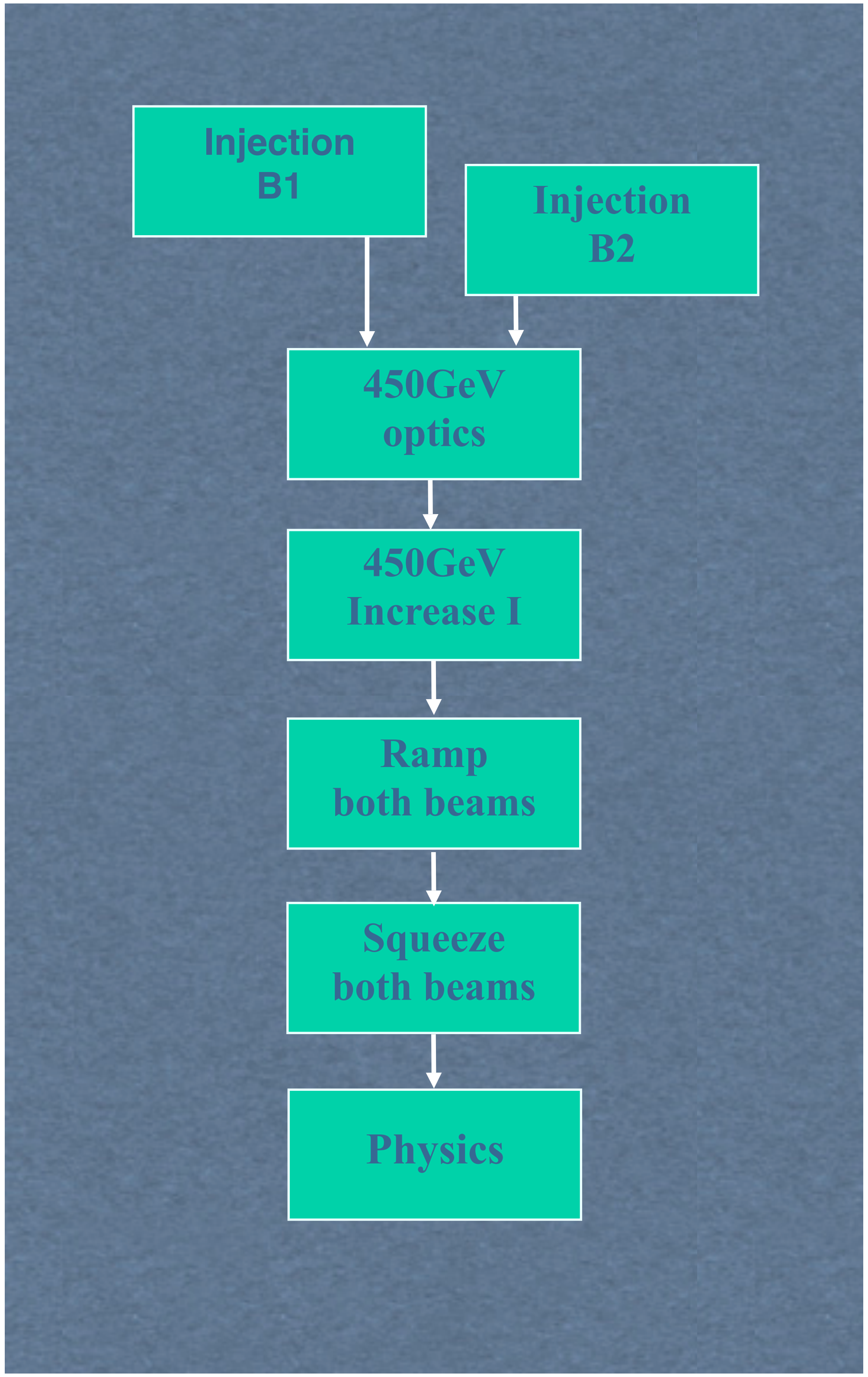
Injection First turn
Circulating beam
450GeV initial
450GeV optics
450GeV Increase I
Injection First turn
Circulating beam
450GeV initial
450GeV optics
450GeV Increase I
450GeV 2 beams
Snapback Ramp
Top energy checks
Squeeze
Snapback Ramp
Top energy checks
Squeeze
Ramp both beams
Top energy Collisions
Squeeze both beams
Pilot physics
Experiment magnets OFF
Dipoles OFF
Beam 2
Beam 1
2 beams

Flow chart

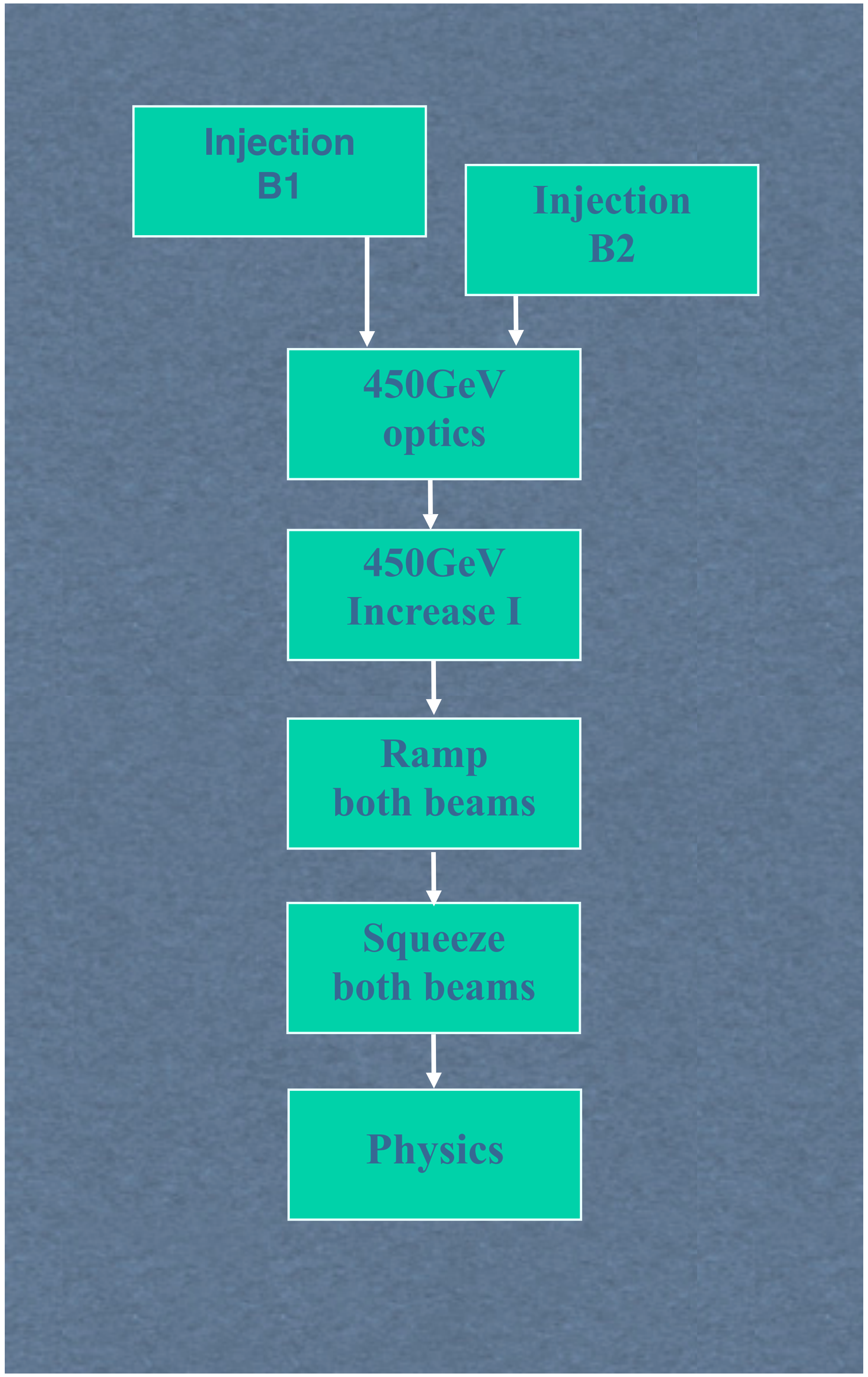


Injection First turn
Circulating beam
450GeV initial
450GeV optics
450GeV Increase I
Injection First turn
Circulating beam
450GeV initial
450GeV optics
450GeV Increase I
450GeV 2 beams
450GeV Collisions
Snapback Ramp
Top energy checks
Squeeze
Snapback Ramp
Top energy checks
Squeeze
Ramp both beams
Top energy Collisions
Squeeze both beams
Pilot physics
Experiment magnets OFF
Dipoles OFF
Beam 2
Beam 1
2 beams

Flow chart - nominal operation



Flow chart - nominal operation



Clearly, we must go back to the commissioning flaw in case of ***major machine*** *changes:*

- *Intensity / energy steps*
- *Changes of crossing schemes*
- *Early re-commissioning*
- *...*

Both CC ***Phase I*** *and* ***Phase II*** *have to be considered "major machine changes" and therefore require:*

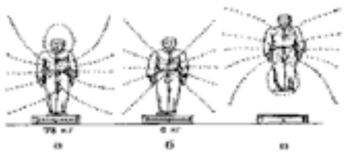
- *full integration into existing procedures*
- *dedicated commissioning time*

Details: steps of commissioning phases

Work in progress

Stage A

Pilot physics run



LHC Beam Commissioning

Phase A.4

450 GeV optics

- home
- overview
- description
- entry conditions
- procedure
- exit conditions
- problems
- questions
- references
- acronyms

Ü previous next Þ

Procedure for Phase A.4:

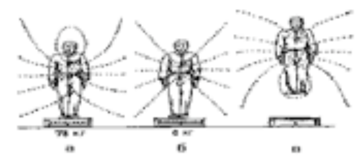
Step	Activity	Who	Priority
A.4.1	**Measurement and correction of the closed orbit**		**1**
A.4.1.1	Measurement and correction of arcs and IPs (independently for beam 1 and 2)	ABP/BI/OP	1
A.4.1.2	Measurement and correction of each IR (needs another iteration with 2 beams)	ABP/BI/OP	1
A.4.1.3	Iterate after more detailed optics knowledge, if needed	ABP/BI/OP	2
A.4.2	**Measurement and correction of the linear optics**		**1**
A.4.2.1	Commissioning of MQX linear correctors (if not in A.4.1.1), polarity checks for MQT, MQS circuits	OP	1
A.4.2.2	Tune	ABP/BI/OP	1
A.4.2.3	Coupling (possibly needs another iteration with 2 beams)	ABP/BI/OP	1
A.4.2.4	Beta-beat (needs another iteration with 2 beams)	ABP/BI/OP	1
A.4.2.5	Dispersion (needs another iteration with 2 beams)	ABP/BI/OP	1
A.4.2.6	Refined optics model -> Response matrix, BPM calibration (no beam time)	ABP/BI/OP	2
A.4.2.7	Generation of new reference settings for correctors, if necessary	ABP/BI/OP	2
A.4.2.8	Additional local beta measurements with K-modulation (IR's, wires, collimators, ...)	ABP/BI/OP	2
A.4.3	**Measurement and correction of the aperture**		**1**
A.4.3.1	Commission the software for sliding bumps, if available	ABP/OP	1
A.4.3.2	Global aperture measurements	ABP/OP	1
A.4.3.3	Local bumps to centre orbit into aperture [if needed]	ABP/OP	2
A.4.3.4	Iteration of A.4.3.1 and A.4.3.2 until we achieve tolerances [if needed]	ABP/OP	2
A.4.3.5	Update/maintenance of the aperture database [if available]	ABP/OP	2
A.4.3.6	Dedicated local aperture measurements (IR's, dump, ...)	ABP/OP	2
A.4.3.7	Commission other measurements (emitance blow-up, AC dipole), cross checks	ABP/OP	2
A.4.4	**Detailed RF measurements**		**1**
A.4.4.1	Final commissioning of the radial loop with updated optics knowledge	RF	1
A.4.4.2	Longitudinal profile [parasitic]	RF	1
A.4.5	**Measurement of the momentum aperture**		**1**
A.4.5.1	Radial steering scans	ABP/OP	1
A.4.6	**Beam commissioning of collimators and protection devices for energy ramp**		**1**
A.4.6.1	Beam-based alignment of the required collimators (TCPs, TCDQ, TCTs, some TCSs)	Coll/BT	1
A.4.6.2	Empirical measurements of local beta-functions and beam sizes	Coll/BT	1
A.4.6.3	Beam-based information into the database, define reference settings, ...	Coll	1
A.4.6.3	First estimate of setting reproducibility	Coll	1
A.4.7	**Measurements of the global non-linear optics**		**1**

Details: steps of commissioning phases

Work in progress

Stage A

Pilot physics run



LHC Beam Commissioning

Phase A.4

450 GeV optics

- home
- overview
- description
- entry conditions
- procedure
- exit conditions
- problems
- questions
- references
- acronyms

Ü previous next Þ

Proced

Step	Activity
A.4.1	**Measurement and correction of the**
A.4.1.1	Measurement and correction of arcs an
A.4.1.2	Measurement and correction of each IF
A.4.1.3	Iterate after more detailed optics know
A.4.2	**Measurement and correction of the**
A.4.2.1	Commissioning of MQX linear corrector MQS circuits
A.4.2.2	Tune
A.4.2.3	Coupling (possibly needs another iterat
A.4.2.4	Beta-beat (needs another iteration wit
A.4.2.5	Dispersion (needs another iteration wit
A.4.2.6	Refined optics model -> Response matr
A.4.2.7	Generation of new reference settings f
A.4.2.8	Additional local beta measurements wit
A.4.3	**Measurement and correction of the**
A.4.3.1	Commission the software for sliding bu
A.4.3.2	Global aperture measurements
A.4.3.3	Local bumps to centre orbit into apertu
A.4.3.4	Iteration of A.4.3.1 and A.4.3.2 until w
A.4.3.5	Update/maintenance of the aperture d
A.4.3.6	Dedicated local aperture measurement
A.4.3.7	Commission other measurements (emi
A.4.4	**Detailed RF measurements**
A.4.4.1	Final commissioning of the radial loop v
A.4.4.2	Longitudinal profile [parasitic]
A.4.5	**Measurement of the momentum a**
A.4.5.1	Radial steering scans
A.4.6	**Beam commissioning of collimator**
A.4.6.1	Beam-based alignment of the required
A.4.6.2	Empirical measurements of local beta-f
A.4.6.3	Beam-based information into the datat
A.4.6.3	First estimate of setting reproducibility
A.4.7	**Measurements of the global non-li**

A.4.2 Measurement and correction of the linear optics [single bunch, I~1e10p; one beam at a time]

A.4.2.1 Commission MQX linear correctors (if not done in A4.1), polarity checks for MQT, MQS circuits

- Polarity checks and calibration of the required circuits, if needed

A.4.2.2 Detailed tune measurement

- Preliminary measurement before a coupling correction.
- Tune measurements with tune kicker + trajectory acquisition. See A.3.4 [item 5]. Might require tweaking of the chromaticity to get cleaner signals, see pages 8-9 of F. Zimmermann's talk [2].
- If already operational, rely on BBQ and/or PLL
- Correct if necessary
- Iterate again after coupling and beta corrections (A.4.2.3 and A.4.2.4), if needed

A.4.2.3 Coupling (possibly needs another iteration with 2 beams)

- The goal here is to commission the nominal injection optics (in case up to phase A.3 we were forced to used the commissiong tunes with large Qh/Qv tune split)
- If coupling feedback is commissioned and operational, repeat detailed measurement with nominal tunes
- If the coupling is not under control, go to the special working point with increased tune separation.
- Iterate until we can work with the nominal tunes

A.4.2.4 Beta-beat (needs another iteration with 2 beams)

- Phase-advance method proposed by R. Tomas [4, 5]
- Repeat A.4.2.2 if needed

A.4.2.5 Dispersion (needs another iteration with 2 beams)

- Same as for beta-beat [4, 5]

A.4.2.6 Refined optics model: Update response matrices and BPM calibrations for feedback, if necessary

- Compute again the response matrix needed for the correction algorithms (YASP, feedbacks, ...). See A.3.4
- Use a few new COD scans (enough data should be available from previous steps)
- For references, see J. Wenninger's talk [9]
- No beam time needed, use parasitically the data from other measurements

A.4.2.7 Generation of new settings for various correctors, if necessary

- With the best optics knowledge, revise the settings of orbit, tune, coupling and beta corrections, if needed

A.4.2.8 Additional local beta measurements with K-modulation (IR's, wires, collimators, ...)

- Detailed local beta measurements with K-modulation
- Proposed list of locations: Wire scanners, collimator/dump regions, triplets, ...
- Only possible for independently powered quadrupoles during 2008 run (see LTC minutes of August 28th, 2007). K-modulation not possible in the arcs.

Ion commissioning procedures

Commissioning plan elaborated by ion team. Specific aspects tackled separately:

RF, BI, Collimation, protection, BLM quench thresholds

Web documentation addresses specific ion aspects for each step:

http://lhc-commissioning.web.cern.ch/lhc-commissioning/ions/stage_1_EarlyIons.htm

Stage I: From start to first collisions of Early Ion Beam

Assume we slice commissioning procedures to the minimum required to get 2 Early Ion beams to 7 Z TeV (or some lower energy to be decided upon) and collide them unsqueezed. We should be starting from a machine that already does the equivalent with protons so many procedures can be skipped or compressed.

The time estimates for each step are provisional pending experience with protons. Some steps may be skipped or adapted at short notice according to circumstances and priorities.

		Ring factor	Total Time [days] both rings	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 tr -5 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 i
I7	Collisions at 450 Z GeV	1	1 ?	If interesting. Performance to summarise.
I8	Snapback and ramp	2	0.5	Single and then two beams, Magnetically identical to pr Check beam dump at various energies.
I9	7 Z TeV flat top checks	2	0.5	Single beam initially, performed following successful ra
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 & A
	TOTAL to first collisions		6	
I11	Commission squeeze	2	2	Commission squeeze of ALICE to same as presently ac ATLAS (with ATLAS and CMS unsqueezed). May ha 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 g

Ion commissioning procedures

Commissioning plan elaborated by ion team. Specific aspects tackled separately:

RF, BI, Collimation, protection, BLM quench thresholds

Web documentation addresses specific ion aspects for each step:

http://lhc-commissioning.web.cern.ch/lhc-commissioning/ions/stage_1_EarlyIons.htm

Stage I: From start to first collisions of Early Ion Beam

Assume we slice commissioning procedures to the minimum required to get 2 Early Ion beams to 7 Z TeV (or some lower energy to be decided upon) and collide them unsqueezed. We should be starting from a machine that already does the equivalent with protons so many procedures can be skipped or compressed.

The time estimates for each step are provisional pending experience with protons. Some steps may be skipped or adapted at short notice according to circumstances and priorities.

		Ring factor	Total Time [days] both rings	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 tr -5 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 i
I7	Collisions at 450 Z GeV	1	1 ?	If interesting. Performance to summarise.
I8	Snapback and ramp	2	0.5	Single and then two beams, Magnetically identical to p Check beam dump at various energies.
I9	7 Z TeV flat top checks	2	0.5	Single beam initially, performed following successful r
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 & A
	TOTAL to first collisions		6	
I11	Commission squeeze	2	2	Commission squeeze of ALICE to same as presently ac ATLAS (with ATLAS and CMS unsqueezed). May h 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 g

A similar approach is recommended for the crab-cavity commissioning procedures:

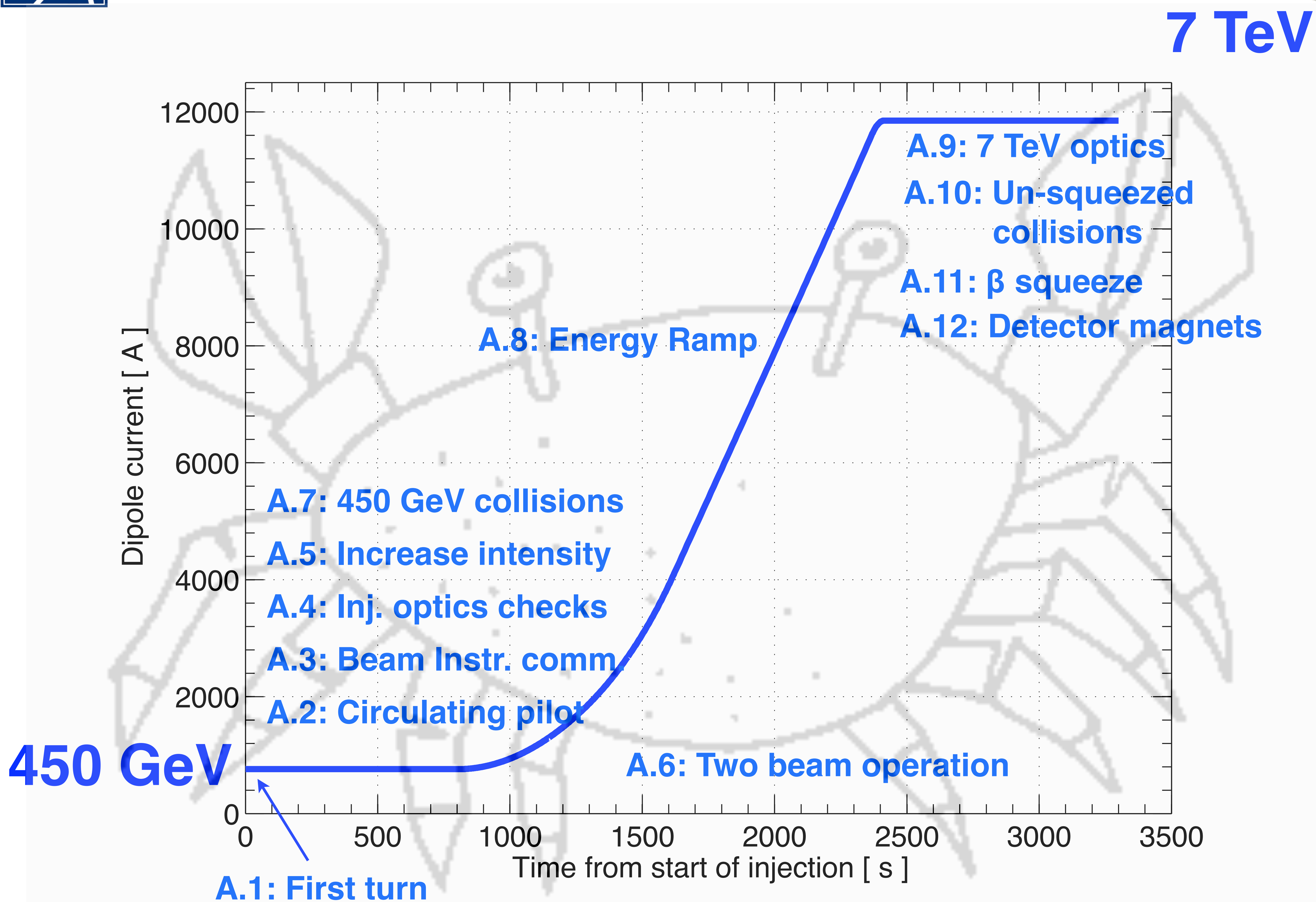
You should prepare one document that presents consistently for each phase the specific aspects related to the commissioning with CC.

A lot of detailed work is required - a few aspects will be mentioned in the following.

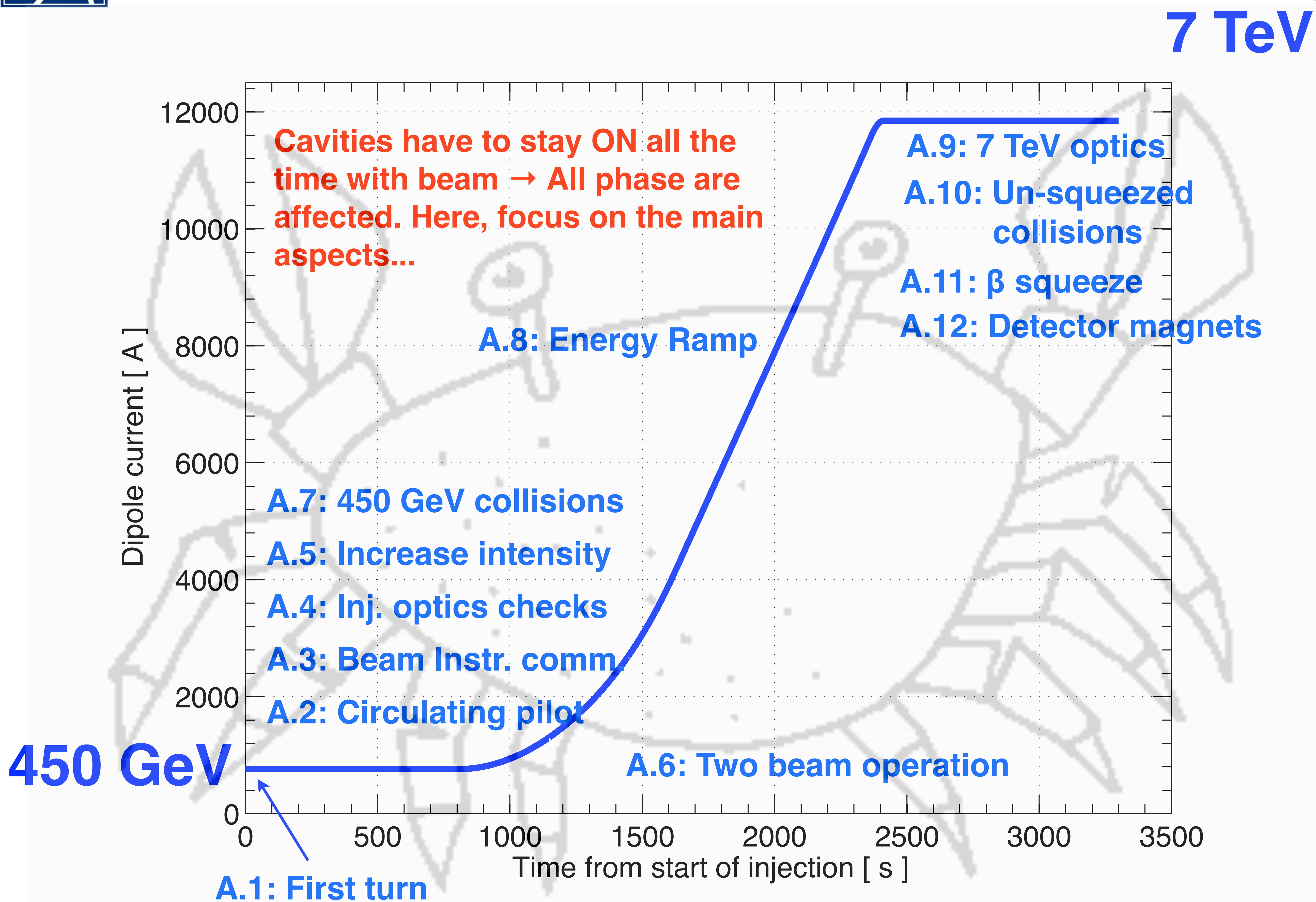
Outline

- Introduction
- Commissioning baseline
  - *Strategy*
  - *Procedures*
- **Crab cavity operation aspects**
  - ***Integration into LHC procedures***
  - ***Safe beam tests***
- Conclusions

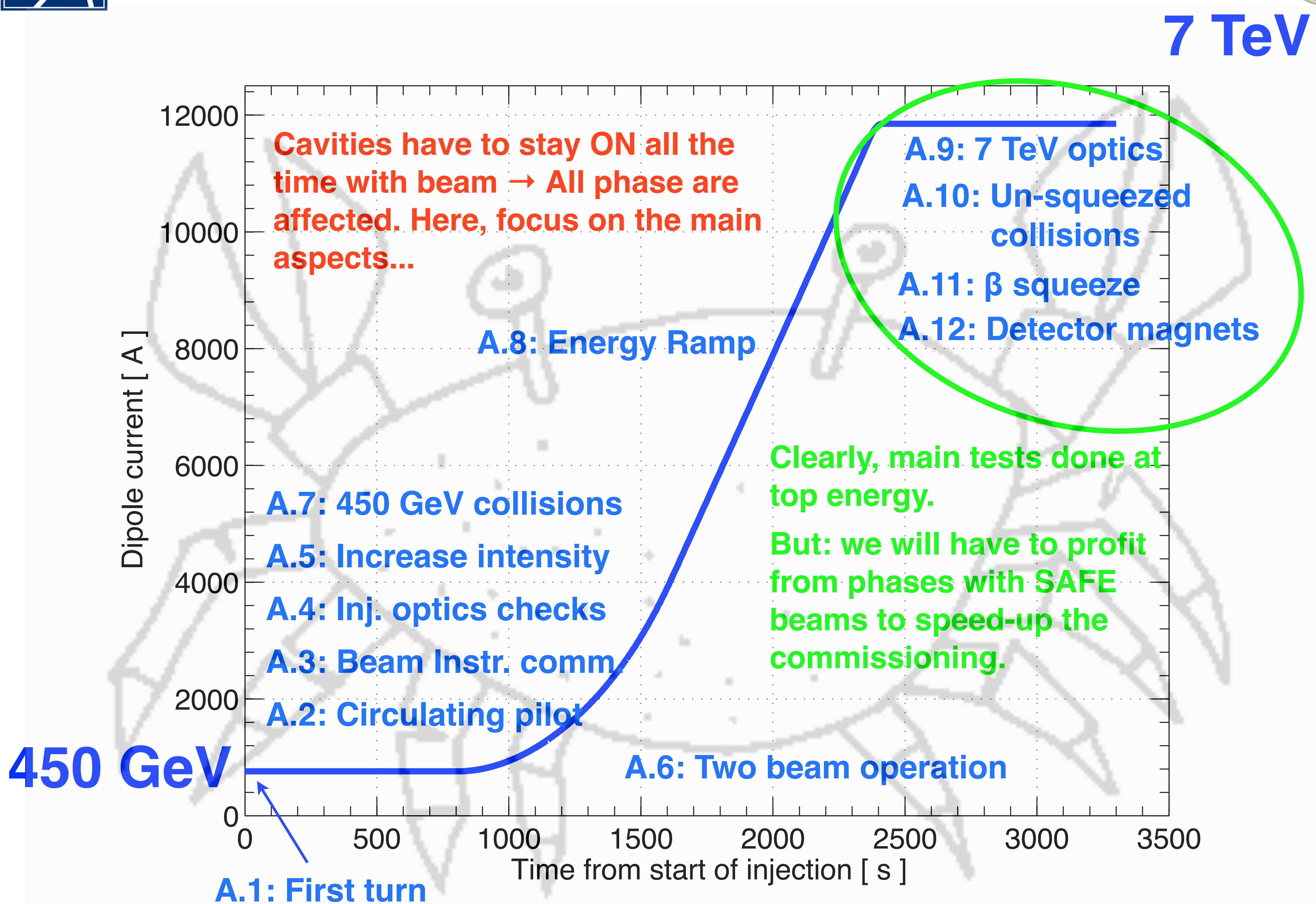
Steps affected by CCs



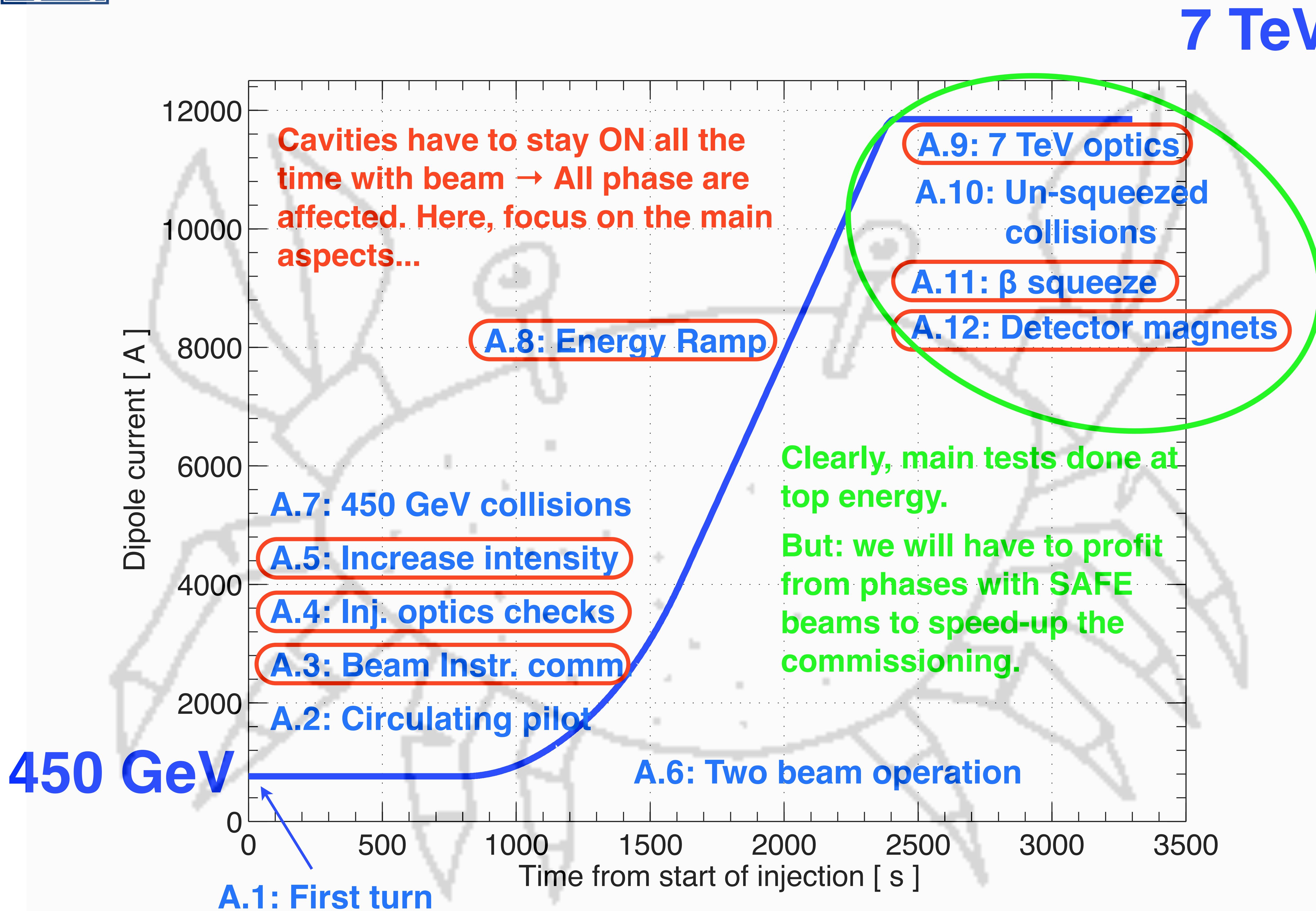
Steps affected by CCs



Steps affected by CCs



Steps affected by CCs



Basic assumptions

Basic assumptions

Assumed status of beam commissioning during CC Phase II:

- *We will master the all commissioning phases (inj→ramp→squeeze→collisions)*
- *One or both beams available on request, multi-bunch operation fully under control.*
- *Variety of commissioning beams available: pilot, intermediate, nominal; single/multi bunches*

Basic assumptions

Assumed status of beam commissioning during CC Phase II:

- *We will master the all commissioning phases (inj→ramp→squeeze→collisions)*
- *One or both beams available on request, multi-bunch operation fully under control.*
- *Variety of commissioning beams available: pilot, intermediate, nominal; single/multi bunches*

Assumptions on SAFE beams:

- ***~ 10^{12} p at injection energy** (updated after a few years of operation)*
- ***No beam is safe at 7 TeV***
- *Will have experience on **machine protection** and **collimators**, but will still need to be very careful!*

Basic assumptions

Assumed status of beam commissioning during CC Phase II:

- *We will master the all commissioning phases (inj→ramp→squeeze→collisions)*
- *One or both beams available on request, multi-bunch operation fully under control.*
- *Variety of commissioning beams available: pilot, intermediate, nominal; single/multi bunches*

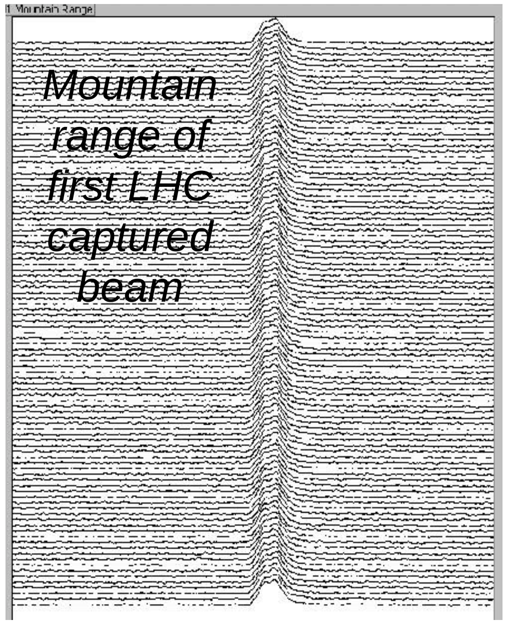
Assumptions on SAFE beams:

- ***~ 10^{12} p at injection energy*** *(updated after a few years of operation)*
- ***No beam is safe at 7 TeV***
- *Will have experience on **machine protection** and **collimators**, but will still need to be very careful!*

Pre-requisites before starting for crab-cavity system:

- *Hardware commissioning without beam completed*
- *Cavity conditioning completed*
- *Basic controls verified (RF levels but also active mechanical alignment)*
- *Detailed tests of RF loops and synchronization without beam*
- *Crab cavities must be super-conducting before putting beam ! (see Joachim's talk)*
- *Established settings for first injection!!*

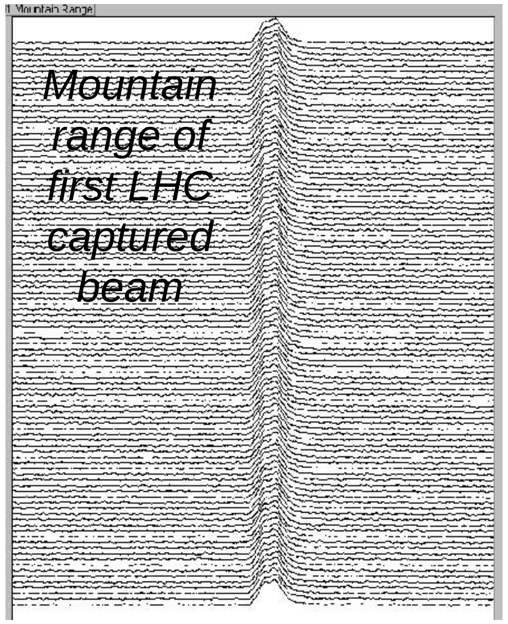
First beam commissioning (A.3)



First beam commissioning (A.3)

Reference beam conditions at injection energy:

- *Both beams captured, optimized lifetime*
- *Single bunches of a few x 10^{10} p, 450 GeV*

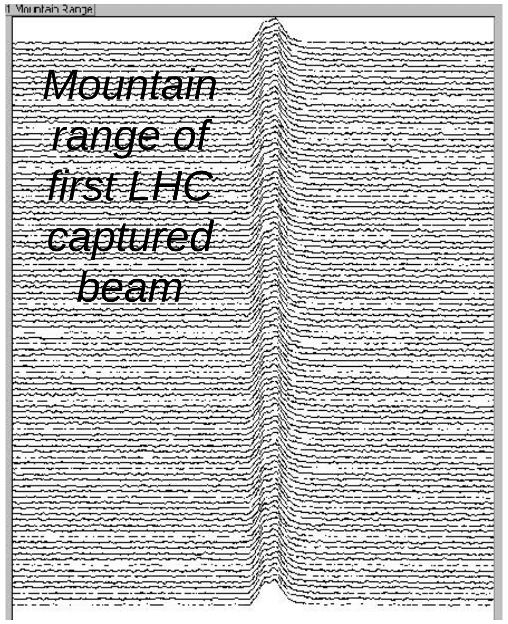


First beam commissioning (A.3)

Reference beam conditions at injection energy:

- *Both beams captured, optimized lifetime*
- *Single bunches of a few x 10^{10} p, 450 GeV*

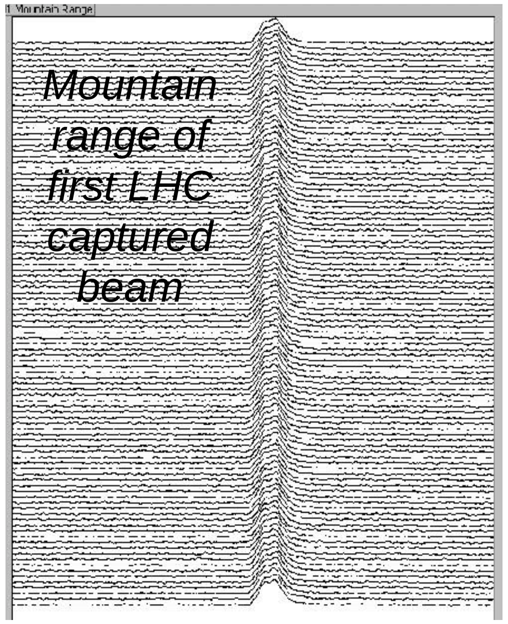
Requires commissioning steps for CC



First beam commissioning (A.3)

Reference beam conditions at injection energy:

- *Both beams captured, optimized lifetime*
- *Single bunches of a few x 10^{10} p, 450 GeV*



Requires commissioning steps for CC

- Verification with beam of the basic controls

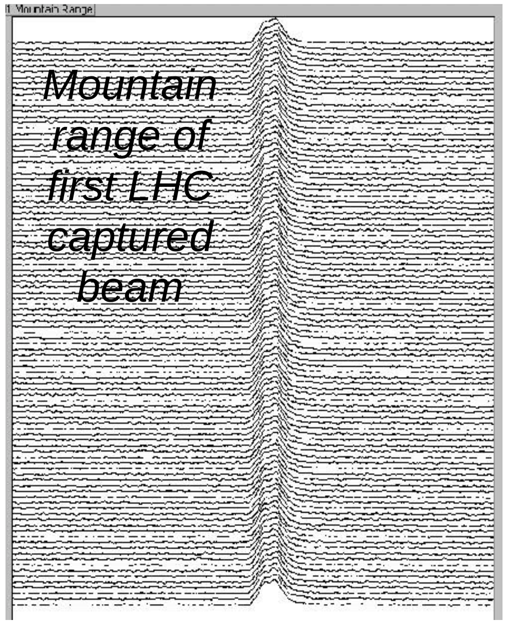
- *Status displays*
- *Settings for RF levels, gain and phase adjustments*
- *Pick-ups?*

First beam commissioning (A.3)

Reference beam conditions at injection energy:

- Both beams captured, optimized lifetime

- Single bunches of a few x 10^{10} p, 450 GeV



Requires commissioning steps for CC

- Verification with beam of the basic controls

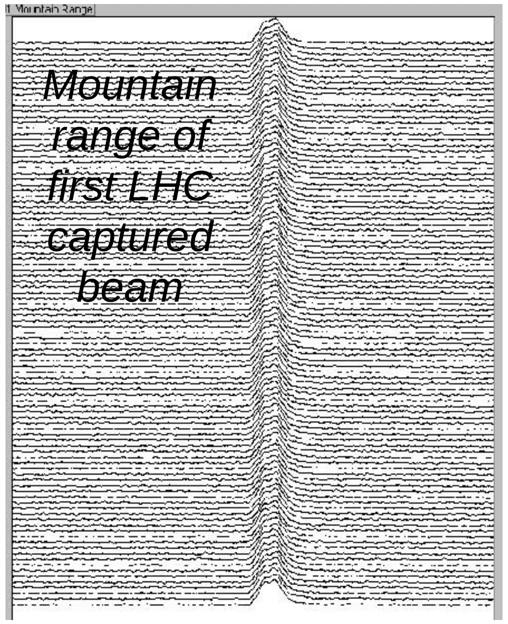
- Status displays

- Settings for RF levels, gain and phase adjustments

- Pick-ups?

- Initial beam commissioning of "standard" RF loops and tuning

First beam commissioning (A.3)



Reference beam conditions at injection energy:

- Both beams captured, optimized lifetime

- Single bunches of a few x 10^{10} p, 450 GeV

Requires commissioning steps for CC

- Verification with beam of the basic controls

- Status displays

- Settings for RF levels, gain and phase adjustments

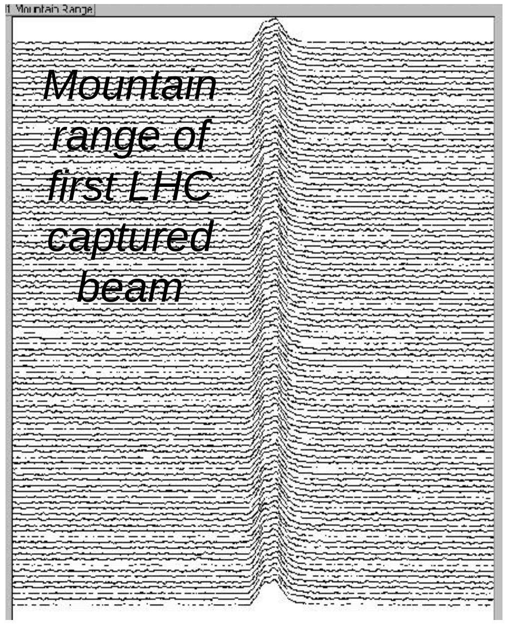
- Pick-ups?

- Initial beam commissioning of "standard" RF loops and tuning

- Initial tests for de-tuning the cavities

Needed as soon as possible!!

First beam commissioning (A.3)



Reference beam conditions at injection energy:

- *Both beams captured, optimized lifetime*
- *Single bunches of a few x 10^{10} p, 450 GeV*

Requires commissioning steps for CC

- Verification with beam of the basic controls

- *Status displays*
- *Settings for RF levels, gain and phase adjustments*
- *Pick-ups?*

- Initial beam commissioning of “standard” RF loops and tuning

- Initial tests for de-tuning the cavities

Needed as soon as possible!!

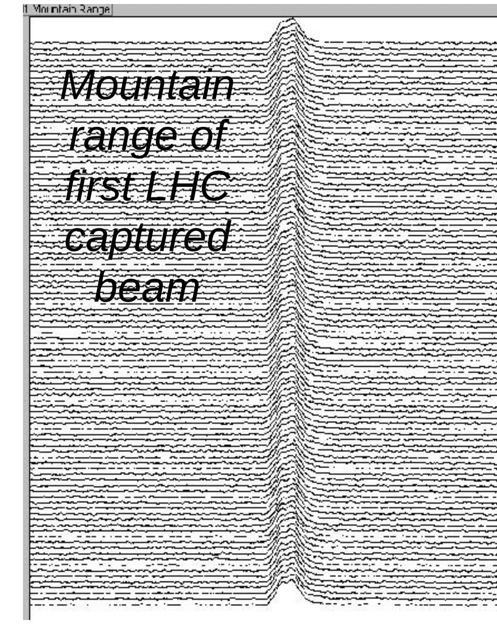
- First tests of voltage ramp up over tens of turns

First beam commissioning (A.3)

Reference beam conditions at injection energy:

- Both beams captured, optimized lifetime

- Single bunches of a few x 10^{10} p, 450 GeV



Requires commissioning steps for CC

- Verification with beam of the basic controls

- Status displays

- Settings for RF levels, gain and phase adjustments

- Pick-ups?

- Initial beam commissioning of "standard" RF loops and tuning

- Initial tests for de-tuning the cavities

Needed as soon as possible!!

- First tests of voltage ramp up over tens of turns

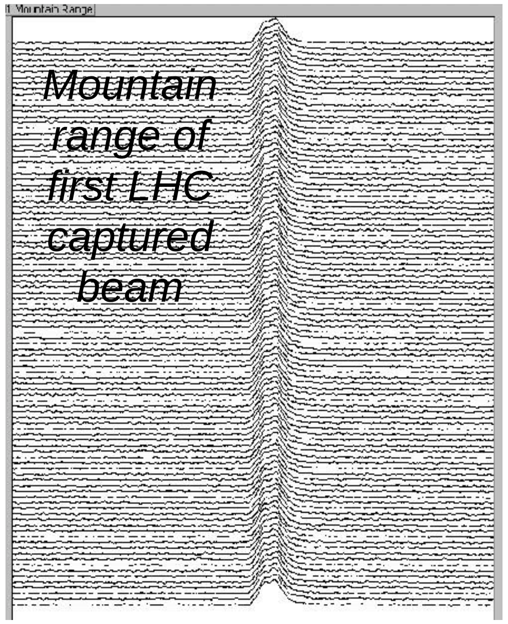
- First scans of crab phase to find the zero field offset

First beam commissioning (A.3)

Reference beam conditions at injection energy:

- Both beams captured, optimized lifetime

- Single bunches of a few x 10^{10} p, 450 GeV



Requires commissioning steps for CC

- Verification with beam of the basic controls

- Status displays

- Settings for RF levels, gain and phase adjustments

- Pick-ups?

- Initial beam commissioning of "standard" RF loops and tuning

- Initial tests for de-tuning the cavities

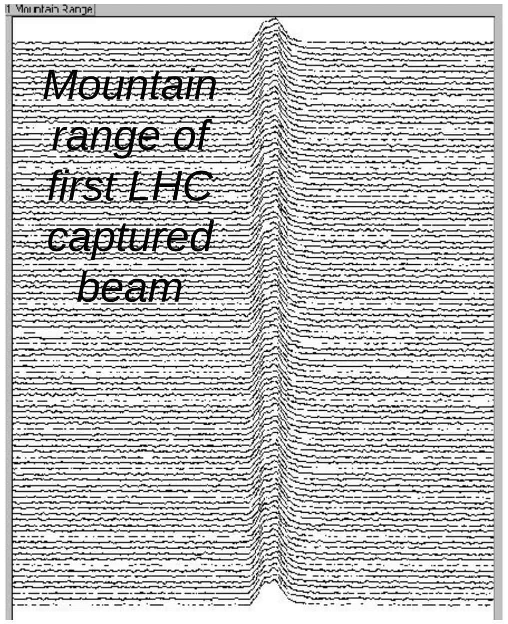
Needed as soon as possible!!

- First tests of voltage ramp up over tens of turns

- First scans of crab phase to find the zero field offset

- Find minimum load position with local orbit bumps

First beam commissioning (A.3)



Reference beam conditions at injection energy:

- Both beams captured, optimized lifetime

- Single bunches of a few x 10^{10} p, 450 GeV

Requires commissioning steps for CC

- Verification with beam of the basic controls

- Status displays

- Settings for RF levels, gain and phase adjustments

- Pick-ups?

- Initial beam commissioning of "standard" RF loops and tuning

- Initial tests for de-tuning the cavities

Needed as soon as possible!!

- First tests of voltage ramp up over tens of turns

- First scans of crab phase to find the zero field offset

- Find minimum load position with local orbit bumps

- Test the active remote mechanical alignment with beam, compare with orbit bump measurements

Detailed optics meas. at 450 GeV (A.4)

This is the phase we establish the **reference beam conditions** for ramp and physics:

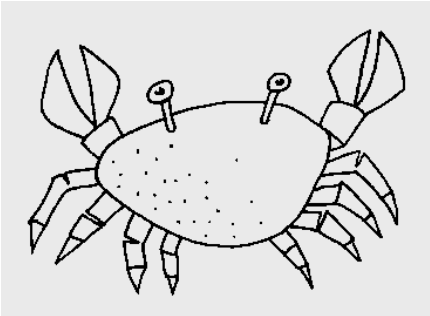
- *Measurements/corrections of aperture, orbit, tunes, optics, ...*
- *Collimator settings*
- *Preparation for energy ramp*
- *Final RF commissioning with detailed optics knowledge*

Detailed optics meas. at 450 GeV (A.4)

This is the phase we establish the **reference beam conditions** for ramp and physics:

- *Measurements/corrections of aperture, orbit, tunes, optics, ...*
- *Collimator settings*
- *Preparation for energy ramp*
- *Final RF commissioning with detailed optics knowledge*

CC →



- Final commissioning of RF loops and synchronization with main RF
- Detailed local measurements of aperture, orbit and optics
- Commissioning of local orbit bumps and orbit feedback (200 µm!)
- Commissioning with safe beams of the **protection interlocks** (local orbit, RF power, ...)
- Establishment of ramp settings to keep **de-tuning**!
- Preliminary measurements of **phase advance** / **closure** of local crab-bump. *Assess perturbations outside the local bump*
- **Impedance** measurements
- **Beam-based alignment** of each cavity, establish reference with respect to the orbit measurements
- Stability of crab performance!

Increasing intensities (A.5)

MP issues for Phase I discussed by Joerg!

Increasing intensities (A.5)

MP issues for Phase I discussed by Joerg!

"Standard" RF check for multi-bunch operation:

- Check synchronization with main RF.

Increasing intensities (A.5)

MP issues for Phase I discussed by Joerg!

"Standard" RF check for multi-bunch operation:

- Check synchronization with main RF.

Re-commissioning loops and controls for multi-bunch operation.

Increasing intensities (A.5)

MP issues for Phase I discussed by Joerg!

“Standard” RF check for multi-bunch operation:

- Check synchronization with main RF.

Re-commissioning loops and controls for multi-bunch operation.

Review orbit stability with higher intensities.

Increasing intensities (A.5)

MP issues for Phase I discussed by Joerg!

"Standard" RF check for multi-bunch operation:

- Check synchronization with main RF.

Re-commissioning loops and controls for multi-bunch operation.

Review orbit stability with higher intensities.

Check **HOM loads** for large number of bunches.

Increasing intensities (A.5)

MP issues for Phase I discussed by Joerg!

“Standard” RF check for multi-bunch operation:

- Check synchronization with main RF.

Re-commissioning loops and controls for multi-bunch operation.

Review orbit stability with higher intensities.

Check **HOM loads** for large number of bunches.

Compare beam-based alignment from CC signal to multi-bunch orbit.

Increasing intensities (A.5)

MP issues for Phase I discussed by Joerg!

"Standard" RF check for multi-bunch operation:

- Check synchronization with main RF.

Re-commissioning loops and controls for multi-bunch operation.

Review orbit stability with higher intensities.

Check **HOM loads** for large number of bunches.

Compare beam-based alignment from CC signal to multi-bunch orbit.

Re-check the crab-bumps with multi-bunch operation.

Increasing intensities (A.5)

MP issues for Phase I discussed by Joerg!

“Standard” RF check for multi-bunch operation:
- Check synchronization with main RF.

Re-commissioning loops and controls for multi-bunch operation.

Review orbit stability with higher intensities.

Check **HOM loads** for large number of bunches.

Compare beam-based alignment from CC signal to multi-bunch orbit.

Re-check the crab-bumps with multi-bunch operation.

Detailed commissioning of protection mechanisms:
- **Establish interlock references (software);**
- **Set-up collimation and protection systems.**

Increasing intensities (A.5)

MP issues for Phase I discussed by Joerg!

"Standard" RF check for multi-bunch operation:
- Check synchronization with main RF.

Re-commissioning loops and controls for multi-bunch operation.

Review orbit stability with higher intensities.

Check **HOM loads** for large number of bunches.

Compare beam-based alignment from CC signal to multi-bunch orbit.

Re-check the crab-bumps with multi-bunch operation.

Detailed commissioning of protection mechanisms:
- **Establish interlock references (software);**
- **Set-up collimation and protection systems.**

Clearly, detailed procedures must be established in preparation for un-safe beams!

Ramp and Squeeze (A.8-11)

Crab-cavities must stay de-tuned all the time with beam in the machine, with RF power ON.

⇒ A “full” commissioning of the system must be **completed** before attempting the first ramp!

- *Even a pilot beam is un-safe at high energy!!*
- *Special care has to be taken during squeeze: reduce aperture at highest energy!*
- *Active control of phase, feedback with V=0 constrain all the time!*

Require detailed **measurements** during optics changes and corresponding **corrections** of

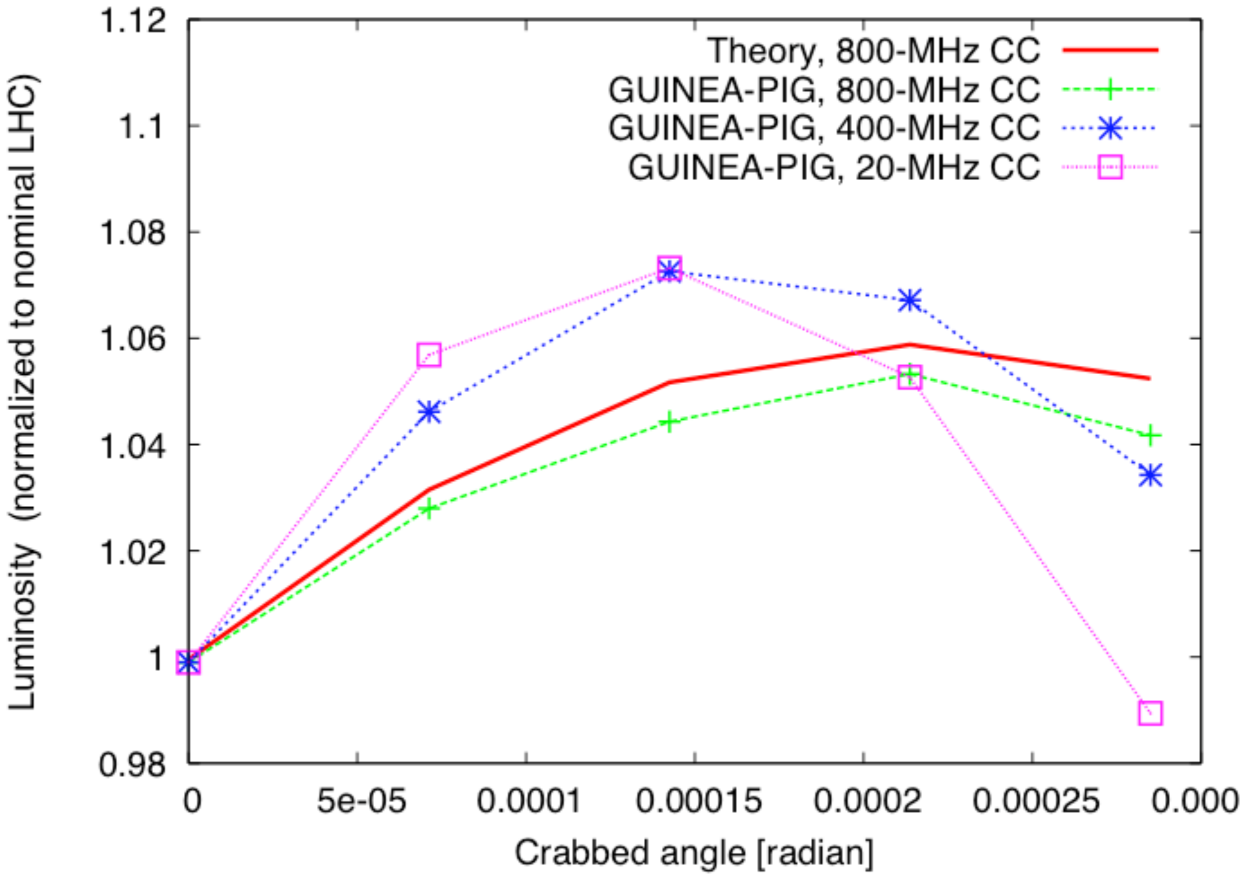
- Local bumps
- Betatron functions and phases at the cavity locations
- Closure of crab bumps
- Aperture, ...

Establish a procedure to ensure **protection** / **collimation** during squeeze.

- *Need to find optimized collimator settings during ramp and squeeze*

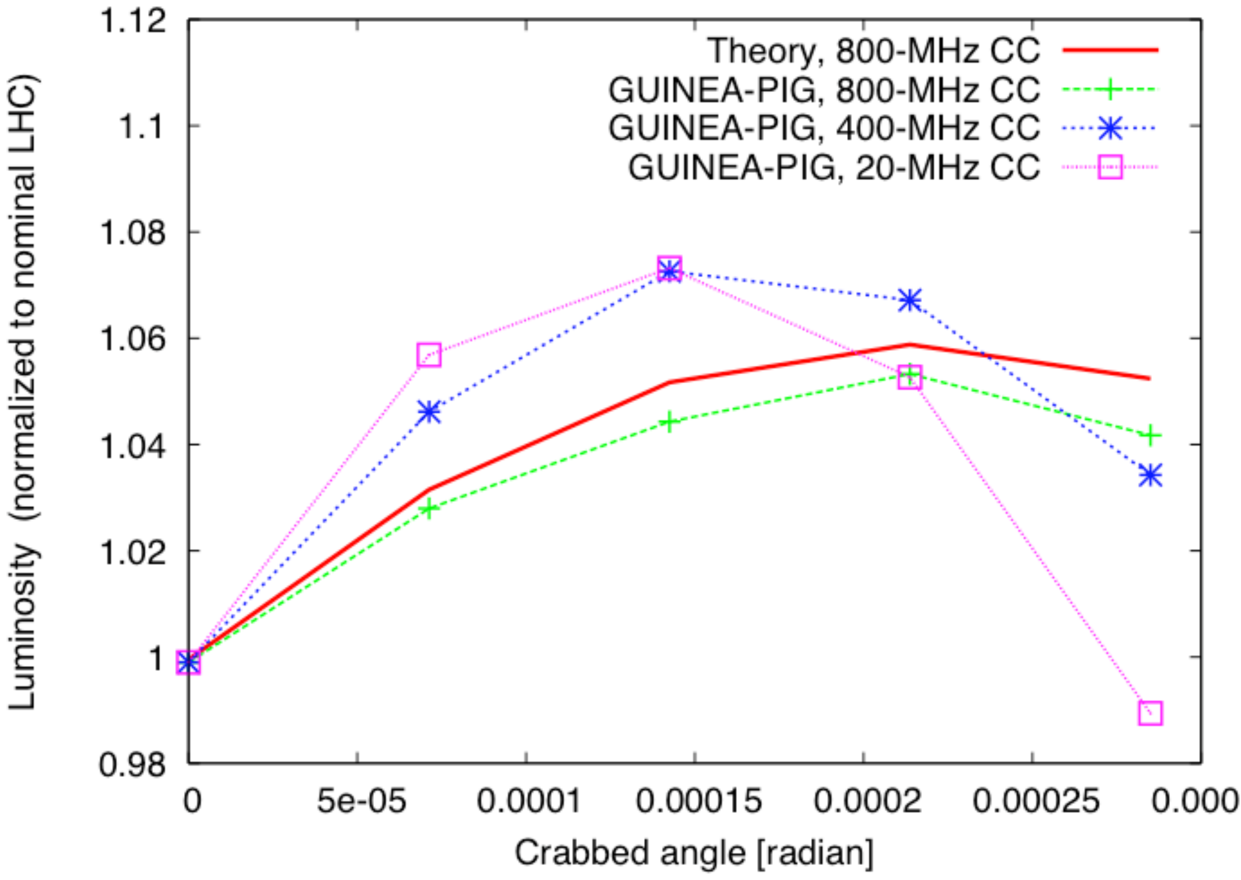
How to check in detail the de-tuning in all stages (change of En or of optics)?

Luminosity tuning and leveling



Luminosity tuning and leveling

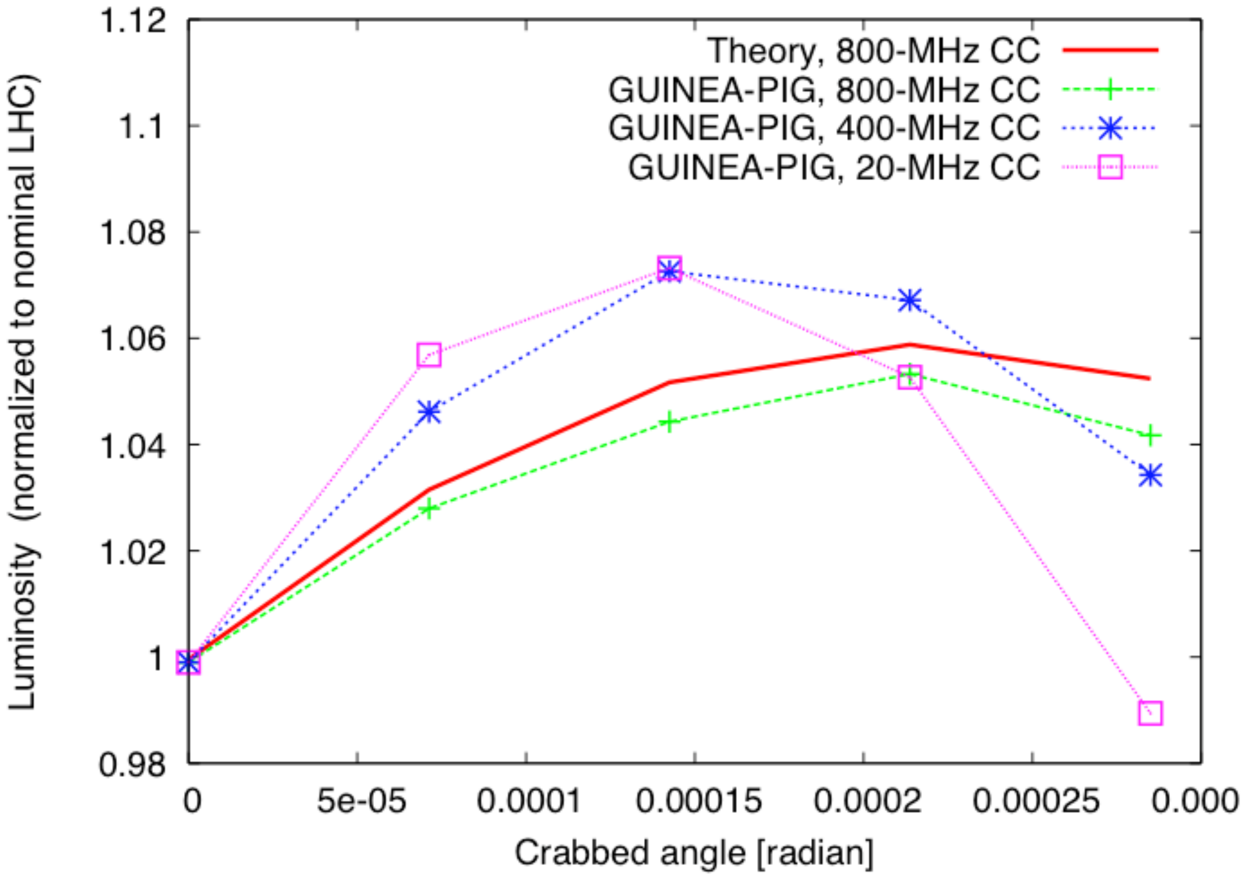
Detailed procedure to be established, largely based on the Phase I experience.



Luminosity tuning and leveling

Detailed procedure to be established, largely based on the Phase I experience.

Define an optimum set of parameters for initial commissioning (number of bunches, I_b, crossing angles, beta*, ...)



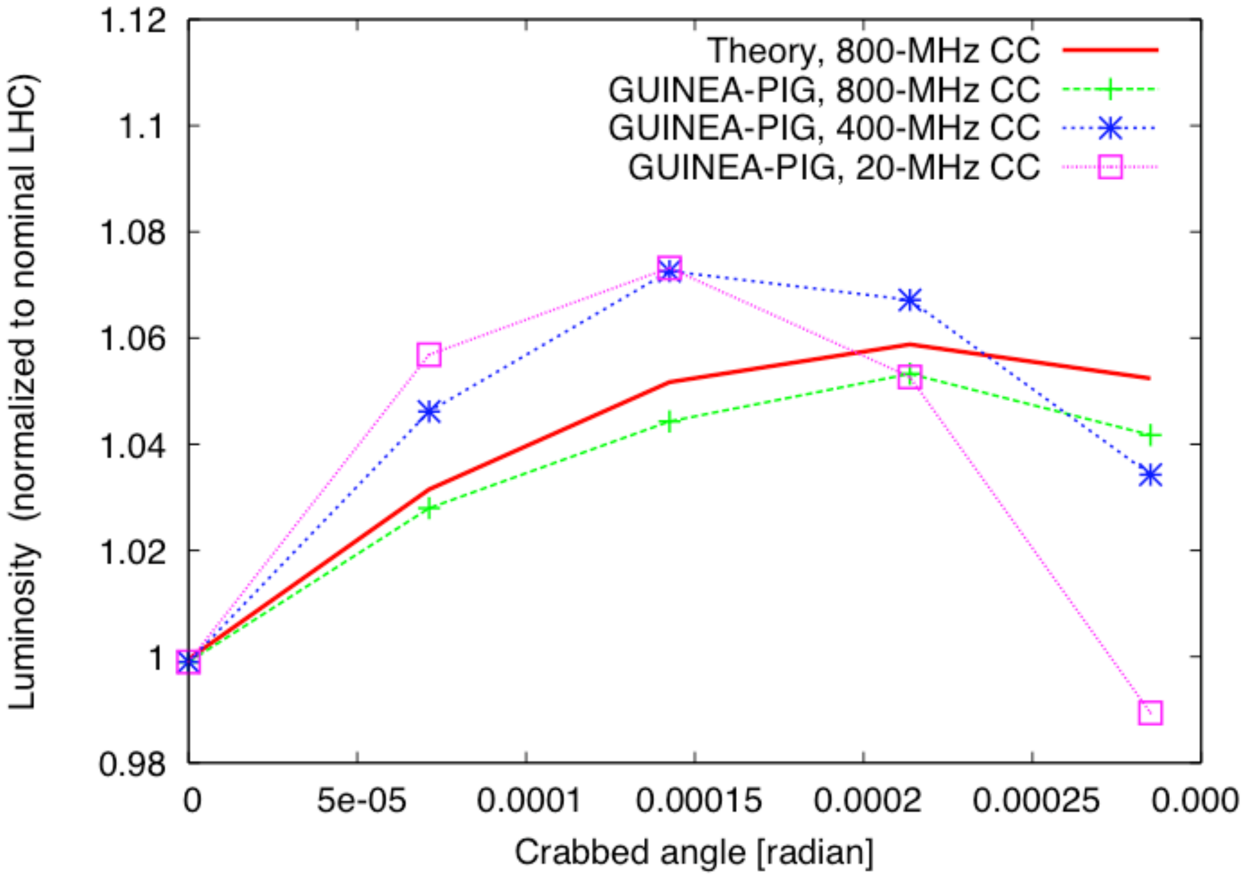
Luminosity tuning and leveling

Detailed procedure to be established, largely based on the Phase I experience.

Define an optimum set of parameters for initial commissioning (number of bunches, I_b, crossing angles, beta*, ...)

Assume that:

- Luminosity optimization without crabbing is well established!
- Reliable luminosity measurements available



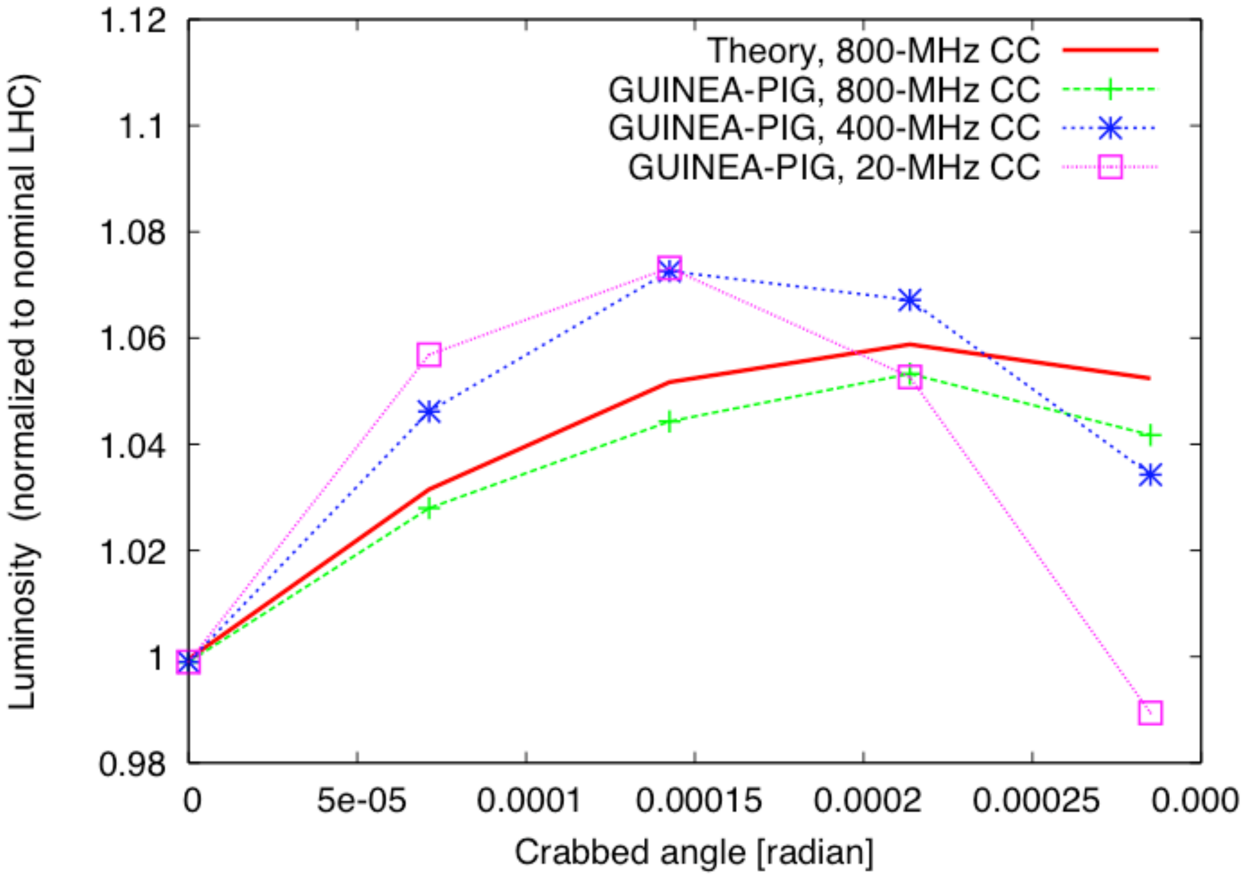
Luminosity tuning and leveling

Detailed procedure to be established, largely based on the Phase I experience.

Define an optimum set of parameters for initial commissioning (number of bunches, I_b, crossing angles, beta*, ...)

Assume that:

- Luminosity optimization without crabbing is well established!
- Reliable luminosity measurements available



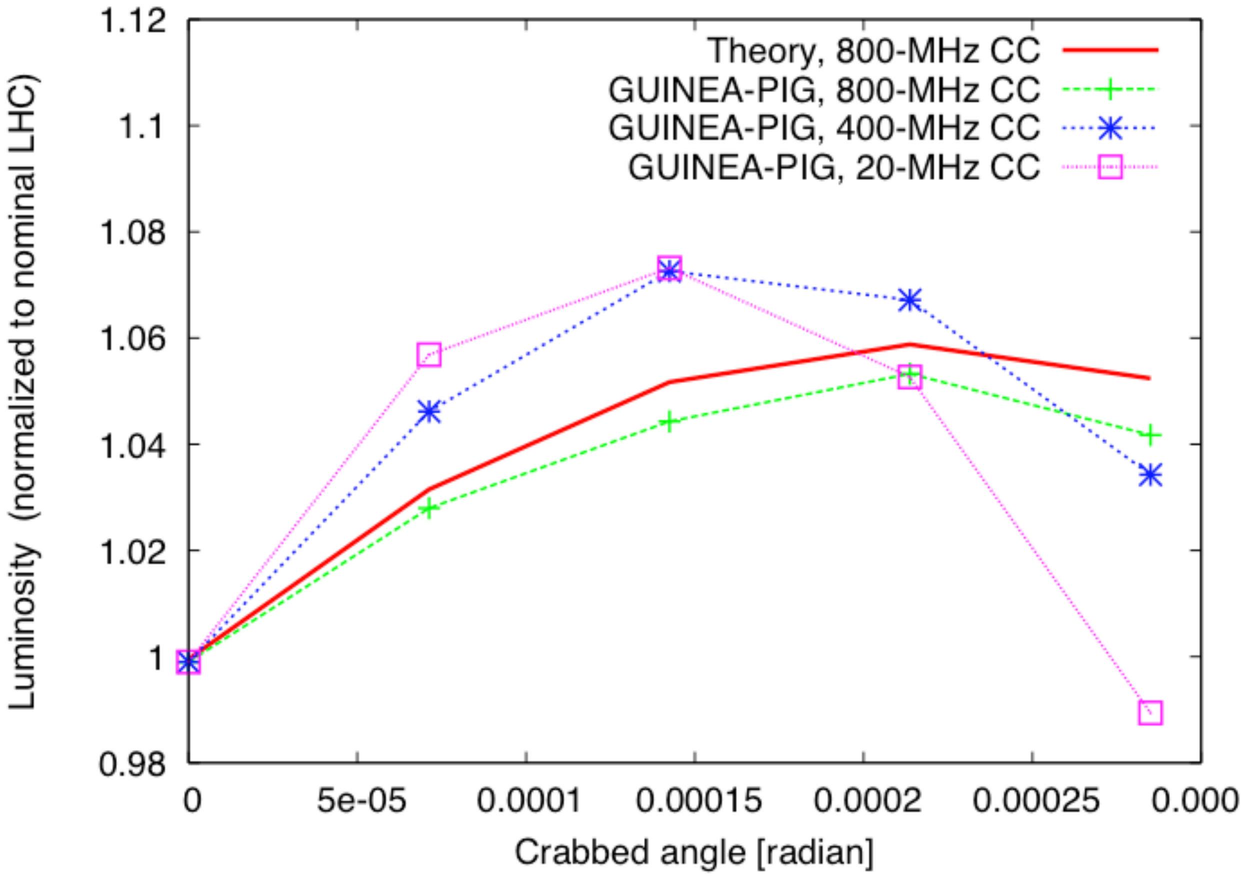
Luminosity tuning and leveling

Detailed procedure to be established, largely based on the Phase I experience.

Define an optimum set of parameters for initial commissioning (number of bunches, I_b, crossing angles, beta*, ...)

Assume that:

- Luminosity optimization without crabbing is well established!
- Reliable luminosity measurements available



BUT:

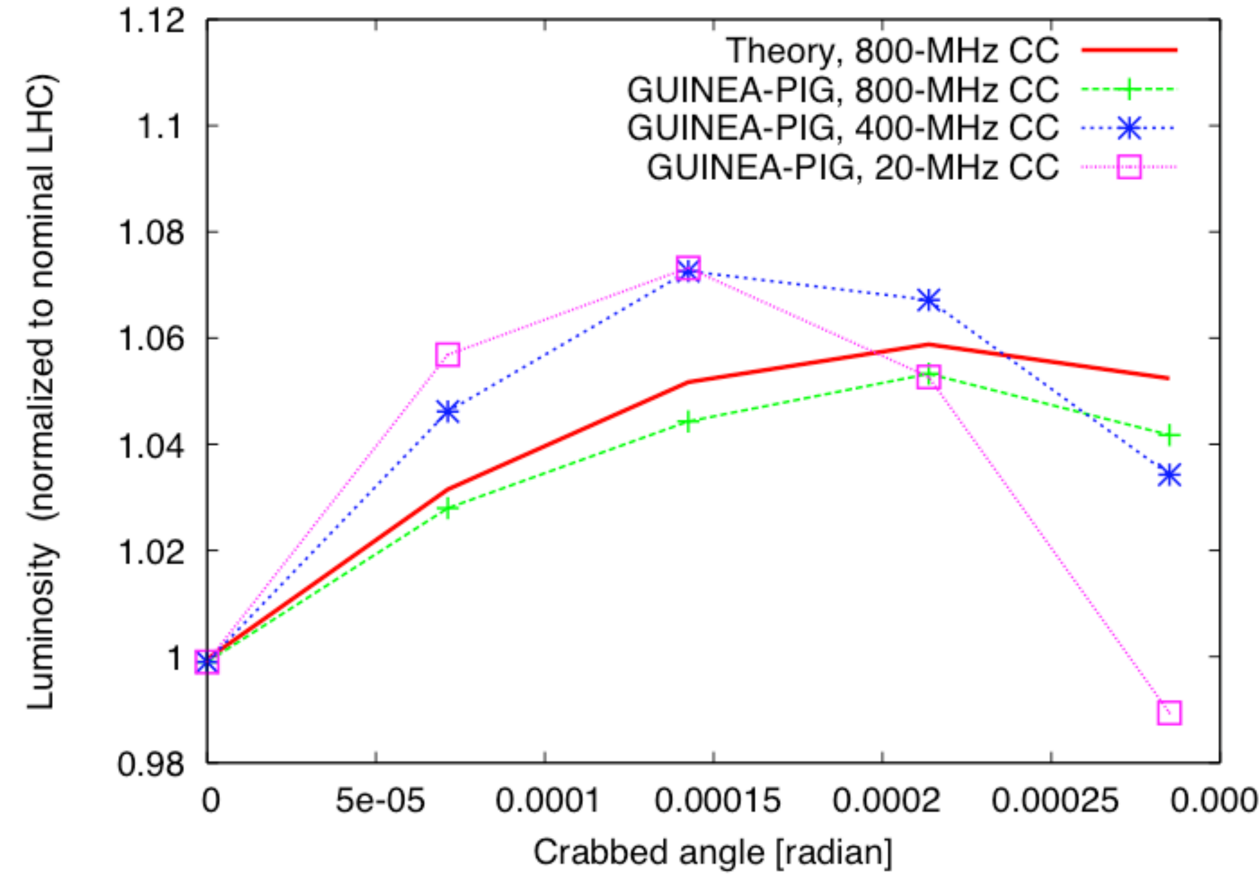
Luminosity tuning and leveling

Detailed procedure to be established, largely based on the Phase I experience.

Define an optimum set of parameters for initial commissioning (number of bunches, I_b, crossing angles, beta*, ...)

Assume that:

- Luminosity optimization without crabbing is well established!
- Reliable luminosity measurements available



BUT:

High risk: Need to define a set of **SAFE conditions for tests**. Little aperture margin available with squeezed beams + crossing.

Already commented on the required beam tests even before CC installation...

I see two additional possible options:

1. Collisions at lower energies

2. Anti-crab to REDUCE luminosity at top-energy WITHOUT crossing

Possible SAFER beam tests

Possible SAFER beam tests

1. Luminosity tuning at reduced beam energies.

Establish a trade off between

- Bunch length
- Aperture: larger beam sizes vs crossing vs β^*
- Accuracy of absolute luminosity measurements

$L \sim 10^{32}$ $cm^{-2}s^{-1}$ at 3.5 TeV, $\beta^* = 1$ m, 10^{11}p x 156 bunches, no crossing

Possible SAFER beam tests

1. Luminosity tuning at reduced beam energies.

Establish a trade off between

- Bunch length
- Aperture: larger beam sizes vs crossing vs β^*
- Accuracy of absolute luminosity measurements

$L \sim 10^{32}$ $cm^{-2}s^{-1}$ at 3.5 TeV, $\beta^* = 1$ m, 10^{11}p x 156 bunches, no crossing

2. Use crab schemes to reduce luminosity at top energy

- Squeezed beams with no crossing, head-on collisions. Nominal emittance.

  Larger aperture margin at the triplet without crossing
- Up to 156 bunches per beam give enough luminosity for tests:

  $L \sim 6 \times 10^{32}$ $cm^{-2}s^{-1}$ at 7 TeV, $\beta^* = 55$cm, no crossing
- What to do:
  - Scan crab bump an tune it to an "optimum" minimum/reduced luminosity value
  - Assess machine performance with (supposedly) closed local bumps in both IPs, in nominal top-energy conditions
    - Machine perturbations
    - Collimation
    - Operability, stability
    - ...

Possible SAFER beam tests

1. Luminosity tuning at reduced beam energies.

Establish a trade off between

- Bunch length
- Aperture: larger beam sizes vs crossing vs β^*
- Accuracy of absolute luminosity measurements

$L \sim 10^{32}$ $cm^{-2}s^{-1}$ at 3.5 TeV, $\beta^* = 1$ m, 10^{11}p x 156 bunches, no crossing

2. Use crab schemes to reduce luminosity at top energy

- Squeezed beams with no crossing, head-on collisions. Nominal emittance.
  Larger aperture margin at the triplet without crossing
- Up to 156 bunches per beam give enough luminosity for tests:
  $L \sim 6 \times 10^{32}$ $cm^{-2}s^{-1}$ at 7 TeV, $\beta^* = 55$cm, no crossing
- What to do:
  - Scan crab bump an tune it to an "optimum" minimum/reduced l… e
  - Assess machine performance with (supposedly) clo… both IPs, in nominal top-energy conditions
    - Machine perturbations
    - Collimation
    - Operability, stability
    - ...

Clearly, the final validation must come from the proof that a POSITIVE luminosity gain can be achieved!

Conclusions

Conclusions

- The operation of crab cavities will be **challenging**
  - *- See also previous talks on MP aspects and safe beam tests*

Conclusions

- The operation of crab cavities will be **challenging**
  - *- See also previous talks on MP aspects and safe beam tests*
- The Crab Cavity system commissioning must be **fully integrated** into the LHC beam commissioning
  - *- General framework for the proton beam commissioning was presented*
  - *- First - preliminary - attempt to integrate into existing procedure was started*
  - *- Detailed procedures must be provided as a part of system approval!*
  - *- Experience of beam operation will have to be taken into account*

Conclusions

- The operation of crab cavities will be **challenging**
  - *See also previous talks on MP aspects and safe beam tests*
- The Crab Cavity system commissioning must be **fully integrated** into the LHC beam commissioning
  - *General framework for the proton beam commissioning was presented*
  - *First - preliminary - attempt to integrate into existing procedure was started*
  - *Detailed procedures must be provided as a part of system approval!*
  - *Experience of beam operation will have to be taken into account*
- From day-1, we will need a **complete commissioning**
  - *Obvious for Phase II, but also for Phase I*
  - *To a large extent, what was presented applies to Phase I as well!*

Conclusions

- The operation of crab cavities will be **challenging**
  - *See also previous talks on MP aspects and safe beam tests*
- The Crab Cavity system commissioning must be **fully integrated** into the LHC beam commissioning
  - *General framework for the proton beam commissioning was presented*
  - *First - preliminary - attempt to integrate into existing procedure was started*
  - *Detailed procedures must be provided as a part of system approval!*
  - *Experience of beam operation will have to be taken into account*
- From day-1, we will need a **complete commissioning**
  - *Obvious for Phase II, but also for Phase I*
  - *To a large extent, what was presented applies to Phase I as well!*
- We must prepare early on **safe procedures**
  - *Phase I experience will be essential*
  - *Need to do as much as possible at low energies*
  - *Should start the luminosity "tuning" with safe beams: work out programs for meaningful tests at lower energies and/or with adequate aperture margins*