MTE Commissioning 2008, plans for 2009

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Thanks to: the members of the PS Multi-Turn Extraction Project (see last slide) and to all the others who contributed to the successful installation and commissioning

Commissioning phases in 2008

Initial goal: provide the CNGS/SFTPRO beams with MTE by the middle of the run

Phase 1

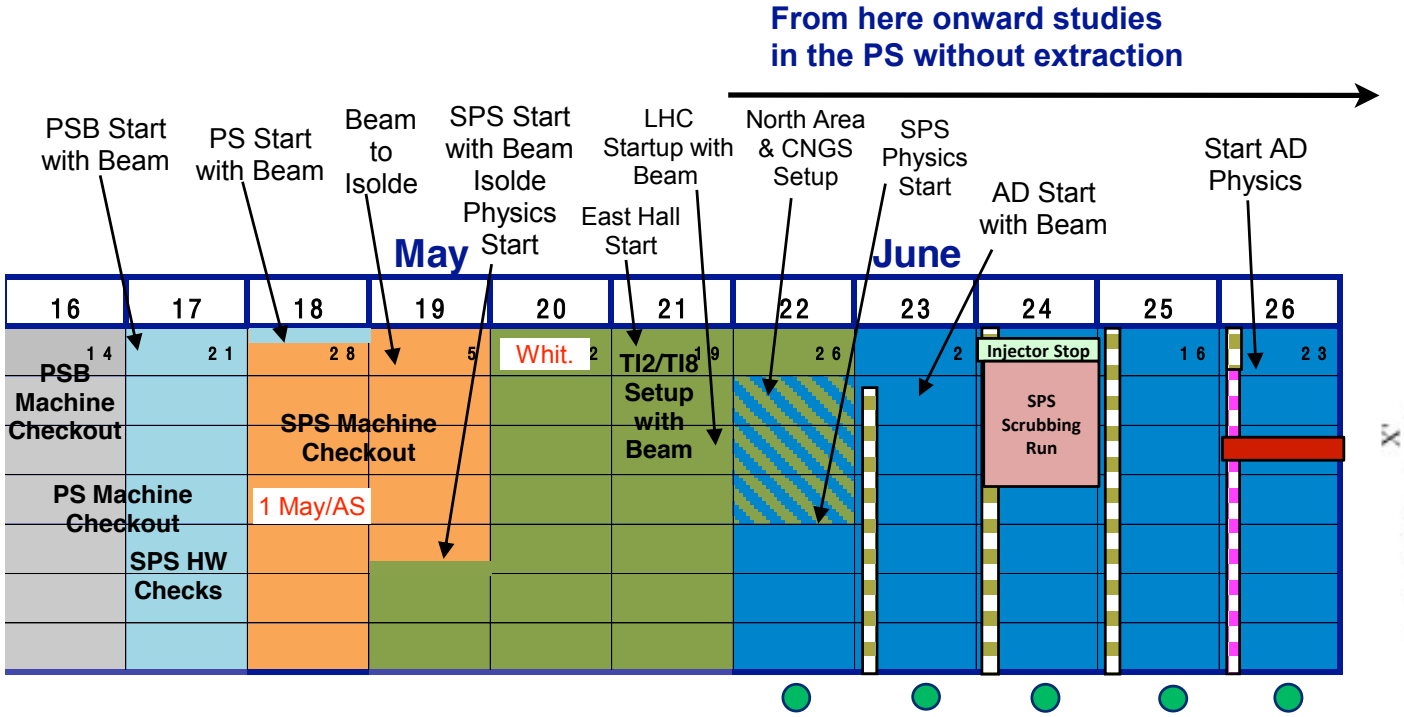
1. Beams preparation ⇒ 2 USERS ⇒ PSB(h1-h2), PS(2 bp for studies, 1 bp for extraction)
2. Measurement of nonlinear chromaticity to establish working point for capture
   ⇒ Working Point (Qx,Qy,Xix,Xiy but also Xix')
3. Re-establish capture ⇒ islands formation and capture optimisation ⇒ 2 bp ⇒ prepare 1 bp
4. Tests of CT extraction with bunched beam: best longitudinal structure to reduce losses in PS keeping the same losses in the SPS as for the classical CT
5. Preparation of the extraction elements
   ⇒ Kickers with no beam on ZERO Cycle
   ⇒ Optimisation/Calibration of the new bump 16

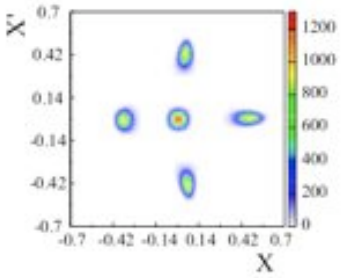
Phase 2

6. Preparation of nominal extraction with moderate intensity for CNGS-SFTPRO operation ⇒ 1 bp
7. Optics study and matching PS-TT2-TT10-SPS
8. CNGS-SFTPRO with MTE extraction
9. make a party ...

MTE commissioning - Schedule 1st part

Phase 1: Capture with normal fast extraction on single turn

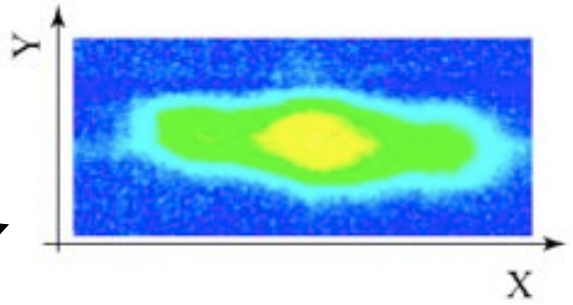




Weeks with MTE commissioning without extraction

MTE Setup and Development with Beam to LHC

Image in physical space on OTR in TT2 of the 5 islands fast extracted on single turn



Different Beams for different purposes...

Beam type	Intensity per bunch	Emittance* H/V	Harmonic	Total intensity (up to)	Number PSB rings	Aim	PS bp
Pencil	50 10^{10}	~2/~1	1	50 10^{10}	1	Xix' meas.	2
Moderate intensity	300 10^{10}	~9/~6	1	300 10^{10}	1-4	Capture study	1-2
Operational	300 10^{10}	~9/~6	2	2400 10^{10}	4	CNGS SFTPRO	1
High intensity	600 10^{10}	~9/~6	1	600 10^{10}	1	Capture studies	2

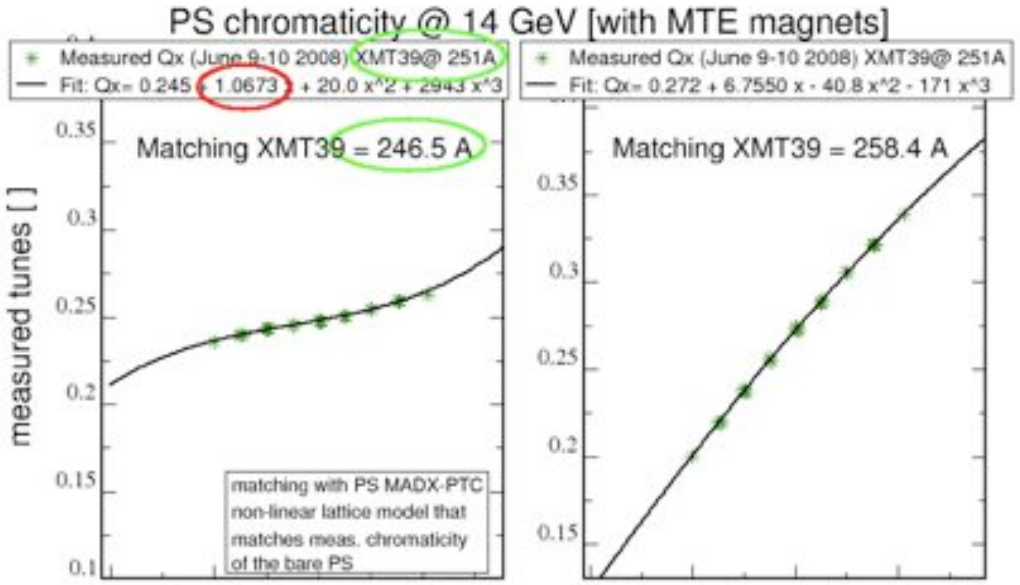
***Emittance: 1 σ normalised of the beam BEFORE capture i.e. from PSB**

	Booster	PS	Aim
During commissioning	MD1	MD1 (1 bp)	Extraction setting up
	TOF	MD2 (2 bp)	Capture preparation & optimisation
	SFTPRO/CNGS	SFTPRO/CNGS	Normal CT extraction
Operation	SFTPRO/CNGS	SFTPRO/CNGS	MTE extraction
	MD1	MD1 (1 bp)	Settings ready for SFTPRO/CNGS *CT extraction switch in case of problems with MTE*
	TOF	MD2 (2 bp)	Further studies

First capture resumed June 13th

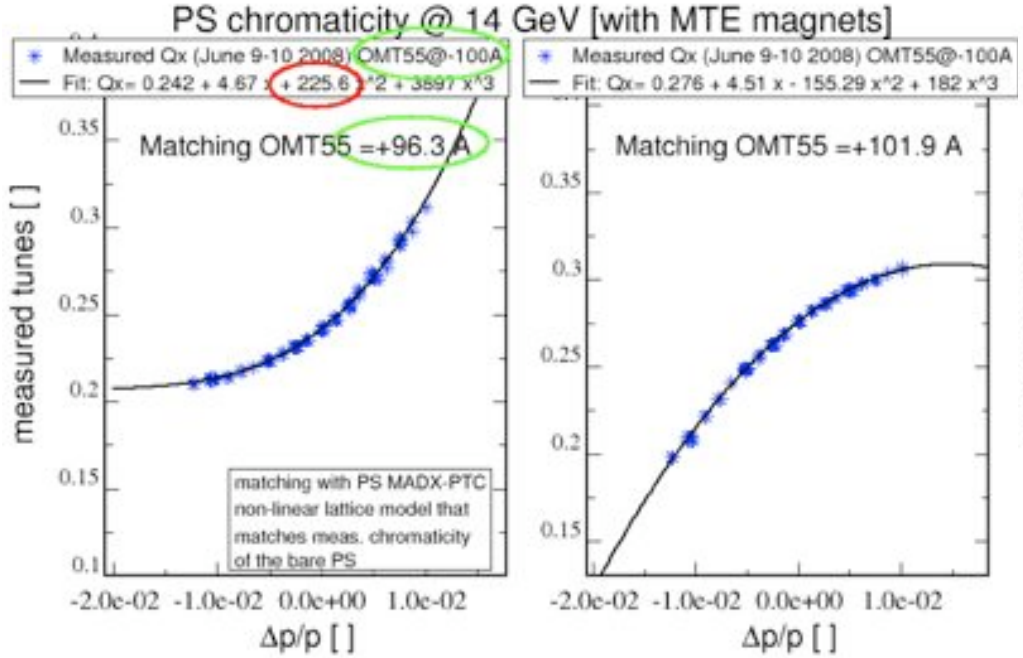
Large H emittance beam prepared by PSB used in first part of the commissioning

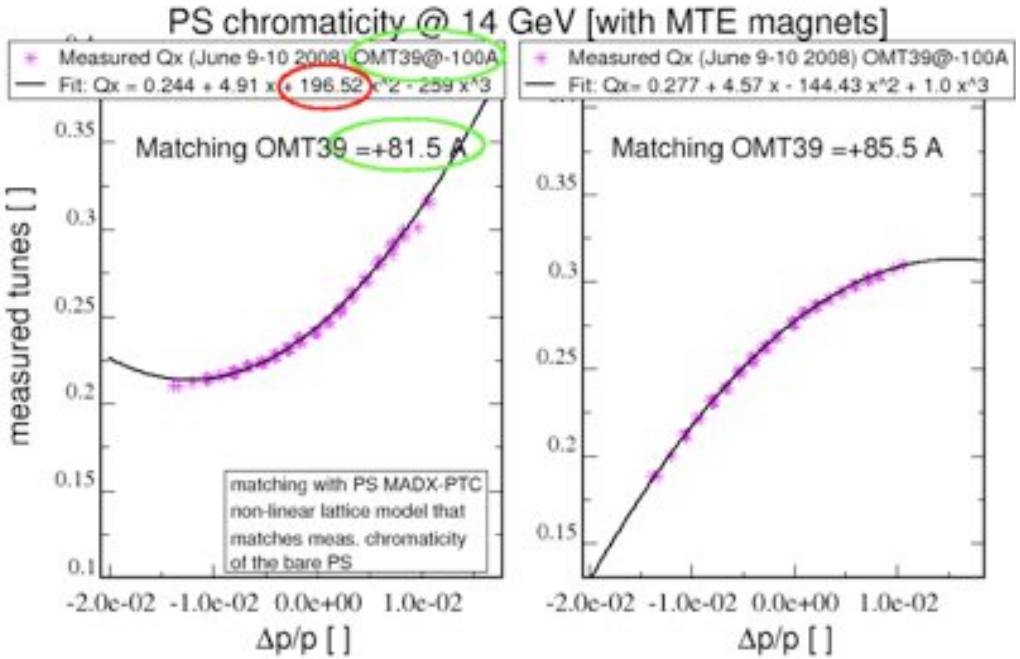
Calibration of new nonlinear elements



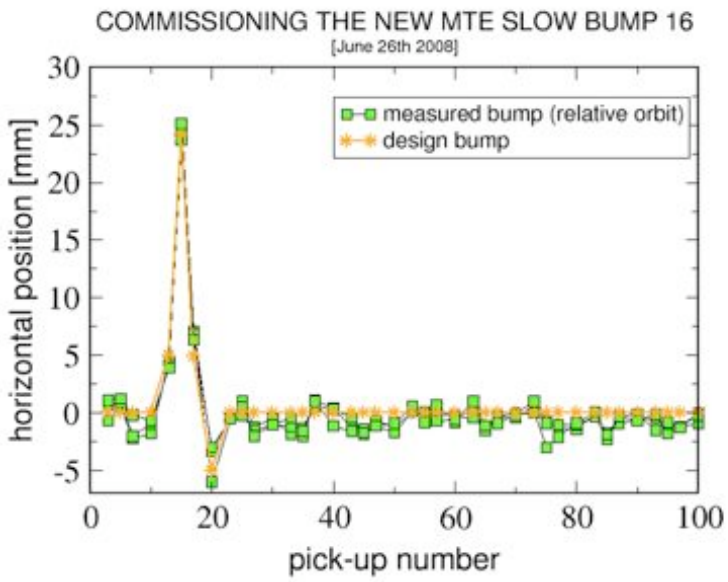
Calibration of non-linear elements showed:

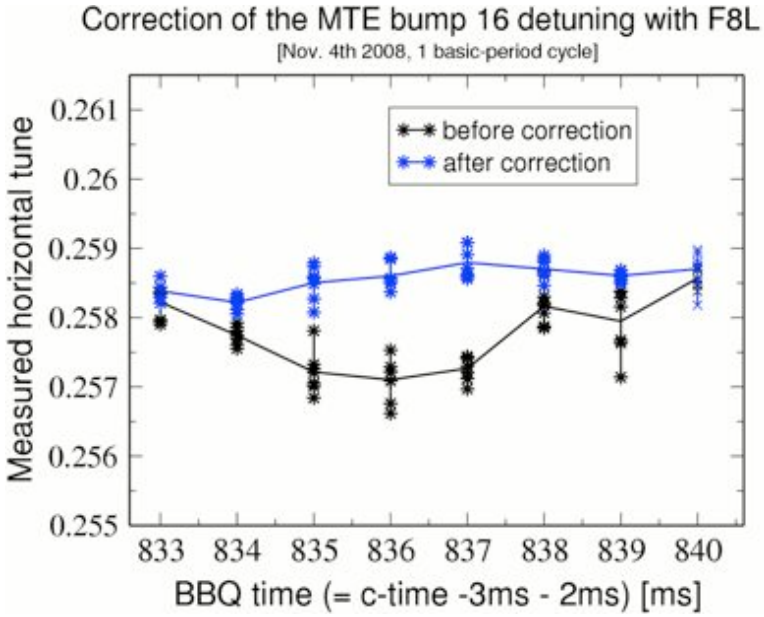
- sextupole calibration and polarity correct
- octupole polarity inversed wrt convention (no pb, pows are bipolar)
- doubts calibration of octupole in ss39 (under investigation feed down from orbit or power converter - magnet OK)

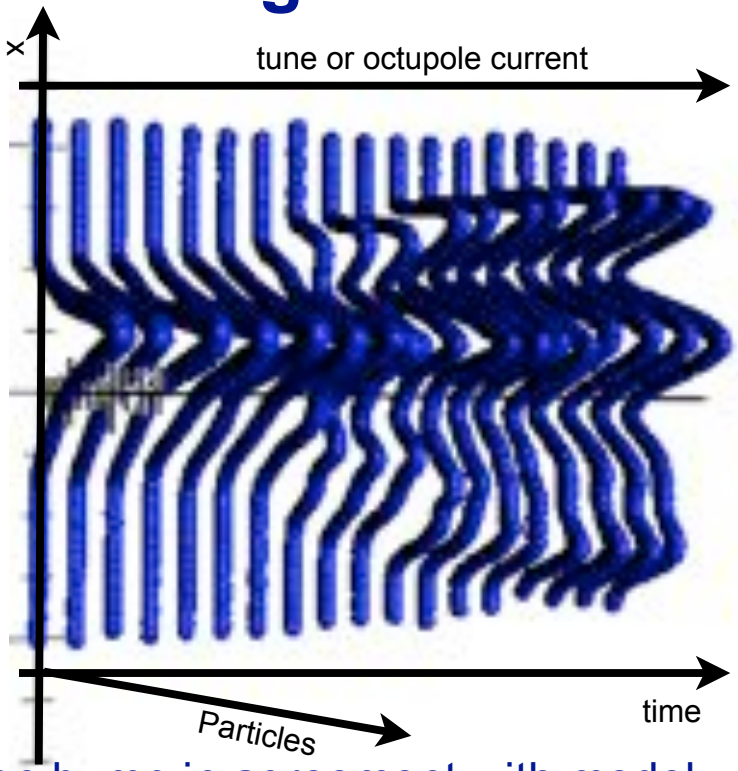




Bump 16 commissioning & tune change correction





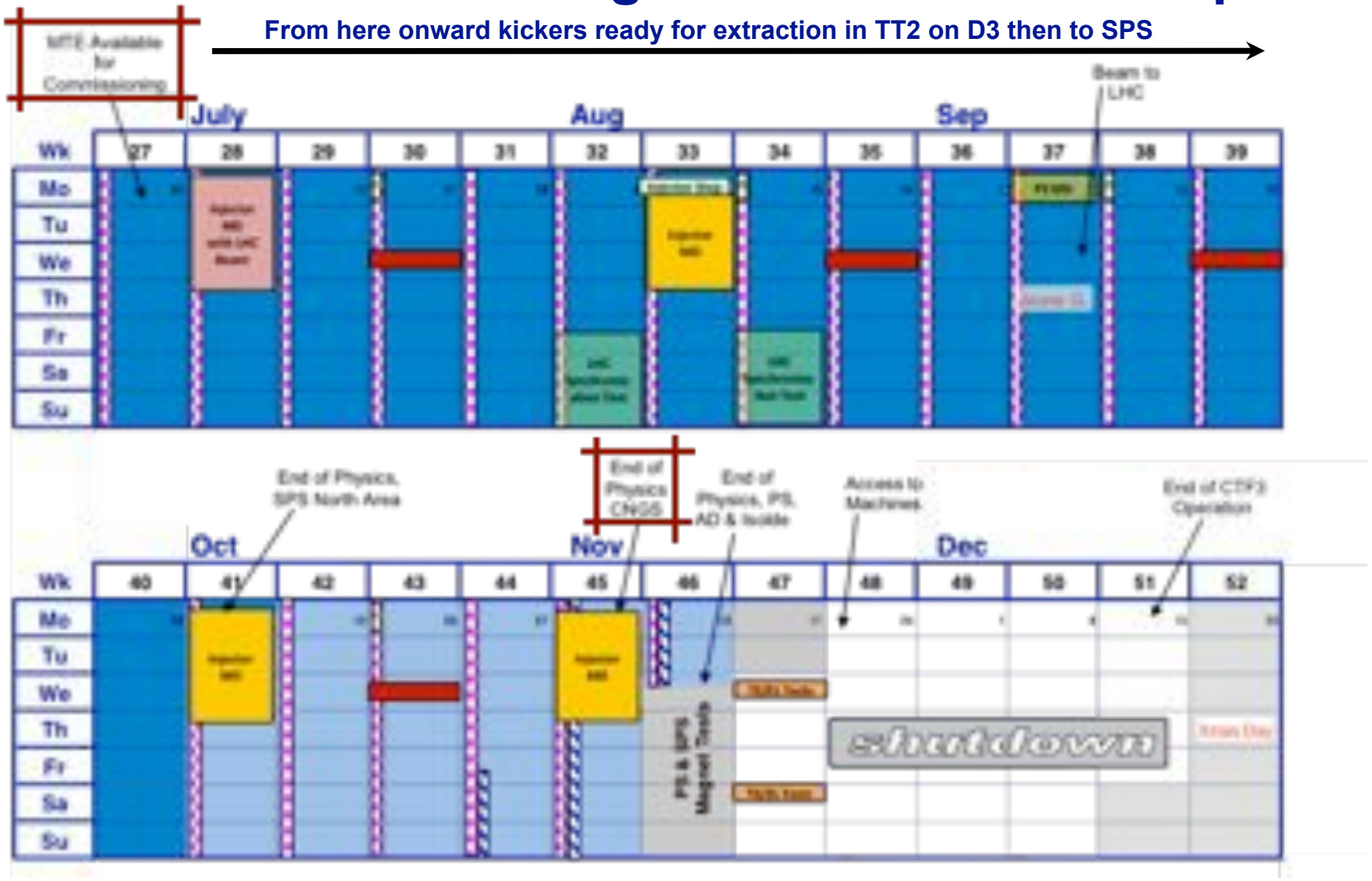


Extraction bump in agreement with model.

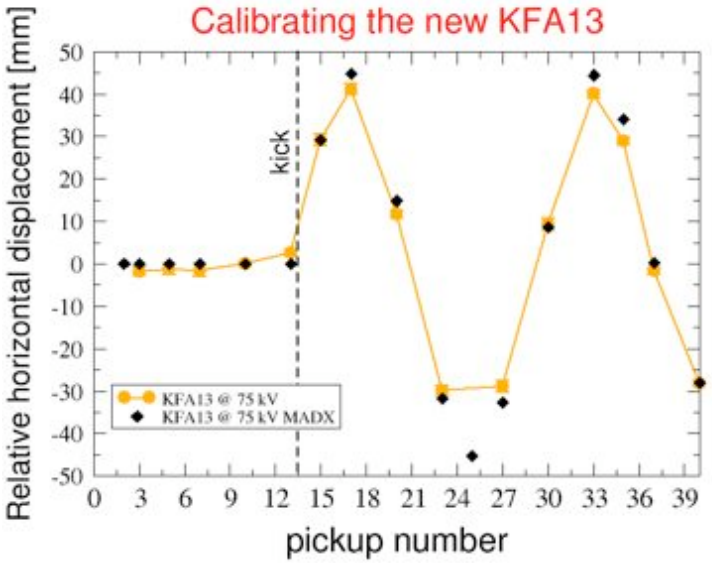
Extraction bump introduces a tune variation that changes the islands separation during ~ 7 ms. Tune compensation done using low energy quadrupoles plus F8L.

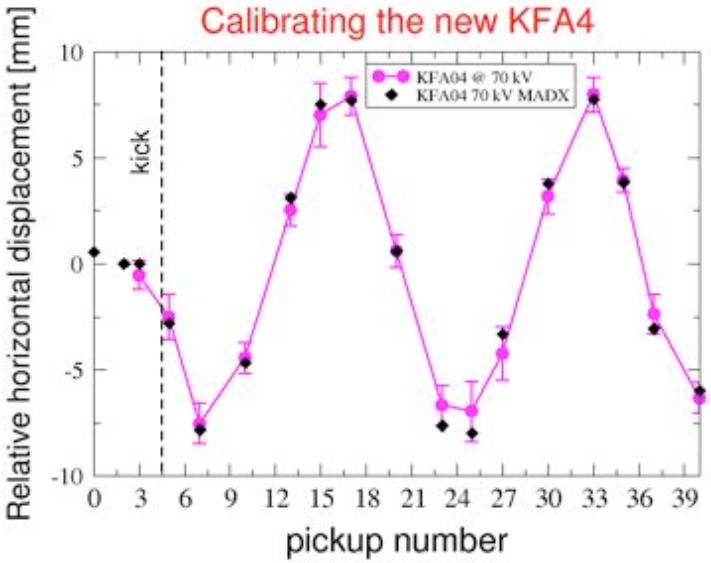
Fundamental for the compensation: correct triggering of the orbit measurements and BBQ. Chirp might be problematic

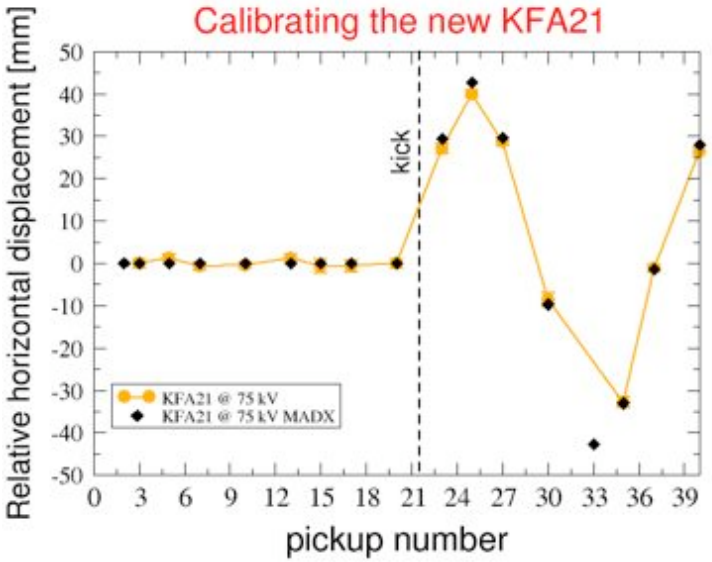
MTE commissioning - Schedule 2008 2nd part

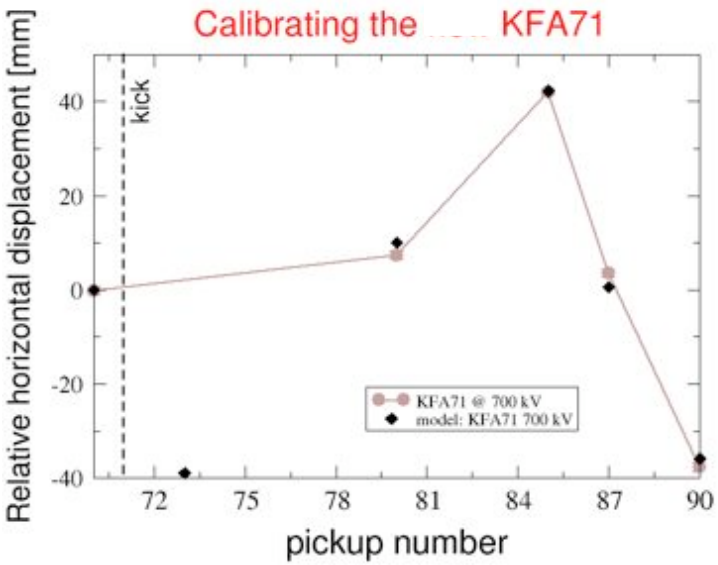


Kicker calibration



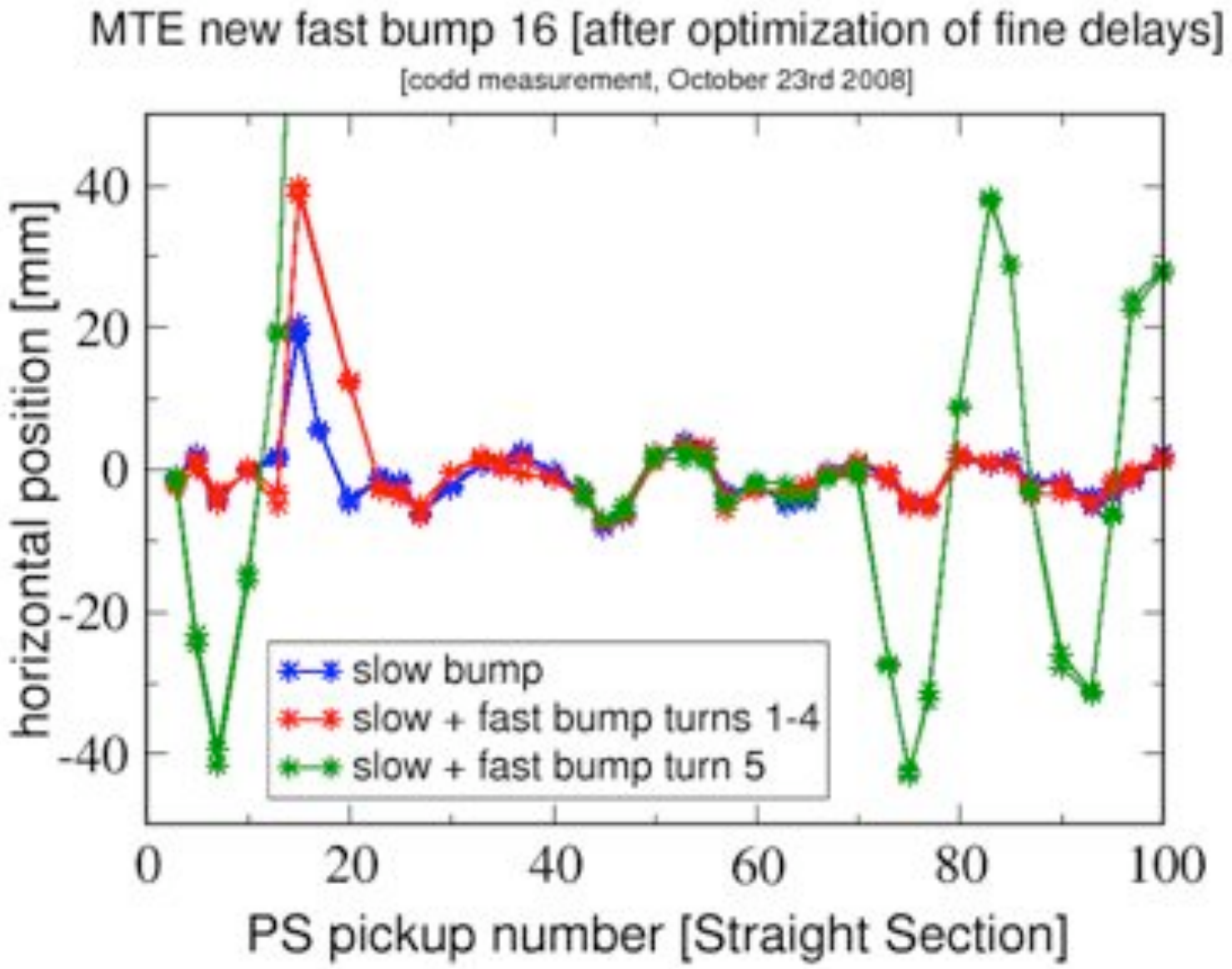




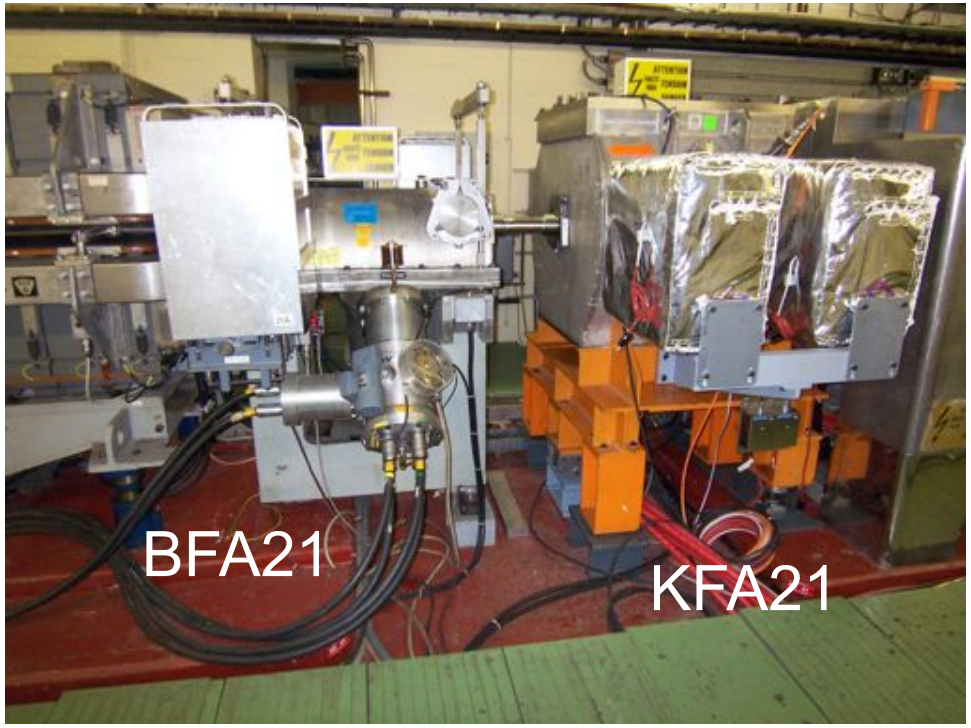


Good agreement between expectation from the model and trajectory measured

Closure of Slow and fast bumps



Kicker commissioning issue



Two “weak” points during new fast bump commissioning:

1. KFA21 HV connectors proved to be weak, had to be changed few times

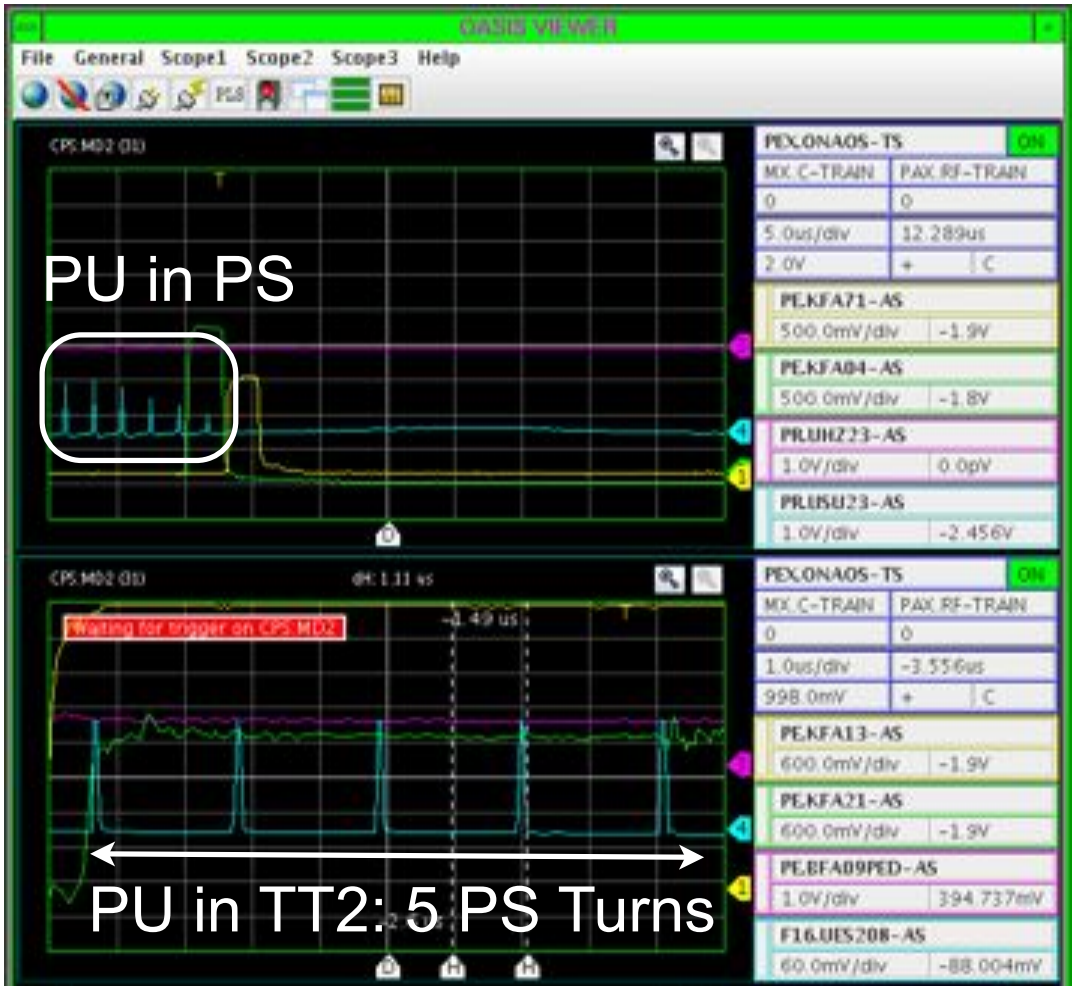
⇒ **New design for 2009**

2. BFA9 (common to classic CT) not fully PPM: change of MTE extraction efficiency due to different supercycle composition (how many CNGS ...)

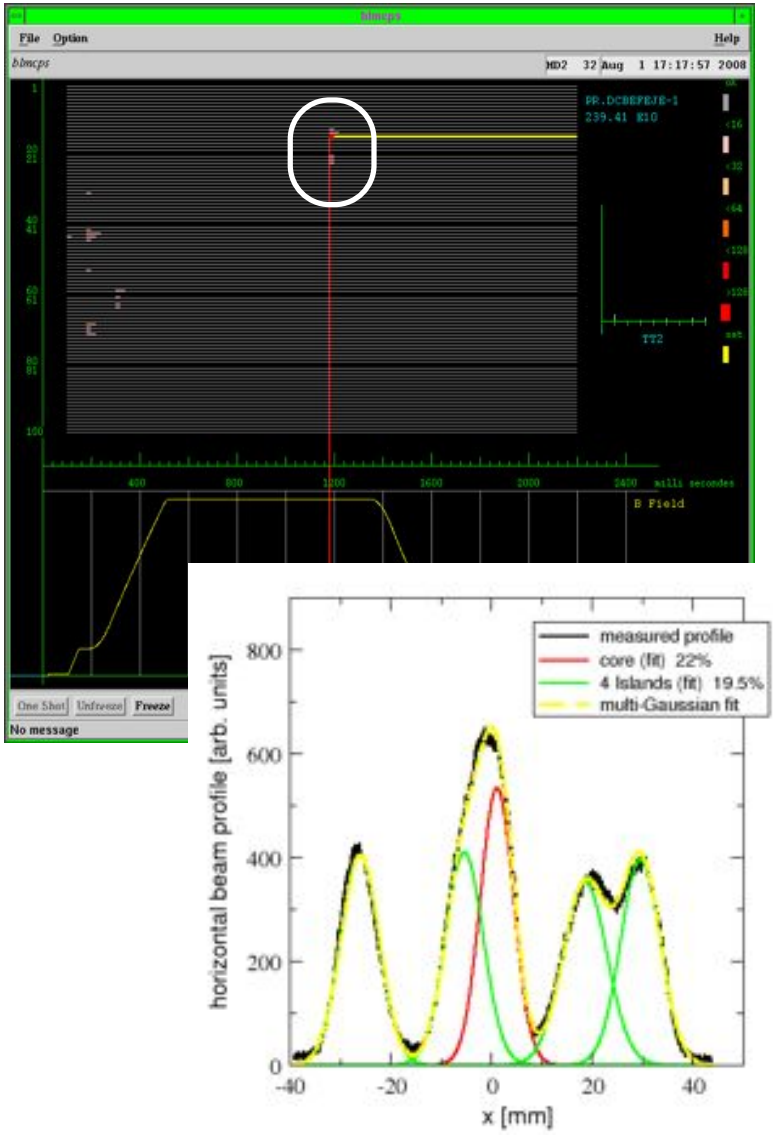
⇒ **Improved power converter for 2009**

First beam extracted in August

Fast MTE signals



Beam loss monitors: losses only SMH16



18%-19% loss less capture per islands

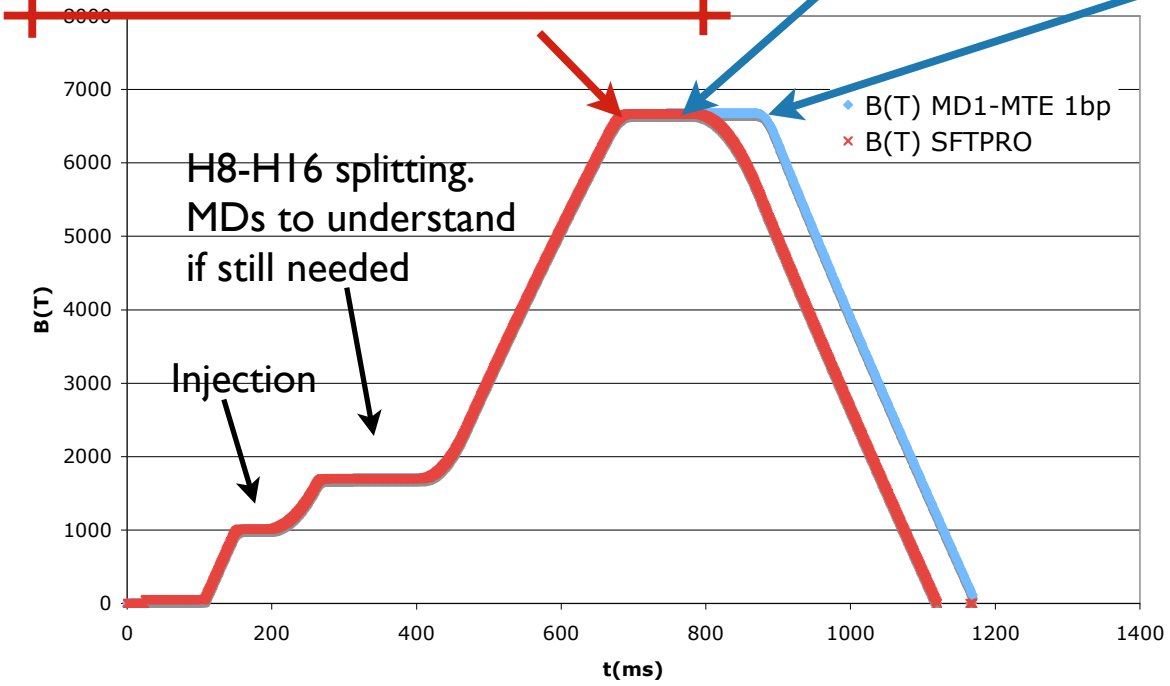
Extraction on 5 turns in TT2 done

Cycle MTE 1bp vs SFTPRO-CNGS CT extracted

SPS placing
De-bunching plus 200 MHz structure
CT extraction ct = 770 ms

Synchronisation (to be done **FIRST**)
Capture which takes about 100 ms

200 MHz structure
MTE extraction at 845 ms



MTE 1bp operational cycle longer than classical CNGS because:

1. capture takes about ~100 ms

2. if bunched extraction,100 ms needed for synchronisation. Bunched extraction best to minimise losses due to kicker rise time (longer than bunch spacing).

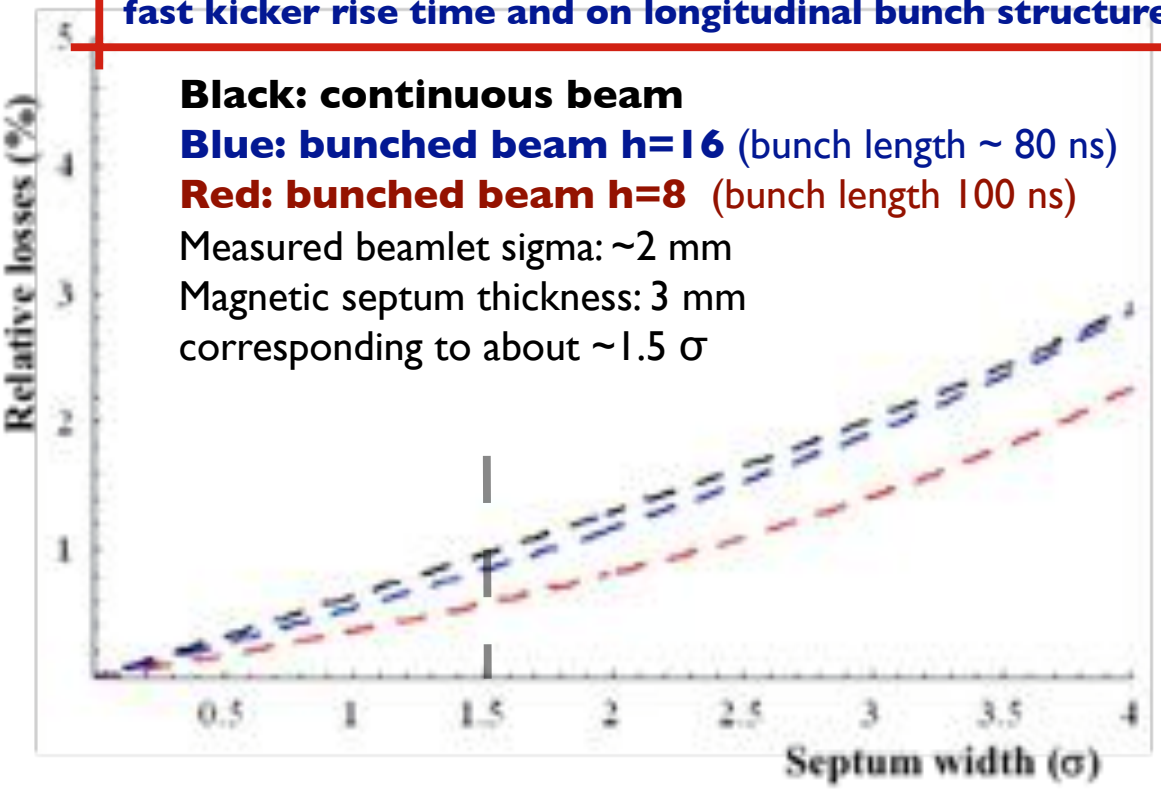
Increasing the cycle length had a direct impact on the operational CT-extracted cycle. To be able to inject in the SPS a CT or an MTE extracted beam minimising the impact on the SPS:

1. all the PS FT operational cycles had to be reprogrammed to have the same MTE extraction timing
2. change the MTG offset between the PS and SPS

Losses vs longitudinal structure

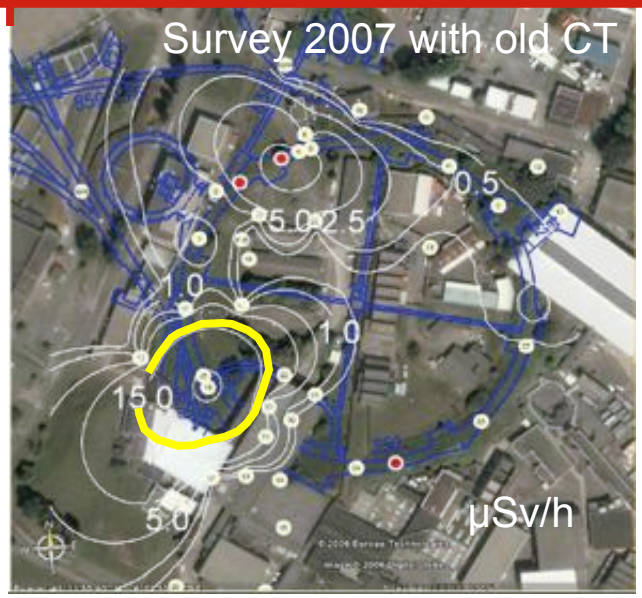
Losses on the septum 16 depends on septum thickness, fast kicker rise time and on longitudinal bunch structure

Black: continuous beam
Blue: bunched beam h=16 (bunch length ~ 80 ns)
Red: bunched beam h=8 (bunch length 100 ns)
Measured beamlet sigma: ~2 mm
Magnetic septum thickness: 3 mm
corresponding to about ~1.5 σ



Loss diff. between h16 and debunched is only marginal.

MD needed to understand if SPS can accept bunched beam, either h8 or h16. 200 MHz structure always there to allow trajectory measurement in TT2-TT10 - 1st turn in the SPS



Simulated

	Beam losses (%)		
	Continuous	Bunched (h=16)	Bunched (h=8)
Nominal configuration	1	0.9	0.6
Total (capture+extraction)	3–4	2.9–3.9	2.6–3.6
Improved kickers (faster rise time)	0.6	0.5	< 0.1
Total (capture+extraction)	2.6–3.6	2.5–3.5	2.1–3.1
Reduced thickness of magnetic septum	0.6	0.5	0.3
Total (capture+extraction)	2.6–3.6	2.5–3.5	2.3–3.3

Longitudinal structure study results

- Study done by injecting in the SPS a CT extracted beam:
  - bunched and synchronised in h8 with different RF voltages
  - bunched and synchronised in h16 with different RF voltages
  - debunched from h8 with same debunching time as for h16
  - debunched from h16, as in normal operation for the CNGS/SFTPRO
- **Results after many iterations** which caused also a change, few times, of the operational CNGS and SFTPRO users and a change of the MTG offset between the PS and SPS
  - Not possible to have a bunch splitting h8-h16 at 14 GeV/c in the PS
  - Not possible to synchronise with less than 40 kV with existing hardware
  - The SPS has minimum losses with two structures: a) debunched from h16; b) bunched h16 with 4 kV in the PS, which is practically a debunched beam and cannot be synchronised
- **Not possible to minimise losses in the PS by using an h8 beam**.
  Further study to reduce the cycle length by debunching from h8.

Thanks to G. Metral, T. Bohl, H. Damerau, S. Hancock, K. Cornelis, J. Wenninger, and OP crews

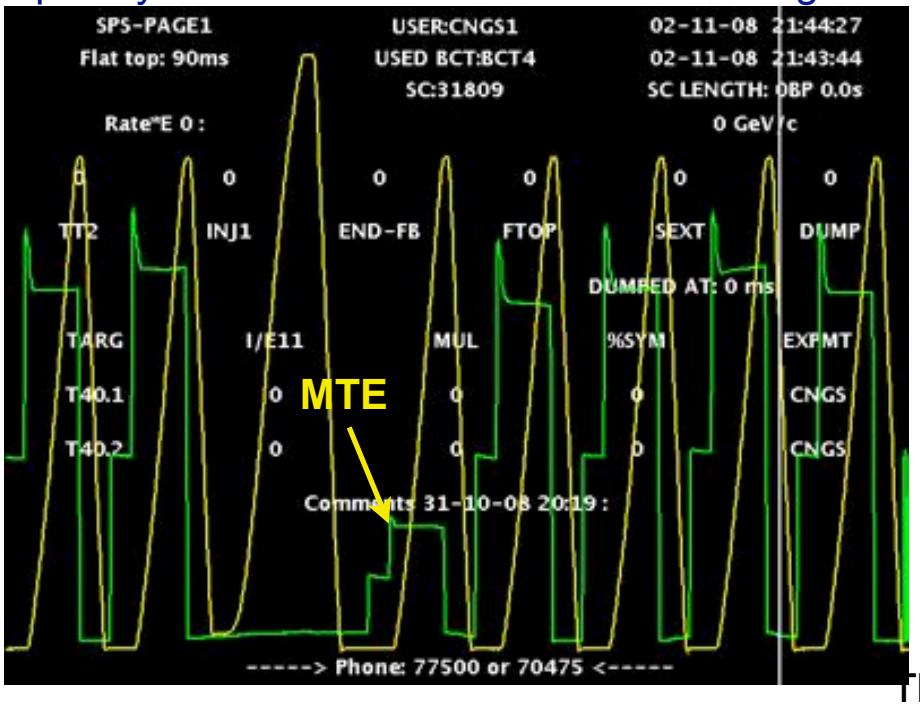
MTE beam injected in SPS - up to CNGS target

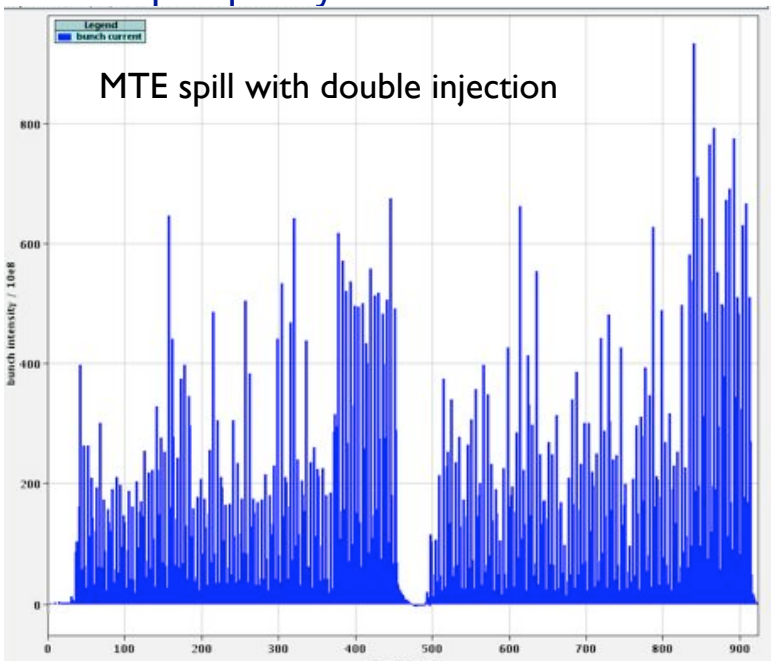
A) **MTE bunched beam has been injected in the SPS, accelerated and extracted to the CNGS**.
B) Double injection done with about **600-700e10 per injection**.

C) **No time to match the injection optics, LHC type optics used instead** without the emittance exchange section in TT10. H plane larger than on normal SFTPRO but V smaller.
Losses up to 15% observed at injection most probably from large optics mis-match, in particular Dy.

D) **Longitudinal structure not optimum for the SPS** ⇒ Bunched h16 synchronised (60 kV) with 200 MHz structure. Losses during acceleration. **De-bunched beam prepared after the SPS stop.**

E) **Extraction left in operation for the last night of the CNGS run without any mayor issue**. However, large losses (≈ 10%) in the PS at extraction ⇒ changed beam radial position from synchro. on real SPS frequency. No time to retune extraction during tests ⇒ impact on spill quality.

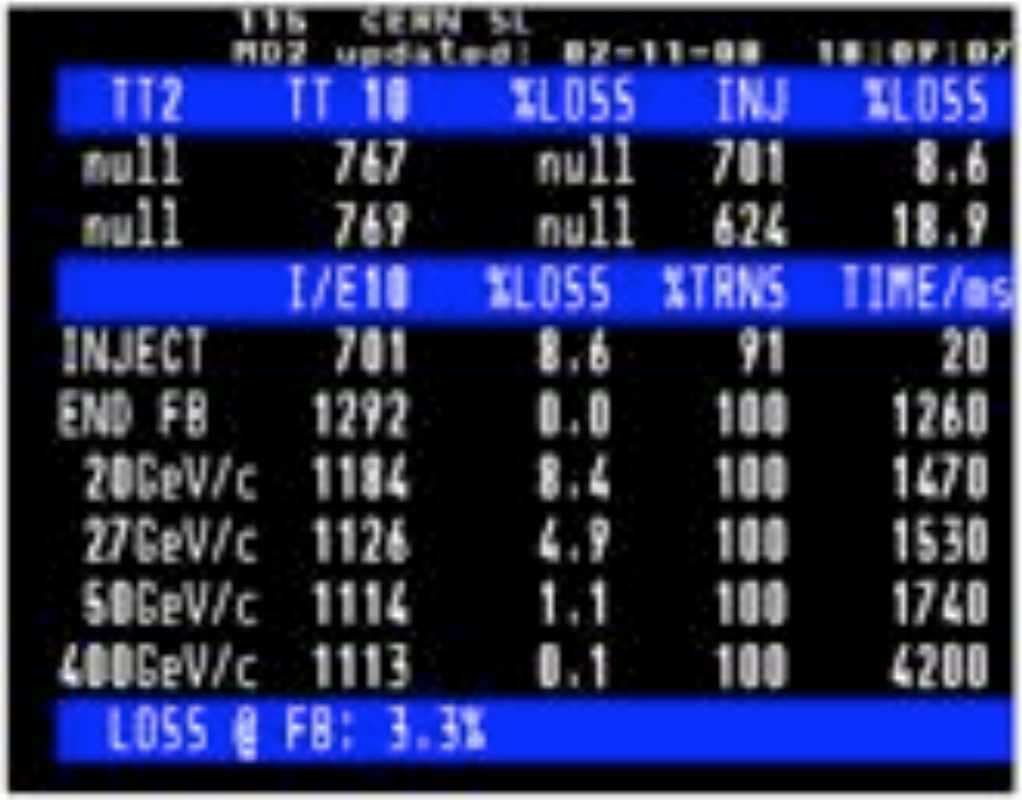




Thanks to T. Bohl, J. Wenninger, D. Manglunki and OP SPS crew

A “LARGE” for MTE-extracted beam in SPS

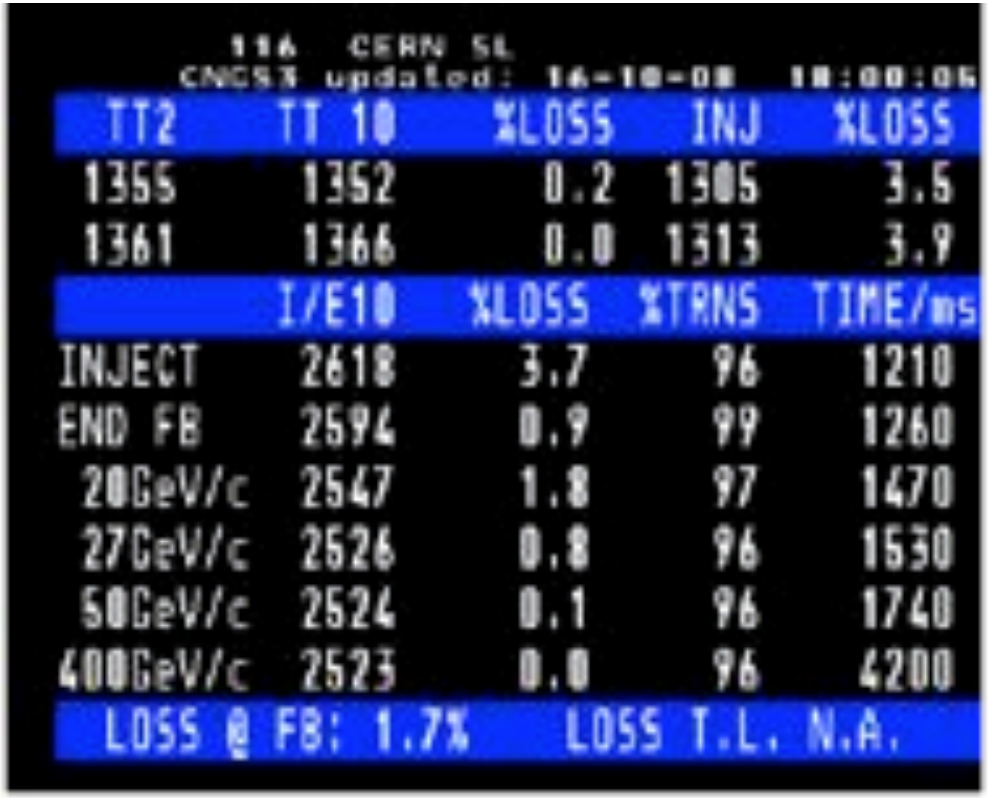
MTE LARGER



TT2	TT 10	%LOSS	INJ	%LOSS
null	767	null	701	8.6
null	769	null	624	18.9
	I/E10	%LOSS	%TRNS	TIME/ms
INJECT	701	8.6	91	20
END FB	1292	0.0	100	1260
20GeV/c	1184	8.4	100	1470
27GeV/c	1126	4.9	100	1530
50GeV/c	1114	1.1	100	1740
400GeV/c	1113	0.1	100	4200

LOSS @ FB: 3.3%

CT LARGER

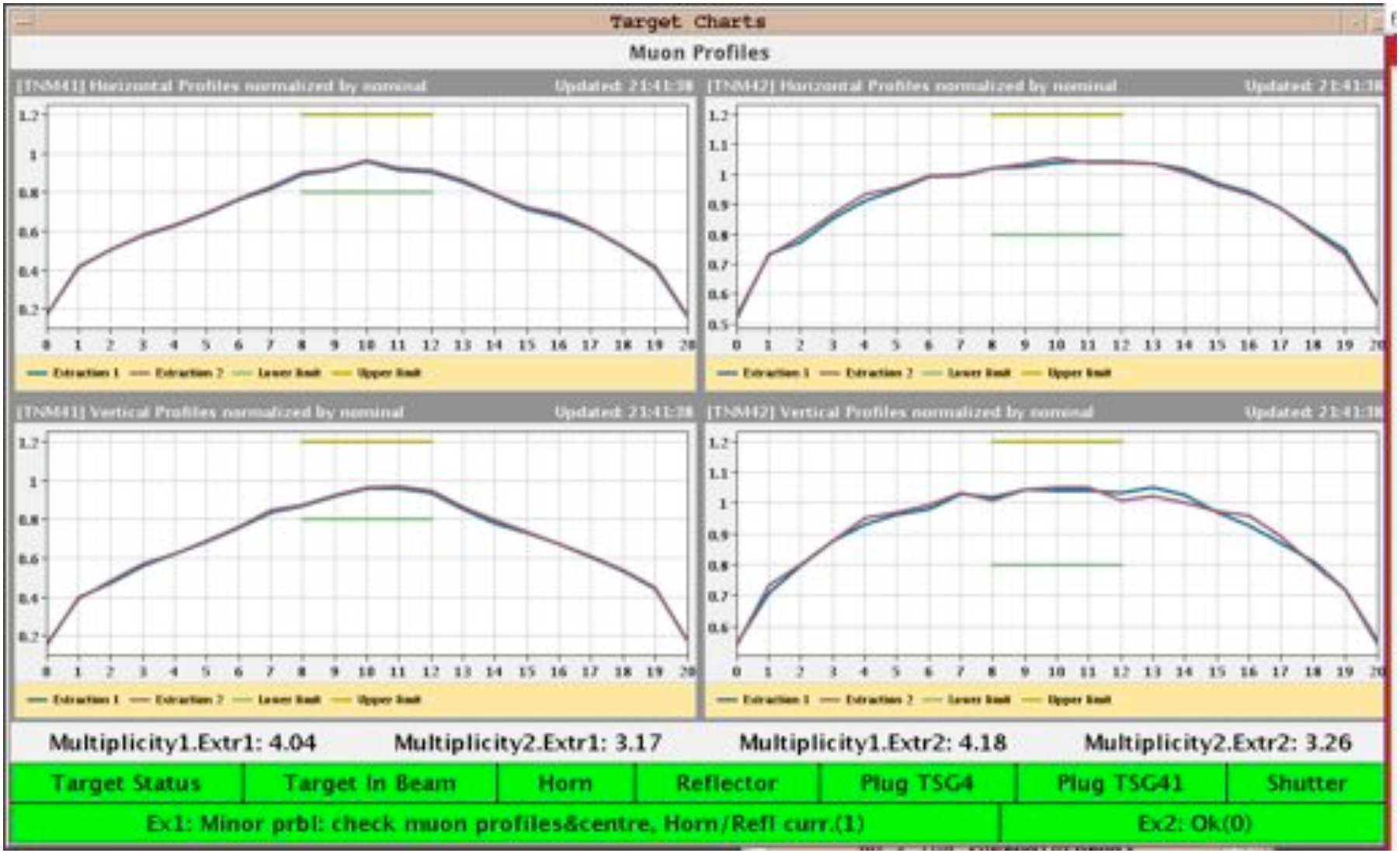


TT2	TT 10	%LOSS	INJ	%LOSS
1355	1352	0.2	1305	3.5
1361	1366	0.0	1313	3.9
	I/E10	%LOSS	%TRNS	TIME/ms
INJECT	2618	3.7	96	1210
END FB	2594	0.9	99	1260
20GeV/c	2547	1.8	97	1470
27GeV/c	2526	0.8	96	1530
50GeV/c	2524	0.1	96	1740
400GeV/c	2523	0.0	96	4200

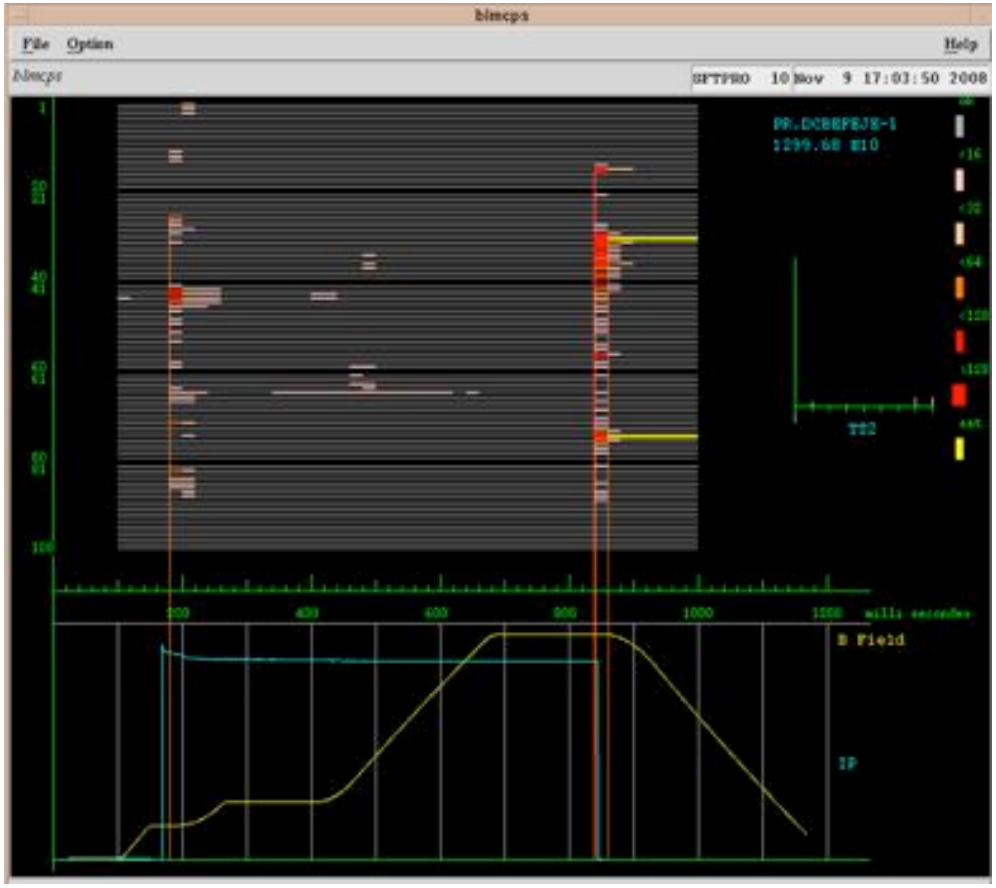
LOSS @ FB: 1.7% LOSS T.L. N.A.

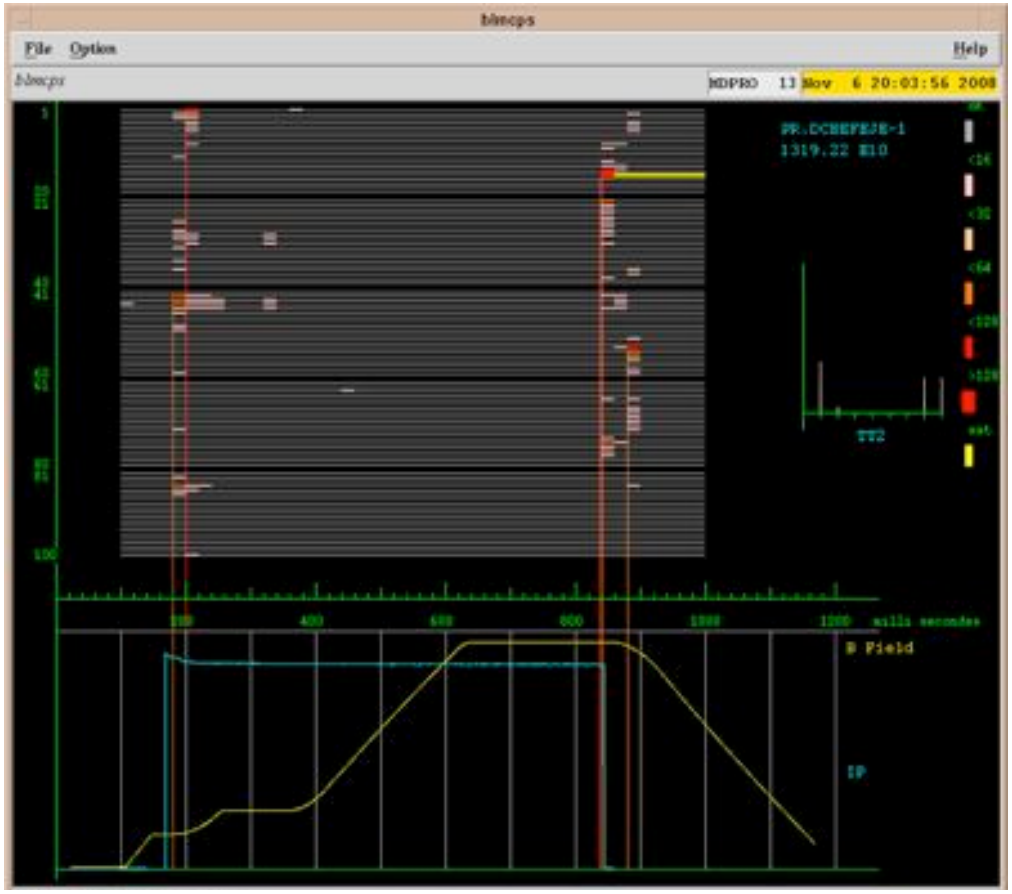
courtesy of T. Bohl

First MTE's neutrinos ...



SFTPRO-CT vs SFTPRO-MTE





MTE commissioning continued after the end of the SPS run

De-bunched SFTPRO-like MTE beam has been extracted with losses about 1/2 of the normal CT for the same accelerated intensity (1.3 10^{13})

MTE ≈ 97-98 % extr. eff. vs CT ≈ 95 % in agreement with expectation.
Losses concentrated on SMH16 as expected due to kicker rise time and large core emittance

Islands emittances

Islands and core emittance deduced from profile measurements and PS optics model:

emittance H core (1sigma,normal) ~ 43 mm mrad

emittance H islands(1sigma,normal)~ (6.8+-3) mm mrad

Core emittance too large with respect to islands emittance confirmed by measurements in TT2: ~ 38 mm mrad and in SPS at extraction: ~ 22 mm mrad (full beam, reduced by losses)

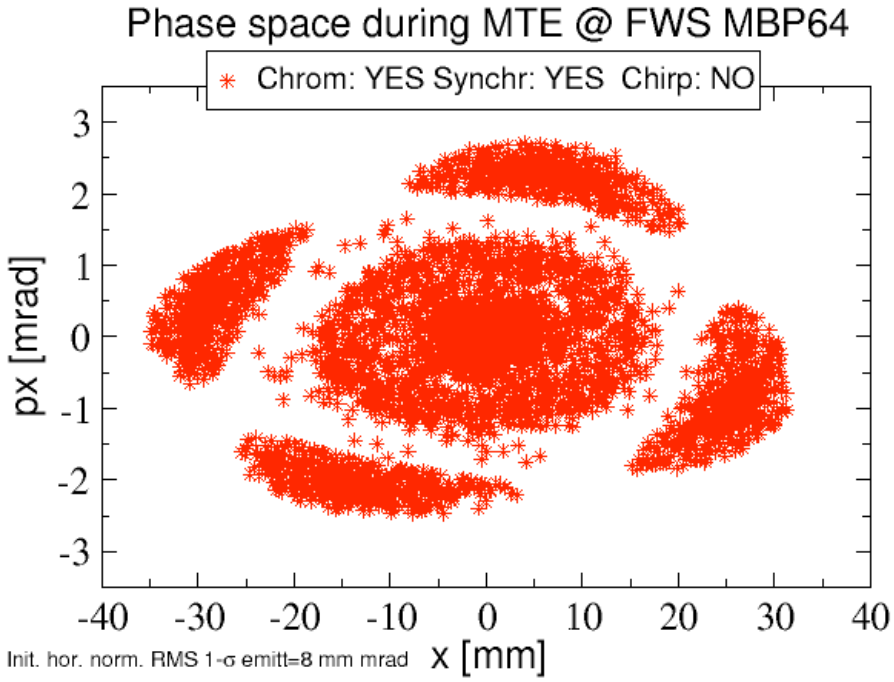
As shown by simulations, negative chromaticity before capture generates large core beam. New non-linear working point to be chosen to keep large intensity sharing and core sufficiently small (as in 2007 run).

In vertical plane, no emittance change before/after capture observed: emittance V (1sigma,normal) ~ 4.25 mm mrad

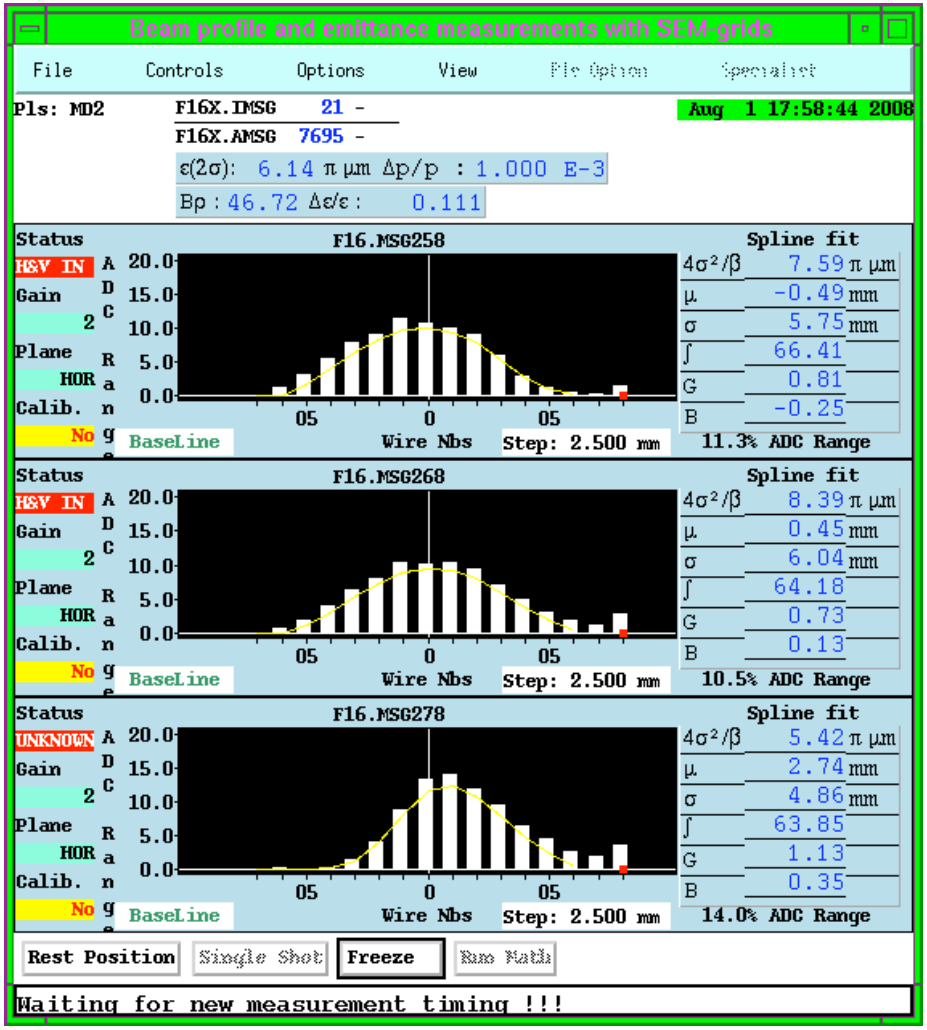
Once injected into SPS, without TT10 phase exchange, losses @ injection due probably to large core horizontal emittance+large optics mismatch.

Not possible to measure the H emittance @ injection during test.

Vertical emittance increasing during SPS acceleration, from ~ 4 mm mrad to 7 mm mrad.
Instability observed in the V plane to be understood.



TT2-TT10-SPS matching



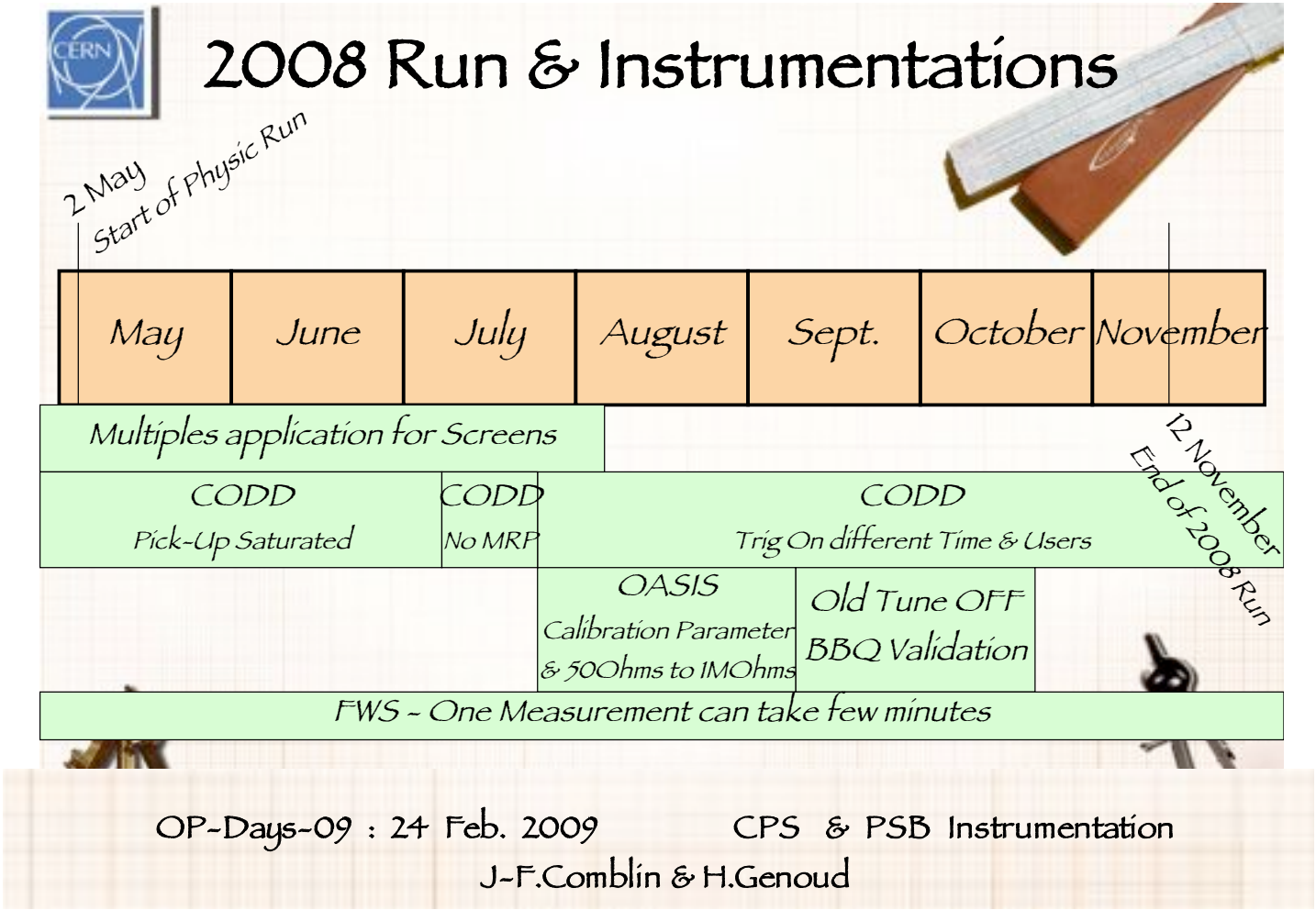
Matching study started:

Large profiles observed in TT2 due to different island trajectories at extraction.

Optics with and without phase exchange in TT10 computed (E. Benedetto)

Measurements will be repeated since core emittance should be reduced with better nonlinear working point

Instrumentation issue



Unfortunately we had only rarely all the instrumentation needed available at the same time, as for normal operation.

Commissioning program “adapted” according to the instrument operational at the particular moment and MTE resources used to help in debugging/validating the different systems.

2009 start-up

- Open questions from last year:
  - large core emittance ⇒ chromaticity too small, even negative in same cases ⇒ different ξ choice
  - Matching with SPS ⇒ best matching optics w/wo the TT10 phase exchange ⇒ start without phase exchange
  - Instabilities and losses in the SPS ⇒ debunched beam from PS required
  - Capture optimisation using chirp excitation ⇒ no need of large emittance beam from PSB
  - Longitudinal gymnastics ⇒ debunching from h8/h16 before capture
  - Definitive choice of magnetic cycle/extraction timing
- Proposal for this year:
  - **Start to provide SFTPRO-CNGS beams with the classical CT**.
  - **Prepare in parallel an MTE extracted beam with the same intensity as SFTPRO**.
  - Once the SPS starts, an MD cycle should be included in the Super-Cycle, even without acceleration, to optimise the PS-SPS matching.
  - **Provide as soon as possible SFTPRO with MTE extraction.**
  - CNGS will start with a normal CT.
  - Initially, one CNGS cycle could be served by MTE. The intensity will be the highest compatible with the status of the MTE setting up.

MTE first planning

	Activity	Tot. Int.	DATE	BI instrum.
Activities before MTE start up	Commissioning of TT2 PU+transfo 212			TT2 PU TRANSFO
	Optimization of SMH16 angle with CT	2.00E+12		BLMs
MTE start up activities: PS only	Nominal Cycle setting-up	1.00E+11		
	Non-linear chrom nominal working point	1.00E+11		Qmeter
	Check OMT39 by Q' meas	1.00E+11		Qmeter
	Setting up of debunching	1.40E+13	SFTPRO nom intensity > 29/04	
	Capture setting up	1.40E+13	SFTPRO nom intensity > 29/04	FWS + Qmeter
	Bump16 setting up			CODD
	Bump16 tune variation compensation			Qmeter
	Fast bump recommissioning			CODD
	Setting up of MTE extraction	1.40E+13	SFTPRO nom intensity > 29/04	FWS + Qmeter +CODD
	Optimization of SMH16 angle with MTE	1.40E+13	SFTPRO nom intensity > 29/04	BLMs
	TT2 optics study & steering	7.00E+12		SCREENs+PUs+SEMWIRES/GRIDS
MTE start up activities: SPS with special user on MD segment	TT2-TT10 optics study	1.40E+13	end of May. Week 22 and 23	SCREENs+PUs+SEMWIRES/GRIDS+SPS
	SPS injection	1.40E+13		SPS Orbit
	SPS matching study	1.40E+13		SPS Orbit
	Deliver SFTPRO with MTE	1.40E+13		

Key elements before commissioning can start:

1) New MPS regulation work finished, operational cycles rebuilt -> work ongoing should be finished soon (this week)
2) BI instrument commissioning finished: a) BBQ seems in good condition now; b) BSW still not operative

-> Preparation of the cycle will start soon, but to resume the capture the BSW is necessary

Key dates:

1) Moderate intensity SFTPRO needed to setting up the de-bunching without radial position drift observed last year
-> then capture will be resumed since the non-linear working point depends on the radial position -> after the 29 of april.

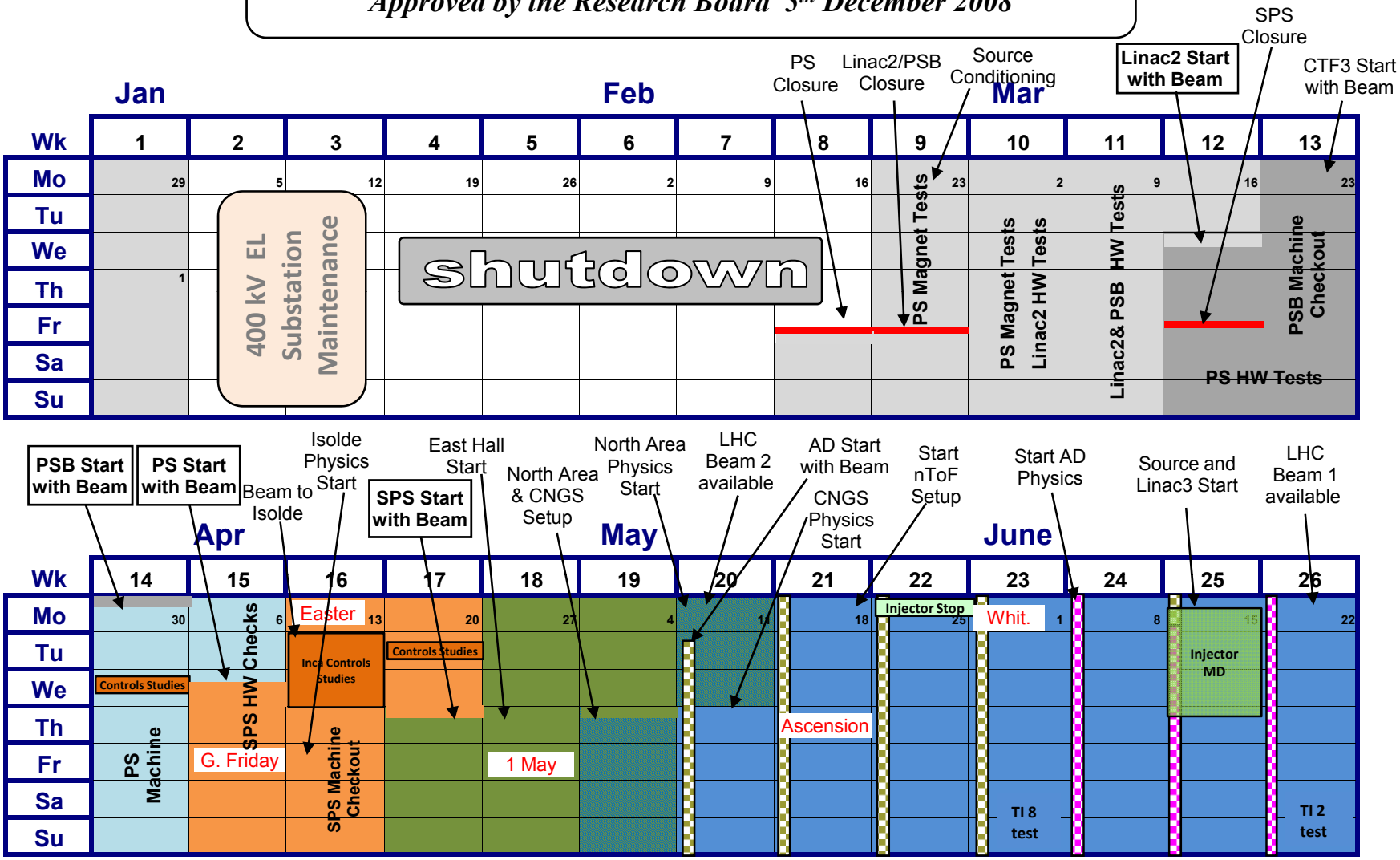
2) SPS will be available for injection tests by the end of May, then in week 22-23, one cycle available for injection when the LHCFAST will not be in the SC.

pc

1/3/2009
V3.3

2009 Injector Accelerator Schedule

Approved by the Research Board 5th December 2008



Conclusions

1. MTE extracted beam has been provided to the SPS for the last night of CNGS run.

2. Intensity extracted so far 1.3-1.4e13 (typical SFTPRO) with extraction losses down to 2-3%. Stability of the losses however still not reached. Sometime fluctuation up to 10% still to be understood. Most probably due to negative chromaticity during capture.

3. De-bunched extraction has been prepared. Basically same extraction efficiency as for the h16 bunched case. Tests with the SPS have been finished by using the normal CT to define the most suitable longitudinal structure.

4. No major problems encountered for MTE specific equipments. Main delays produced by:
    1. same issues encountered by normal PS operation
    2. more time than foreseen to clarify the best longitudinal structure for the SPS.

5. The 2009 planning aims to provide an SFTPRO-MTE extracted by the middle of the run.

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