REVIEW OF OPERATION IN 2009
B. MIKULEC

With my sincere thanks to everybody providing material for this presentation!

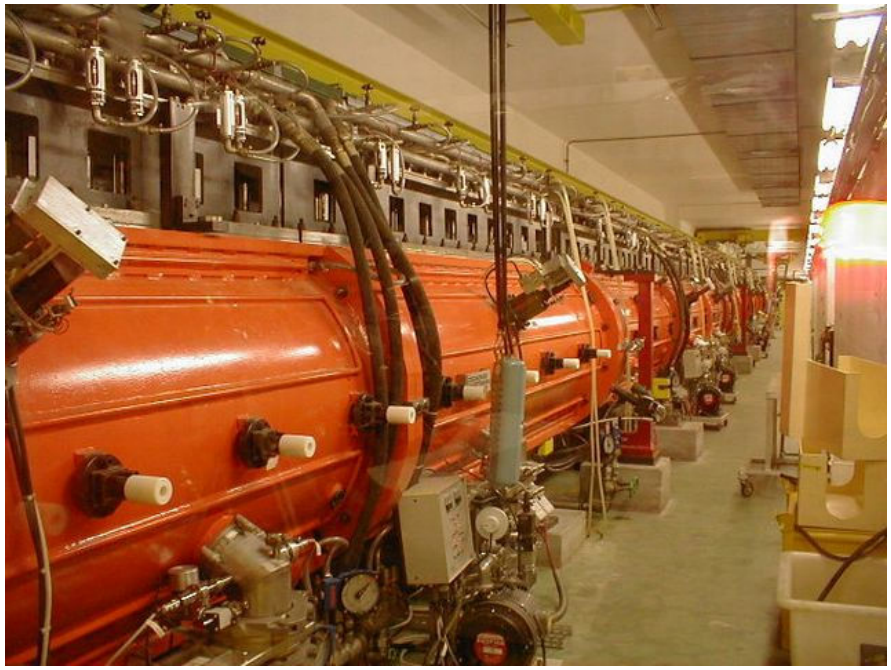
Outline

- The Proton Chain
  - LINAC2, PSB, PS, SPS
  - ISOLDE, EAST AREA, AD, NTOF, NORTH AREA, CNGS
- Towards CLIC – CTF3
- The Ion Chain
  - Linac3, LEIR, PS with ions, SPS with ions

The Proton Chain

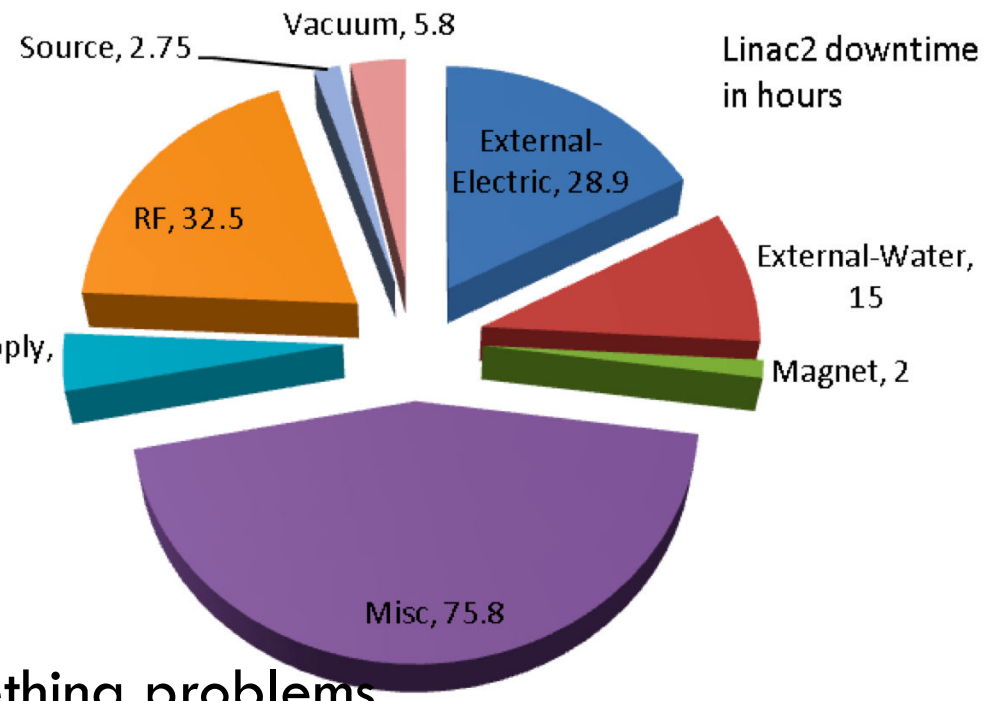
LINAC2

- Year of birth: 1978
- Has to deliver protons for CERN until end of 2014
- Impressive uptime of the past years will be a challenge for Linac4…

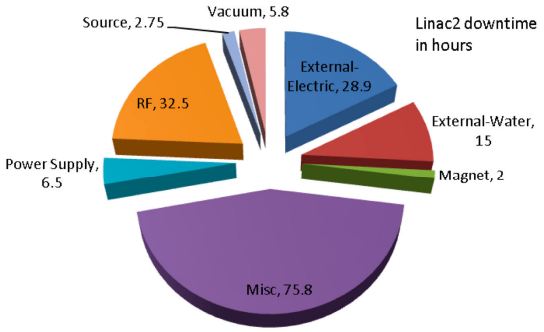


LINAC2

- Run statistics from 1/4/2009 – 16/12/2009 (~5893h)
- Uptime of 97.1%
- Controls
  - no notable issues
- Source, Magnets
  - negligible
- Power Supplies
  - Tank1 quad PS teething problems
  - Damage to LT.BHZ30 by external fire → **Misc.**



LINAC2



- Vacuum
  - Large vacuum leak on tank2 RF coupler → add secondary vacuum system (avoid venting the tank!); leak search → **Misc.**
  - RFQ vacuum pumping system
- External/Water: a few isolated problems; cooling temperature variations affect RF tuning of tanks
- RF
  - 68 faults in total
  - includes 7h over Easter weekend (no specialist intervention requested overnight)
  - 7h attributed to tank2 RF coupler once the leak was found

LINAC2 - Summary

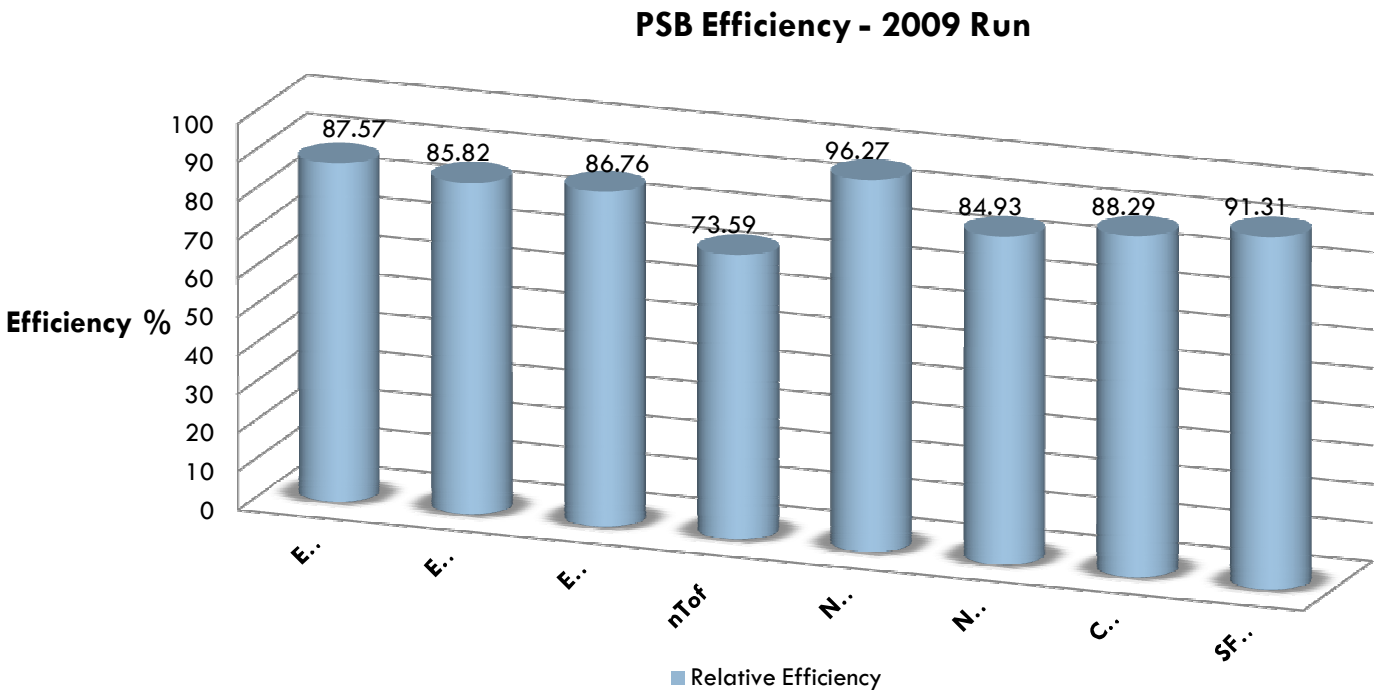
- Reminder: Tanks remain most vulnerable elements
- RFQ: biannual change of ion pumps?
- Measurement of lines foreseen by ABP-SU for long 2011 shutdown

- Mind: Linac2 lift intervention only next shutdown or during ion run? (need to plan in ~8 weeks)

- Operation in 2010 should not anymore be affected by Linac4 construction (low threshold level of 1 radiation monitor, but seems acceptable), but connection Linac2 – Linac4 emergency exit needs to be scheduled

PSB

- Good and stable running with only 1 major breakdown
- Combined p efficiency: 87%
  - From new end-user statistics tool starting at 11th of June:



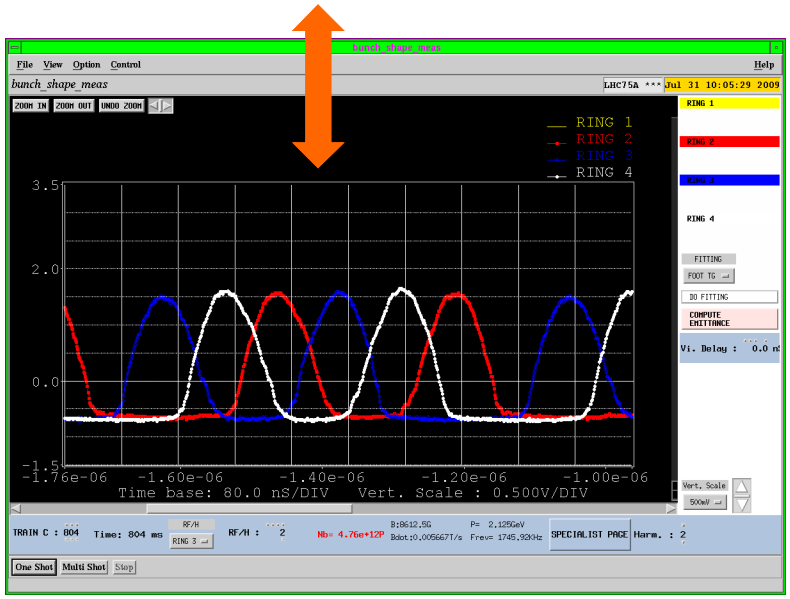
PSB – Main Faults

- May 15th (Friday): leak between water circuit and vacuum on injection septum
  - Run until 18th with reduced intensity without water cooling
  - 24h cool-down and intervention preparation (never before changed; special lifting jig…)
  - Septum exchange on 19th and N_2 flushing of extraction septum to avoid bake-out; pump-down
  - Poor vacuum recovery → detected leak on integrated MTV bellow → MTV intervention on 22nd (spare bellow found), pump-down started again
  - 23rd: final leak detection, bake-out could be avoided
  - Sunday 24th evening: restart with low-intensity beams
- Water leak in 'sieve': removed and not replaced by now

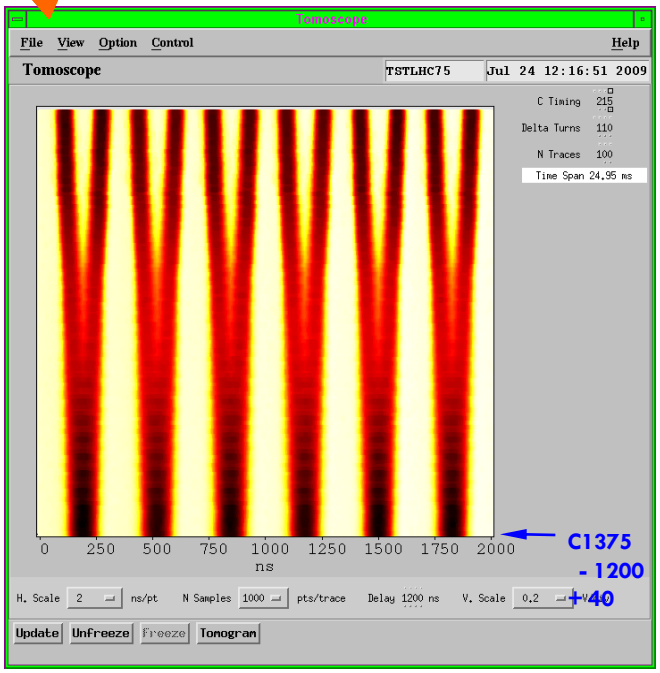
PSB/PS 2009 Highlight

- Commissioning in PSB and PS of LHC50ns and LHC 75ns beams for single batch transfer to the PS
  - In PSB h2 beam using 3 rings with uneven bunch spacing and h1 synchronisation to match PS h7 at injection

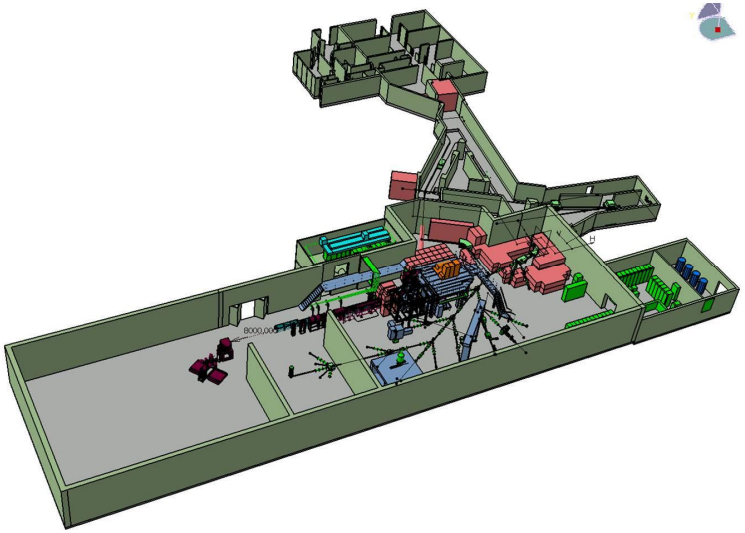
PSB extraction



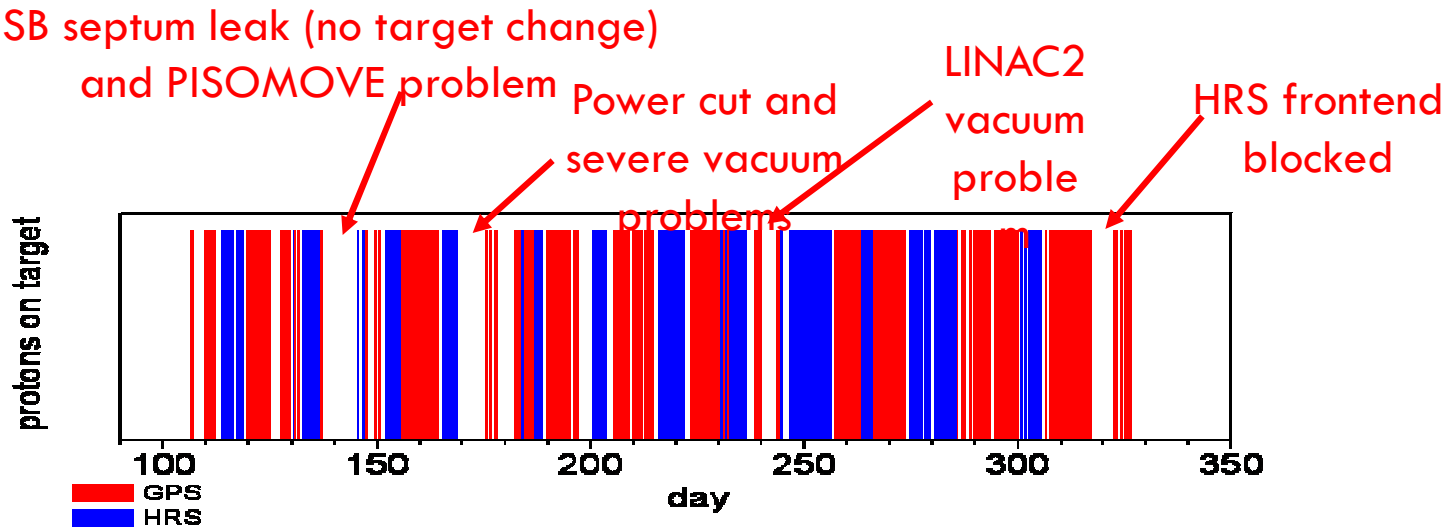
PS (splitting)



ISOLDE/REX



- 'Successful year for users despite some problems' (A. H.)
- 223 days of online operation
  - 2 'normal' runs had to be canceled and 2 REX runs



ISOLDE Issues

- Deflector plate (beam to low energy line) collided with Faraday cup → GPS run canceled
- Vacuum controls
  - Large number of problems and interventions, frequently after power cuts; relying on specialist help

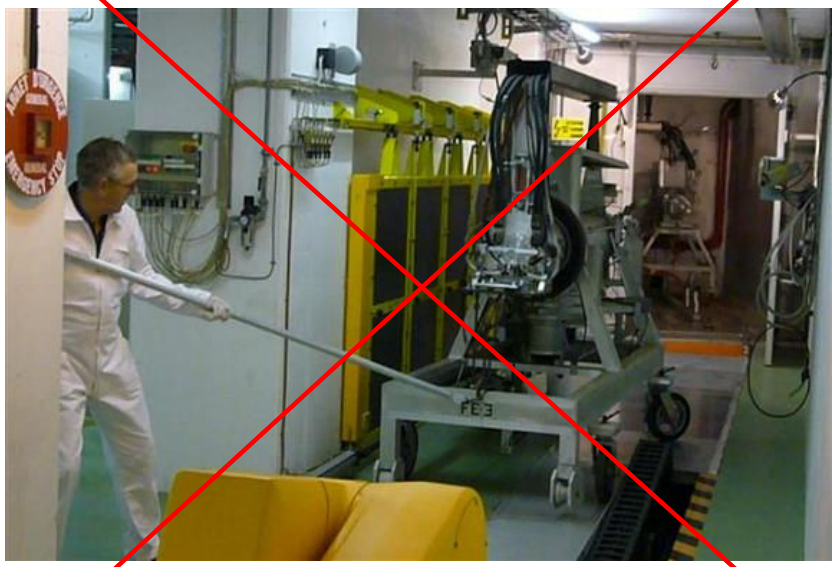
✓ Complete renovation of vacuum controls this shutdown

  - ✓ New racks, modules, gauges etc controlled via PVSS
- AND – problematic target changes!
  - Issues: stepping motor PS for extraction electrode, target valve piston of HRS frontend, wrong storage position programmed, robot clamp not grabbing target correctly, sensor detecting target coupling defective, impossible to unclamp target → DIMR + ALARA Committee before access

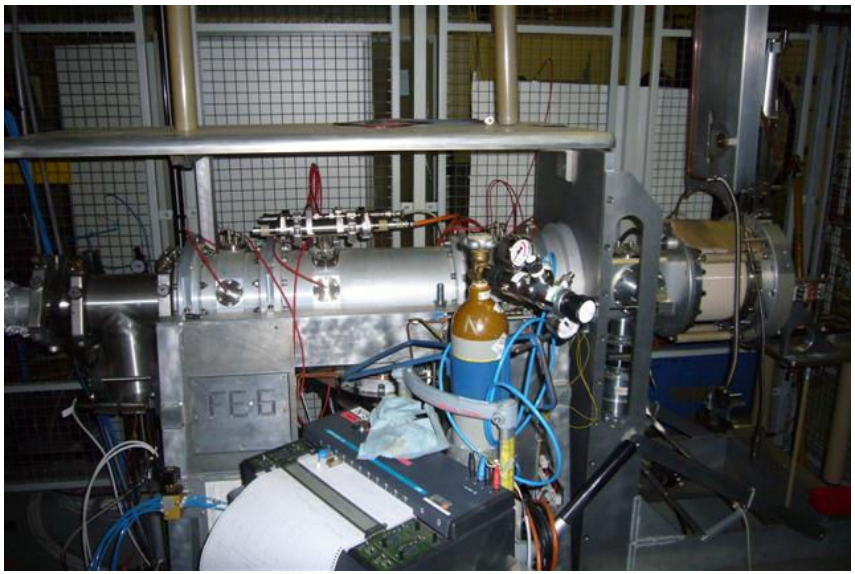
ISOLDE – New Frontend for HRS

- But… GPS will stay with old frontend (realigned) until next shutdown

OLD



NEW

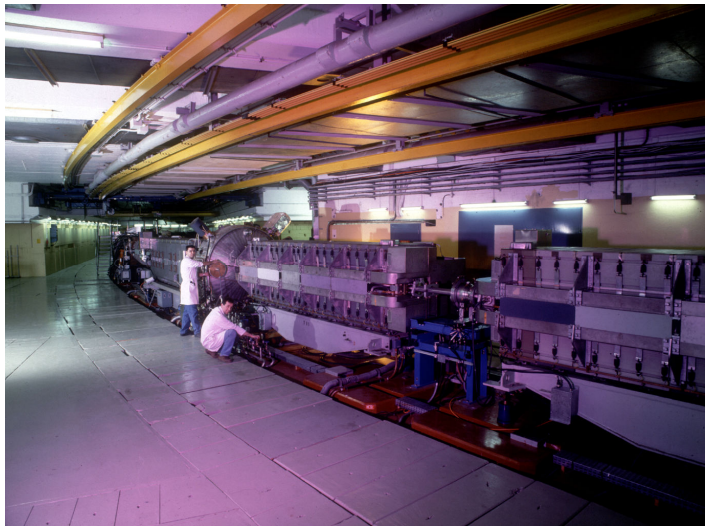


REX Issues

- Cooling of RF amplifiers
  - ✓ Change to water-cooled heat-exchanger this shutdown
  - ✓ New ventilation for RF room
- Vacuum leak on 9-gap cavity
  - Human error → too much RF power
  - REX shielding had to be removed before cavity repair
  - Problem with special seals (spares now available)
- Cathode breakdown of electron source for REX-EBIS
  - ~5 days to recover vacuum conditions

PS

- Started up with new MPS regulation
  - 1st step towards MPS renovation
- MTE commissioning difficult, but ended with successful tests (see presentation S. Gilardoni)



PS Problems (1)

- June 17th morning: leaking ceramic seal between SS52/SS53 due to a broken RF bypass (sparking)
  - Low-intensity beam back already in evening
- September 3rd/4th: degrading insulation of magnet interconnection bus-bar caused earth fault and MPS fault in parallel (one thyristor stack broke as well as auxiliary 15V PS)
  - Exchange thyristor stack and temporary fix for bus-bar
  - Bus-bar replaced by spare during technical stop + MD

PS Problems (2)

- September 18th: fire on roof of MPS building (355) → fire extinguisher powder on power supplies in room underneath
  - Cleaning and dehumidifiers installed
  - ~5.5h lost
  - Additional cleaning during technical stop (corrosion!)
- October 2nd: Leak between water circuit and vacuum on injection septum 42
  - Exchange of septum (5th) followed by bake-out
  - Restart of beam on 11th
- Other issues: video streaming (access), magnets pulsing with value of another user, vacuum leak at wire scanner,…

PS Summary

- Despite many problems good availability of all proton beams (in addition to ions…)
  - average p beam availability: 84%

EAST AREA – 2009 Problems

- Water leak of F61N.DVT01 at startup
  - inaccessible
  - will not be exchanged for moment (compensate with F61N.BVT01)
- Realignment of irradiation facility (T7)
  - Movement by a few cm as only fixed by lead blocks
  - Fixation of elements should be improved
- Telescope of North branch down for a while
  - Steering to North target more difficult
- DIRAC: some problem with ventilation in control room

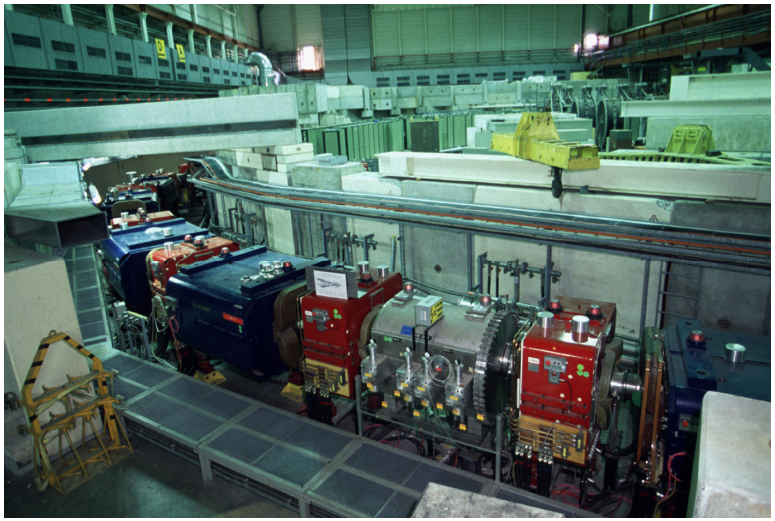
EAST AREA – Summary

- ‘The year was one of the best I remember for both the East Area and the North Area if you take abstraction of the machine performance.

  Lau Gatignon

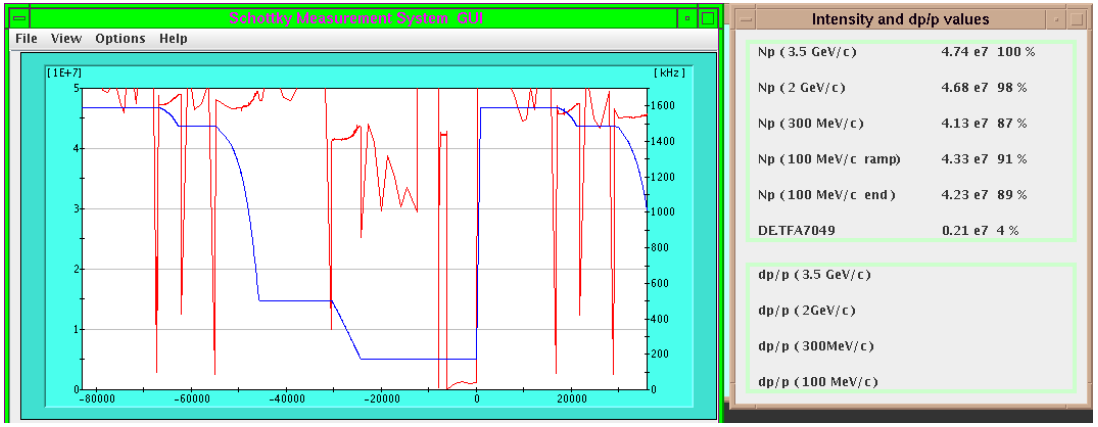
AD

- 92% AD uptime, 79% beam availability
- New horn pulser electronics and interlock operational
- 2 weeks run extension granted mainly on basis of
  - injector problems
  - security chain problems
  - TT6 flooding (access requires beam stop)



AD

- Target positioning system repaired
  - Excellent stability of production beam
  - Many records…
    - Record intensity of delivered beam: ~4E7 pbars/pulse (averaged over 24h)
    - Record deceleration efficiency (>90%) thanks to improved low-energy optics

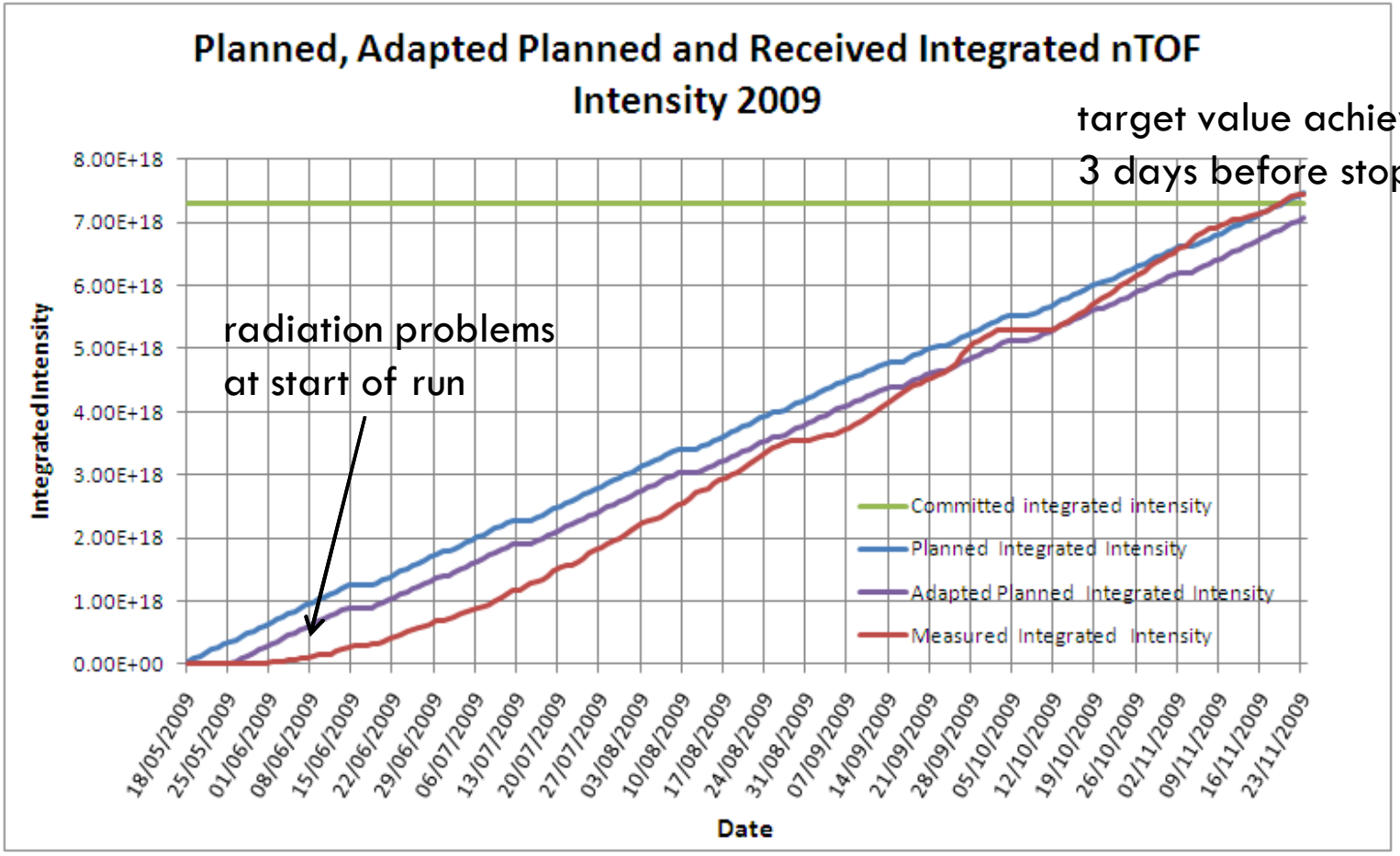


NTOF

- Successful recommissioning after short run in 2008 with new target, water cooling station and ventilation system
- Realignment of beam line during 2008/2009 shutdown
- Dedicated (7E12) and parasitic (3.5E12 p/bunch) beams
- Initially intensity had to be reduced, but improvements in shielding and under-pressure regulation in target area allowed again intensity increase

NTOF

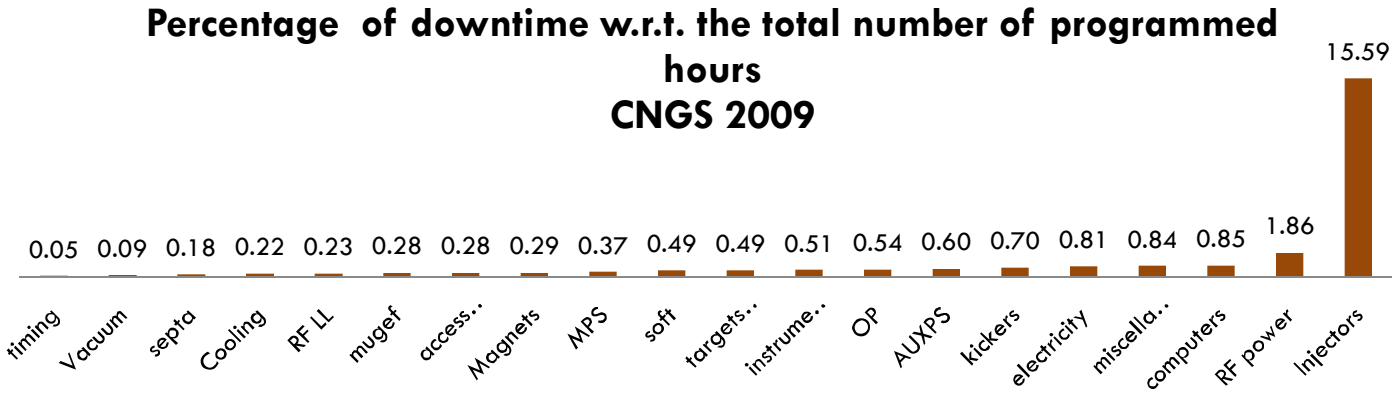
- 7.45E18 instead of goal of 7.3E18 p on target



SPS

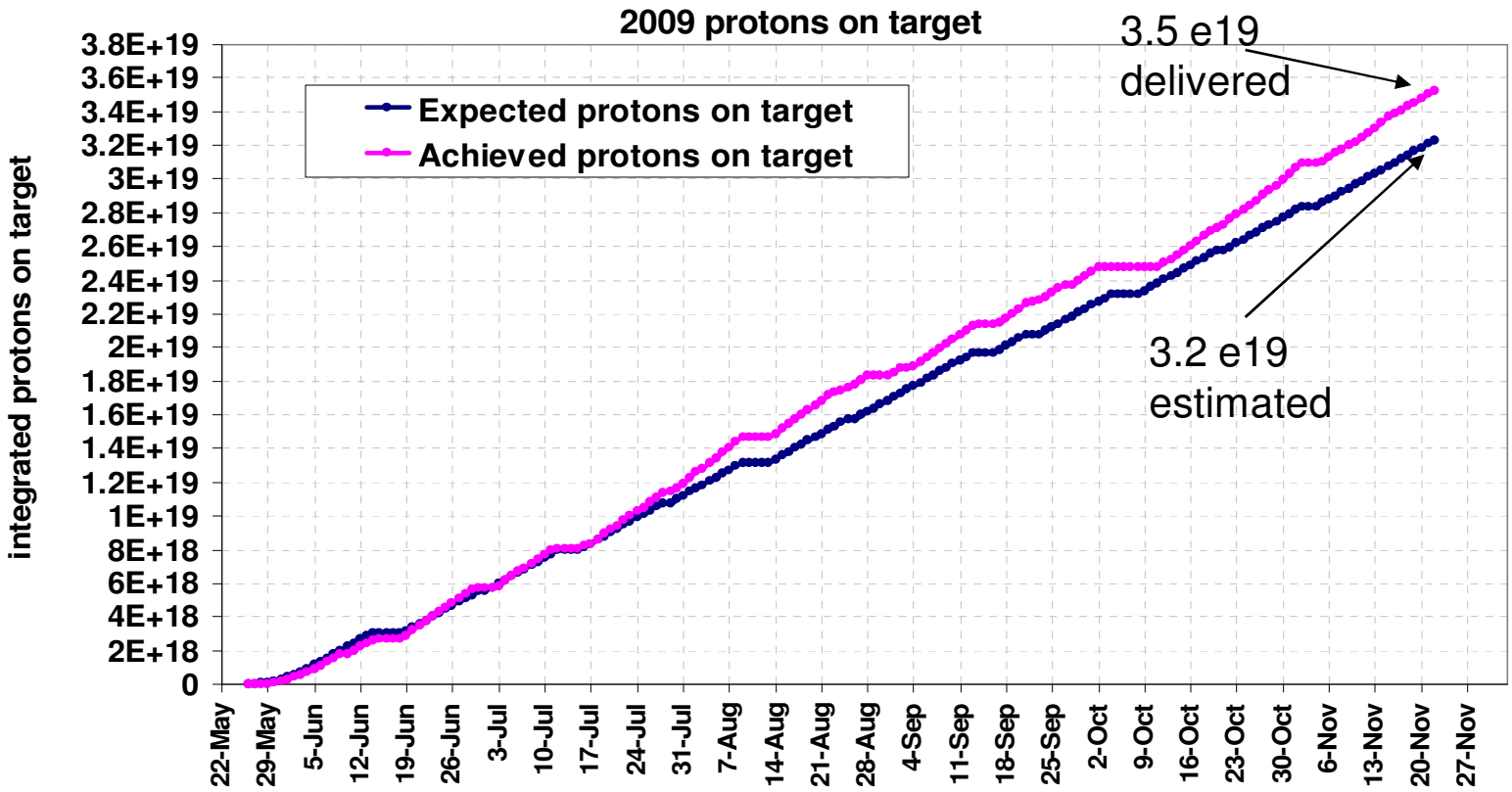
Very good year

- SPS fully ppm
  - increased efficiency for CNGS and MDs
  - flexible response to LHC requirements
  - 2008: 6 CNGS cycles to maintain; 2009: 1 CNGS cycle
  - Automatic economy cycle saved 220 k€ (K. Cornelis)
- Less problems with 18 kV cables and compensator
- RF power improved by factor 2



SPS

- 3.5E19 p for CNGS, 2.8E18 p for FT



…and this without making holes in the SPS!

SPS

- In addition, the SPS provided beam for MDs and
  - UA9, LHC collimator studies and long range beam-beam studies
  - studies with coated magnets for e-cloud suppression
  - many flavours of LHC beams
    - in particular since beginning of November single batch transfer PSB-to-PS 50 and 75 ns beams with nominal intensities and emittances and no e-cloud and outgassing inconveniences → will save 20% LHC filling time

NORTH AREA

- New telescope installed in H6
- Some cooling problems in H2 leading to frequent trips of power supplies for readout electronics installed in NA61 rack (slow restart of DAQ; solved after ~4 weeks)

- 'The year was one of the best I remember for both the East Area and the North Area if you take abstraction of the machine performance.

  Lau Gatignon

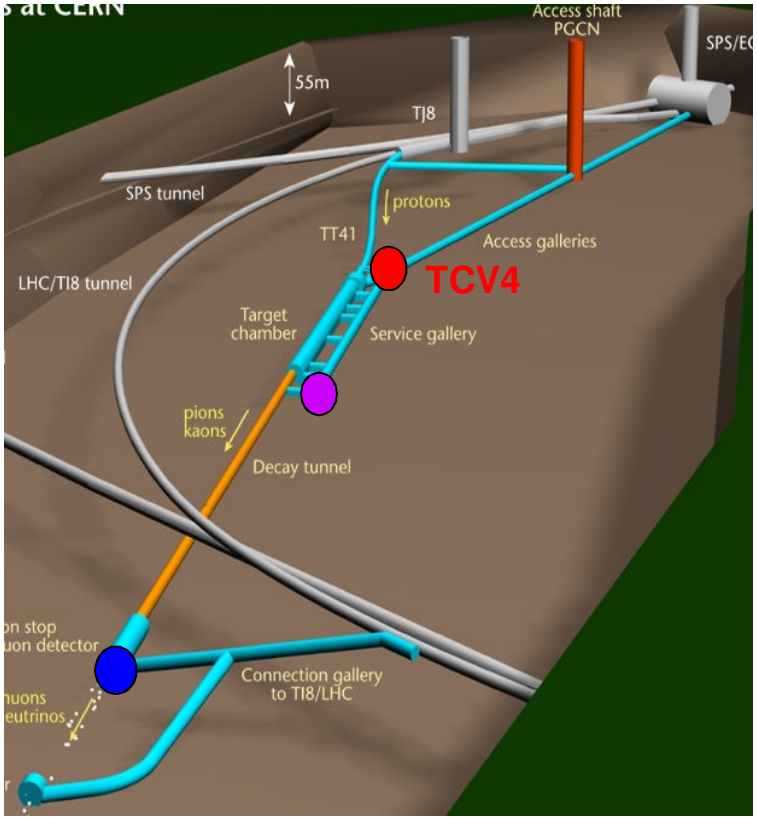
CNGS

- In 2009: New cartridges for horn/reflector water cooling system (only radiation resistant materials, double time until exchange, less radioactive waste)

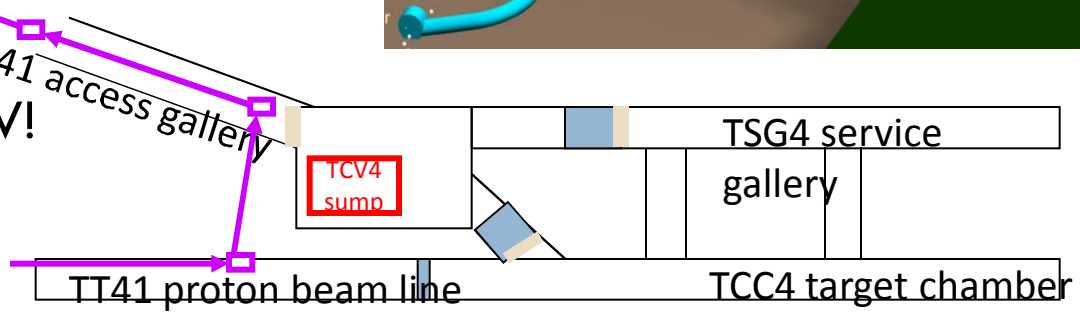
- Restart of CNGS delayed due to earthquake in the Abruzzo region
- Otherwise very smooth restart
- Equipment reliable and stable
- Very good run
  - 3.5E19 pot (see SPS plot)

CNGS Water Issue

- TC4 sump collects water from the area upstream the CNGS target chamber
  - should not contain tritium
  - automatic release every ~10 days
- Since >2008: water is above release limit
  - have to empty in containers



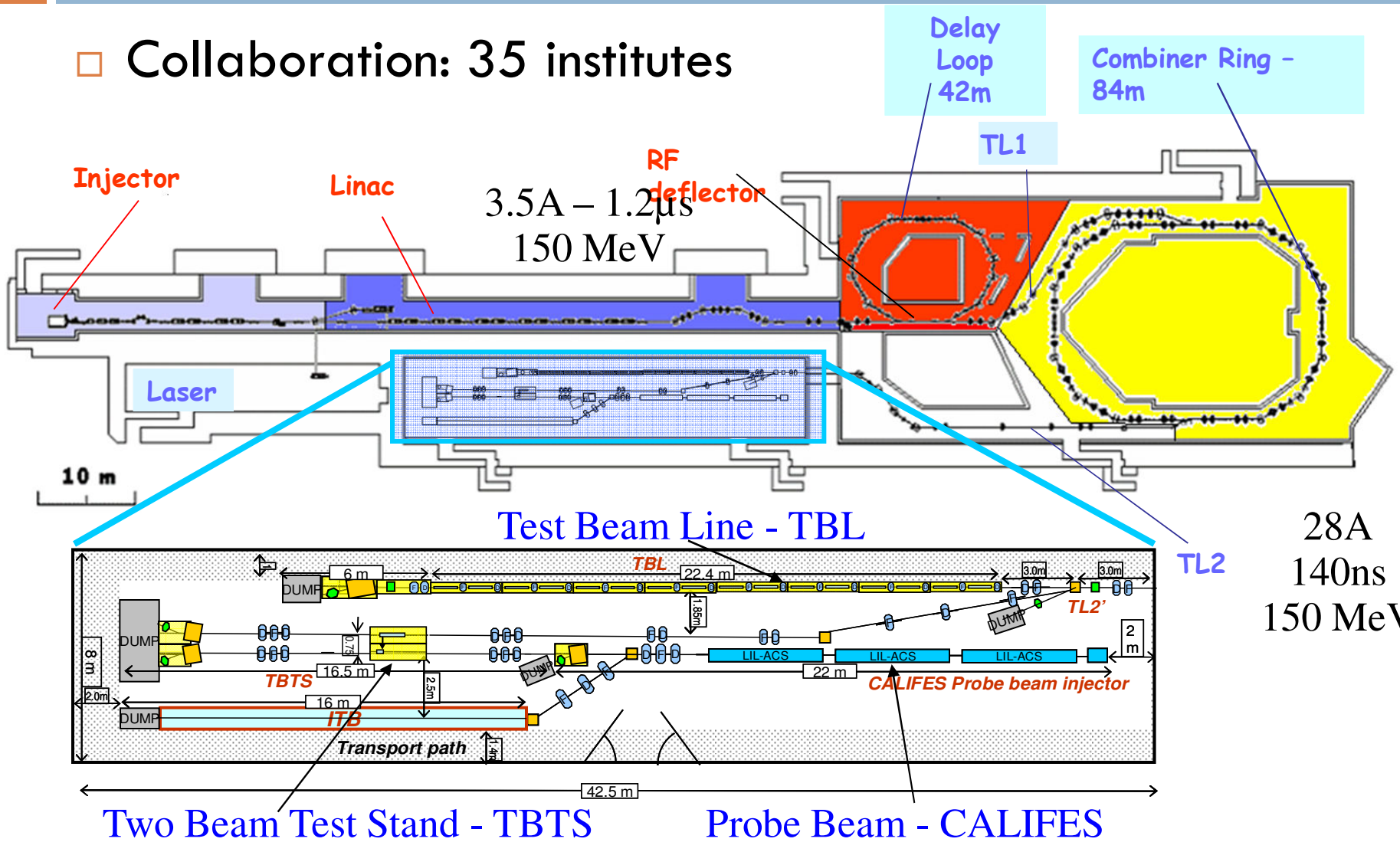
- Remedy: Pump out 'clean' water from p beam line and gallery immediately from radioactive area TCV4
  - Civil engineering and CV!
  - Shortcut with extra pipes and 3 sumps



Towards CLIC – CTF3

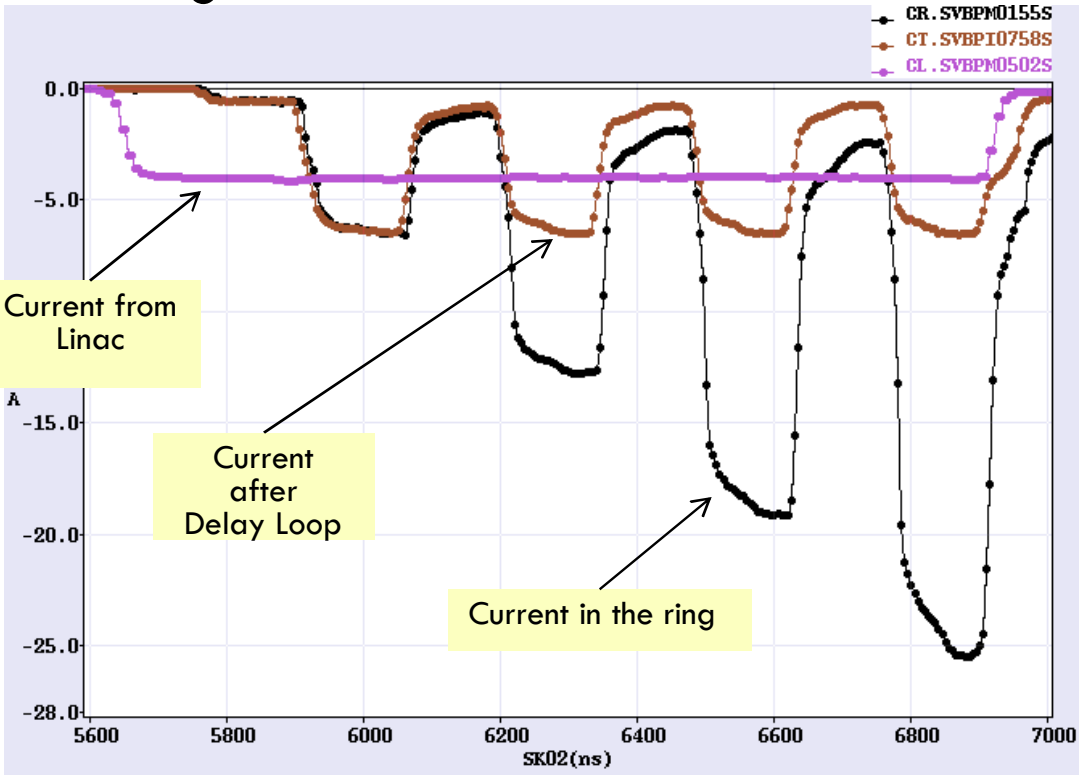
CTF3

- Collaboration: 35 institutes



CTF3 – 2009 Highlights (1)

- Drive beam generation achieved (x8 bunch frequency multiplicity with Delay Loop and Combiner Ring)
  - ~26 A combination
  - nominal 140 ns pulse length



CTF3 – Highlights (2)

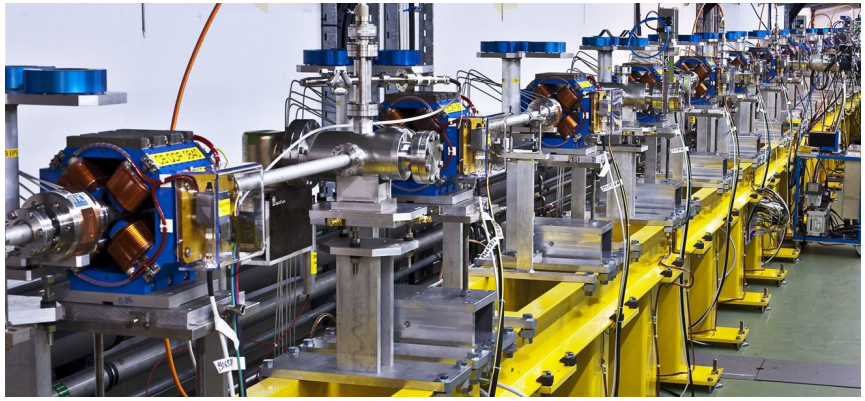
TBTS: Two-Beam Test Stand

- Line for Two-Beam acceleration studies in CLEX (CLIC experimental area)
  - Accelerating structure will be installed this shutdown
- Drive beam running along probe beam until dumps
- 170 MW peak RF power reached in PETS power production structure
- Reached nominal CLIC power (135 MW)!

CTF3 – Highlights (3)

TBL: Line for deceleration studies

- Installation of beam line finished and 1st PETS structure installed
- Beam transported until the end
- 10 A beam produced 20 MW RF power in PETS according to expectation



CALIFES: Probe beam for photo-injector

- Laser performs well, nominal charge state, acceleration to 140 MeV
- Reliable beam to TBTS with 100% transmission
- Detailed optics studies

CTF3 – Outlook

Final year before feasibility report…

- Improve optics in DL to reach equal bunch spacing
- Minimise losses in TL2 (new rad-hard electronics for BPMs this shutdown)
- RF pulse regulation
  - Improve temperature stability and add feedback for phase regulation
- Install additional PETS structures in TBL
- Acceleration structure installed in TBTS this shutdown
  - Reach accelerating gradient of 100 MV/m

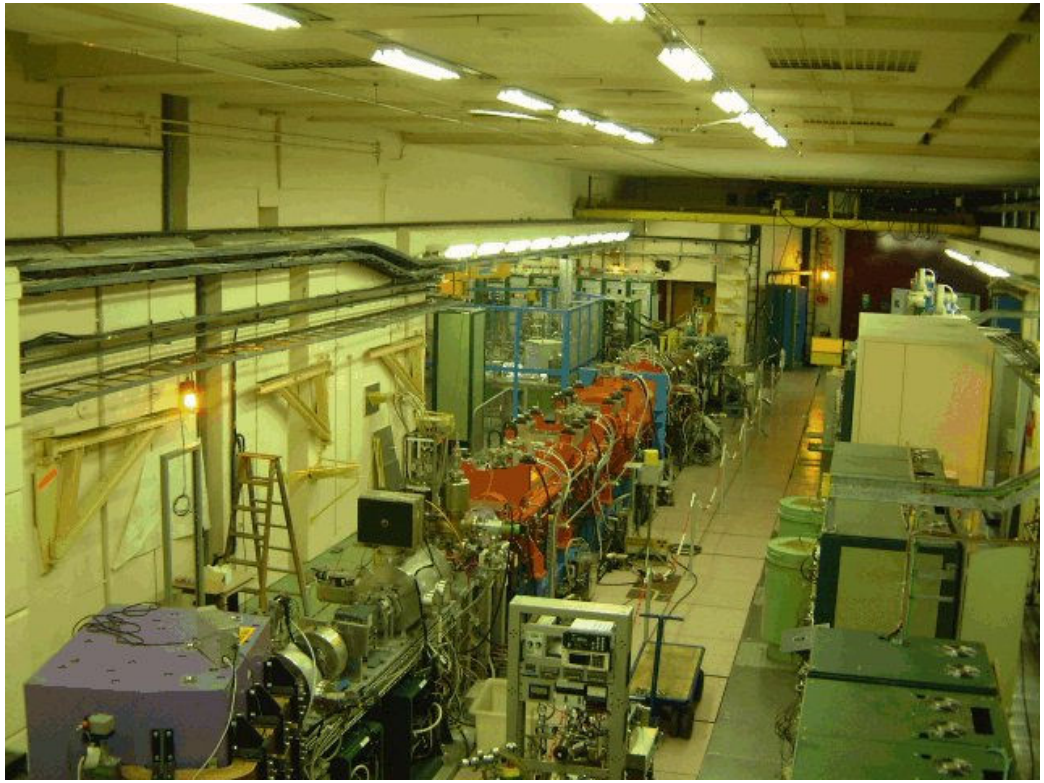
The Ion Chain

2009 Aim for Ion Chain

1. Retrieve conditions for EARLY beam in LEIR, PS and SPS ☑
2. Progress towards NOMINAL beam in LEIR ☑
3. Establish RF gymnastics for NOMINAL beam in PS ☑
4. Extract synchronised beam from the SPS into TI2 and TI8 with consolidated hardware (RF controls) ☑

LINAC3

- 2009 goal: provide Pb ions for SPS commissioning with ions (upgraded LL-RF system for ions) for the 'Early' beam and progress towards 'Nominal' beam parameters
- MDs in addition
  - vacuum desorption (weeks 40+42)
  - source MD (weeks 48-50)



LINAC3 – Setting up

- Start setting up in week 25 (mid-June), run (source MD) finished in week 50
- Problems during setup:
  - Plasma chamber was found with some damage
    - Due to 18 GHz test or long run?
    - No spare chamber available at that time → started with 14.5 GHz operation to be on safe side
  - Software upgrade to ppm operation for the ramping cavity did not work as expected → use old version throughout run

LINAC3 – Issues

- Cooling water temperature too high
  - air conditioning in hall at maximum, but still…
  - frequent source solenoid trips
  - tuning problems of cavities
    - → source water exchanger cleaned
    - → on another occasion refill of cooling water tower
    - week 43: running on reserve water pump with limited power (reduced beam intensity)
- Regular trips of electricity in the hall (hopefully solved)
- Broken klystron of the 14.5 GHz generator (week 45)
  - Klystron replaced; spare to be puchased in 2010
- Short circuit of the intermediate extraction electrode (week 39)
  - Continue running with ~90% intensity

LINAC3 - Issues

- Vacuum leak on edge-welded bellow in ITL line
  - temporary fix (varnish); broke again in week 46
  - spare bellow produced and installed end of November
- Frequent radiation alarms

  in Linac3 wall →

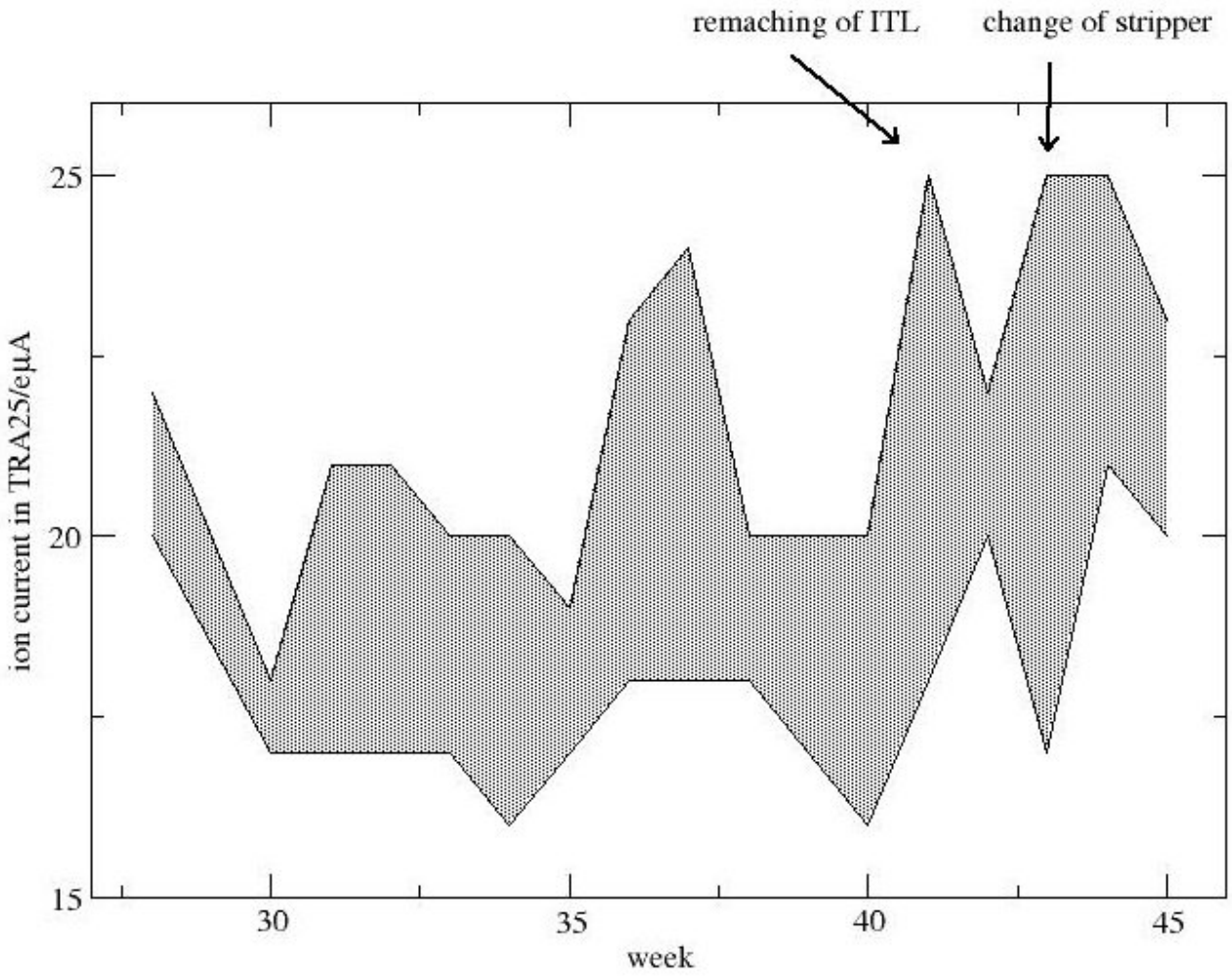
  install concrete wall

  in PS tunnel beside

  septum 16

  during technical stop

LINAC3 Current

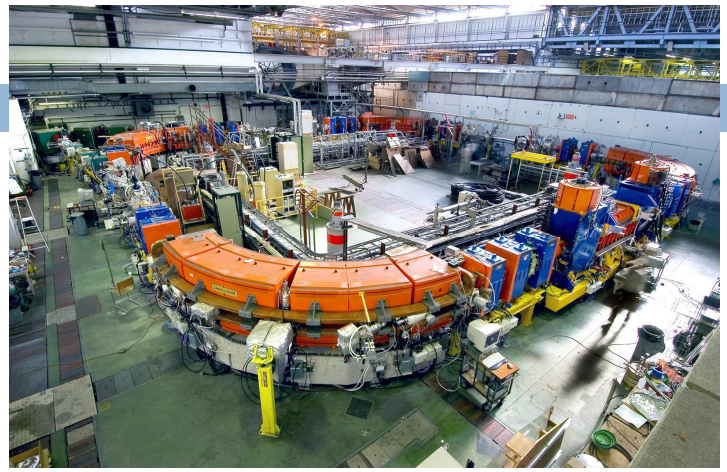


LINAC3 Follow-Ups

- Ramping cavity software
- Consolidation of cooling system (already started…)
- Consolidation of ITL section
  - Replace edge-welded bellows and standardise some flanges
- New stainless steel plasma chamber (performance?)
- More experience with 18 GHz operation
- Upgrade of source controls (long-term)
- In case stable beam would be required from the beginning for LEIR, maybe the start-up time for the linac should be extended (doubled)?

➢ Stand-alone MD time needed to advance efficiently

LEIR

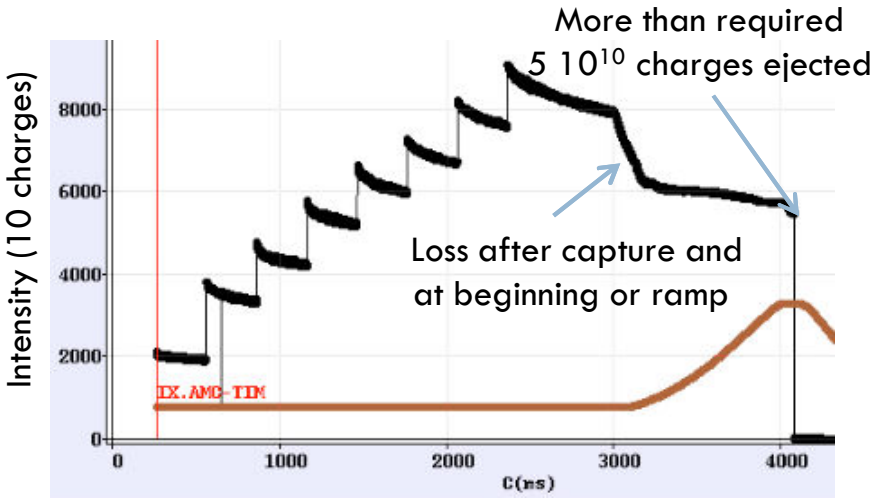


- 2009 goals:
  - Provide 'Early' beam for SPS ion commissioning
  - Study 'Nominal' LHC ion beam
  - Finalise digital LL-RF system and integrate into control system (cavity server loop, double harmonic, …)

- Restart after a long shutdown (18 months)
  - Start prior to beam: many controls-related issues (INCA test bed, new FESA classes, LSA…)
  - Start with beam relatively smooth

LEIR – Issues with 'Nominal' beam

- Generation of long 4.8 s cycle for easier accumulation and long plateau (low average Linac3 current)
  - Could reach >required injected intensity
- At end of run ejection of beam with nominal characteristics, but still losses at ramp (observed since 2006)
  - Working point fine adjustments very important
    - Already at space charge limit? (although space charge tune shift <0.1)



LEIR – Operational Issues

- Continuous LSA and INCA development leads to interruptions and requires testing
- TV screens in injection line not appropriate for ion observation (known issues)
- Solution should be found to wire up spectrum analysers with CCC for diagnostics

- LEIR start with beam on 9th of August for 2010 LHC ion run – maybe once more extended test period prior to start

LEIR Summary

- 'Early' beam provided with high reliability
- Deployment of new digital LL-RF system very successful
- 'Nominal' beam: obtained at end of run, but with longer 4.8 s cycle (aim to work 2010 with only 4 Linac3 injections, increased injection rate every 200 ms and faster cooling)
  - Linac3 injected current low, increased at end of run
  - Losses at start of the ramp since 2006 – improved, but not yet fully understood

- Longer machine study time for LEIR to investigate beam dynamics issues and limitations for 'Nominal' beam
- Move beam stopper from PS ring in ejection line (EE) to allow LEIR operation during PS interventions – to be studied

PS with Ions

- Early startup (week 30) for lifetime measurements
  - Lifetime from 1.8 s before sublimation to ~9 s after automatic sublimation every 24 h
    - The vacuum group agreed to include automatic sublimation into new PVSS controls system
- Thorough review of 'Early' beam
  - 1 bunch inj., 1 bunch ej.; ~6.5E9 ej. intensity
- Preparation of 'Nominal' beam in PS
  - 2 bunches inj., 4 bunches ej.; total intensity x4 of 'Early'

PS with Ions – RF Improvements

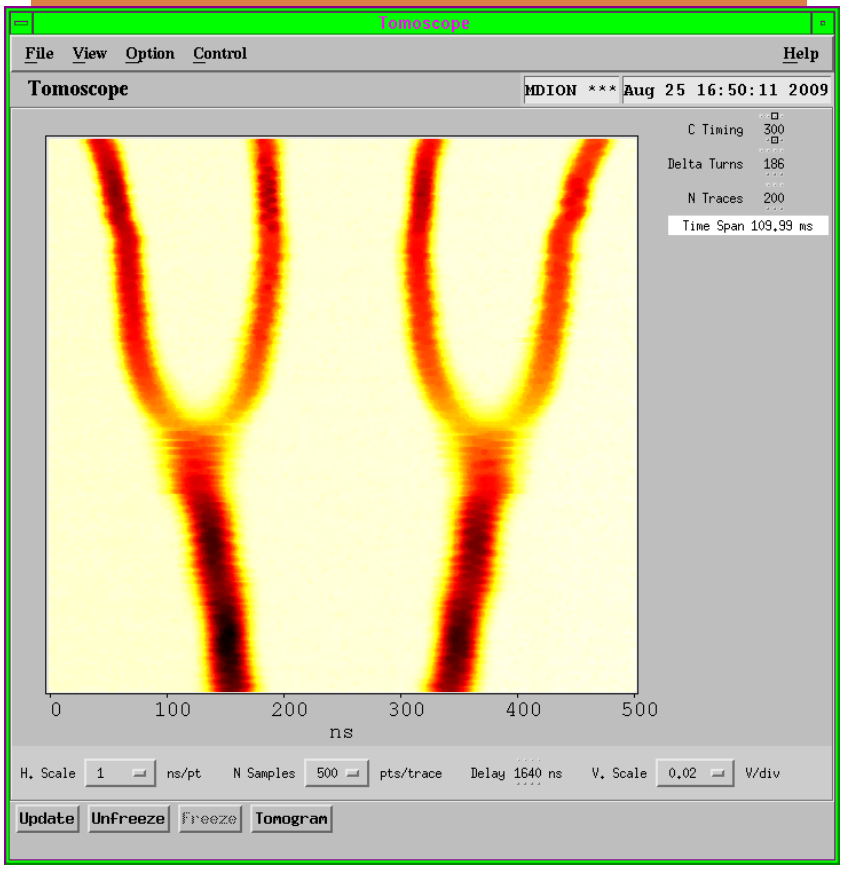
- Injection timing independent on start of LEIR extraction kicker
- Generation and distribution of RF trains revised
- Radial loop: additional filtering added for radial PUs
- Feed-forward phase control
  - Precise compensation of frequency dependencies
  - Allows decoupling of LHC ion cycles and proton cycles
    - Main secret for success

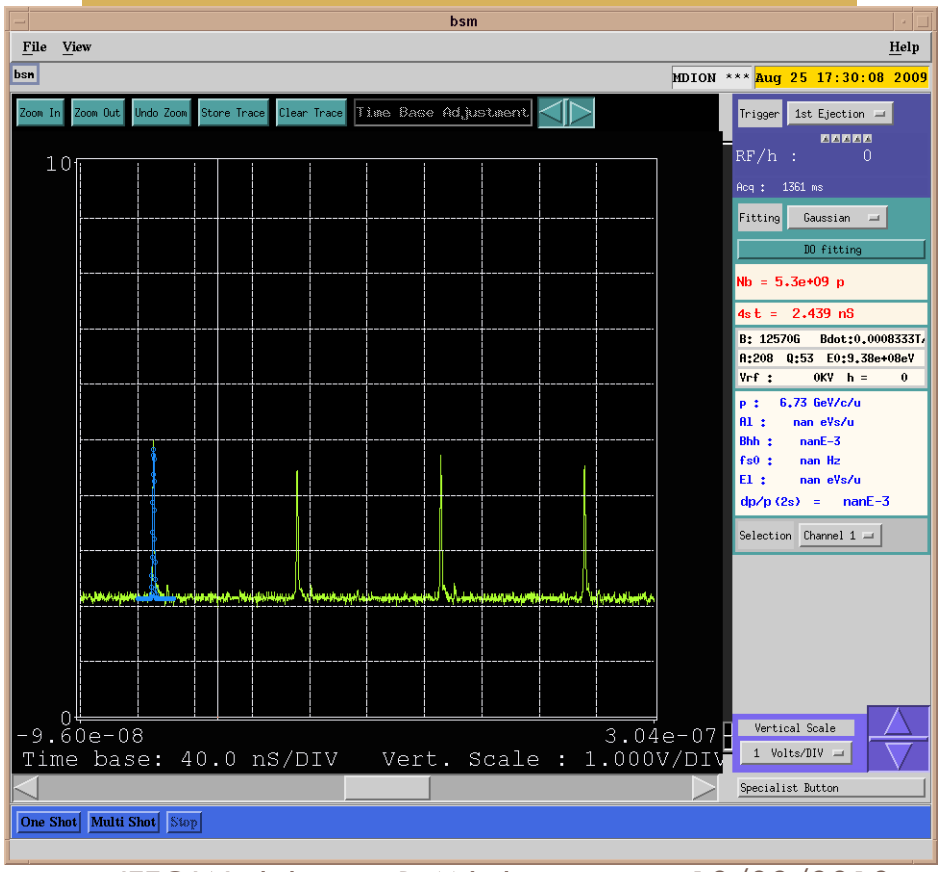
PS with Ions – 'Nominal' Beam

ii) Rebucketing at 80 MHz and bunch shorting before extraction

i) Batch expansion and bunch splitting

iii) Correct bunch spacing at extraction





PS with Ions – Outlook

- Produce 'Nominal' beam with nominal intensity in PS
- Understand mismatch in TT2
- Tune measurement: longer PUs would be needed
- Mind: 80 MHz cavity needed for rebucketing has to be tuned to a different frequency from that for LHC protons
  - No spare cavity when both p and ions are in SC (irrelevant for LHC filling)

- Prepare for LHC ion run end of 2010!

SPS with Ions

- First 2009 ion beam injections into SPS mid-August
- Commissioning of new RF control modules

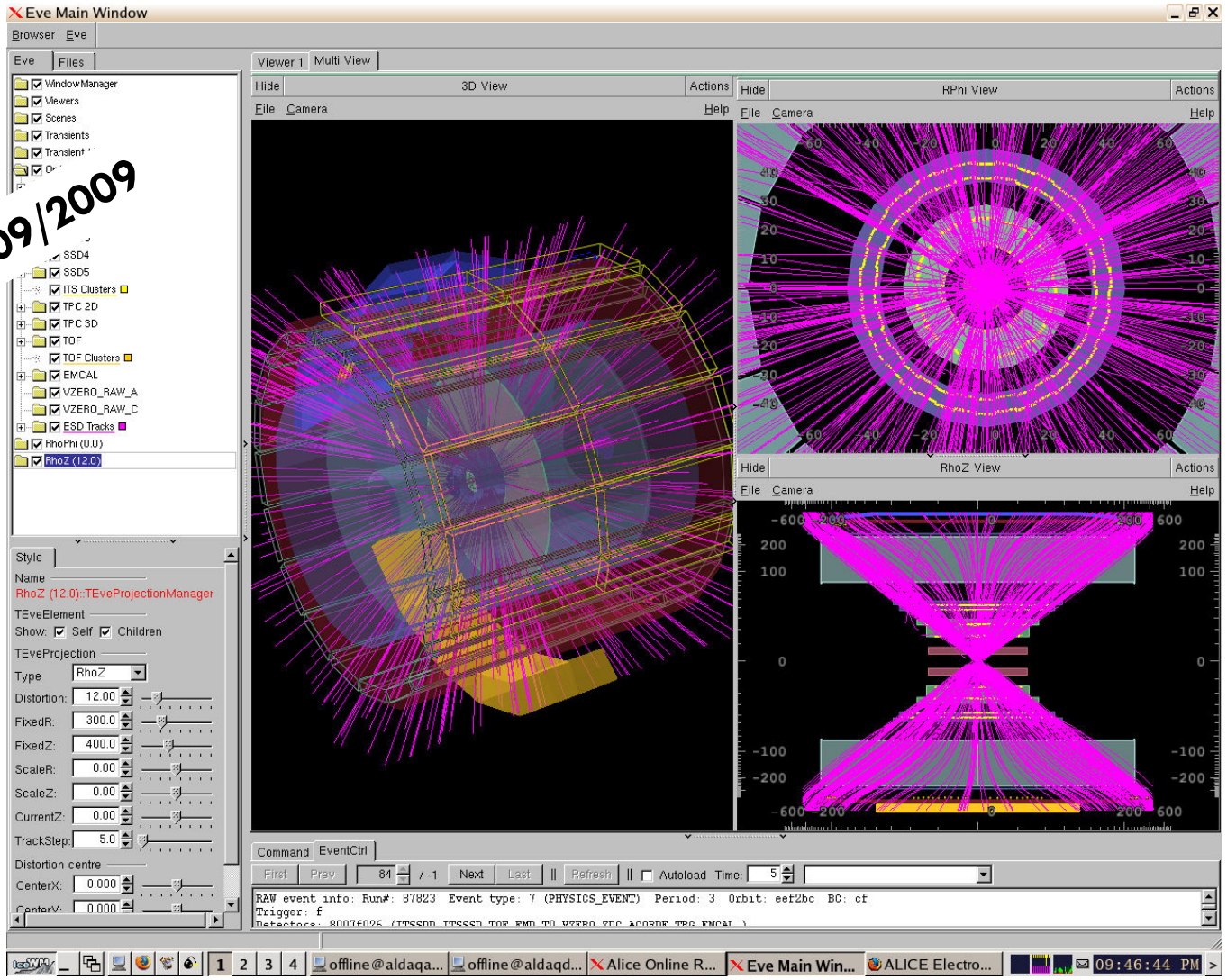
- 21/9: ions extracted into TT60
- 28/9: ions extracted to TI2 (ALICE!) and TI8
- 23/10: ions in LHC!

SPS with Ions – Open Issues

- Optimisation of transition crossing
- Front porch losses
- Variable gain for synchro loop and other optimisations
- Hardware protection (for transmitter), …
- Solve initialisation issues of some LL-RF modules
- and much more…
- Prepare for 'Nominal' beam!

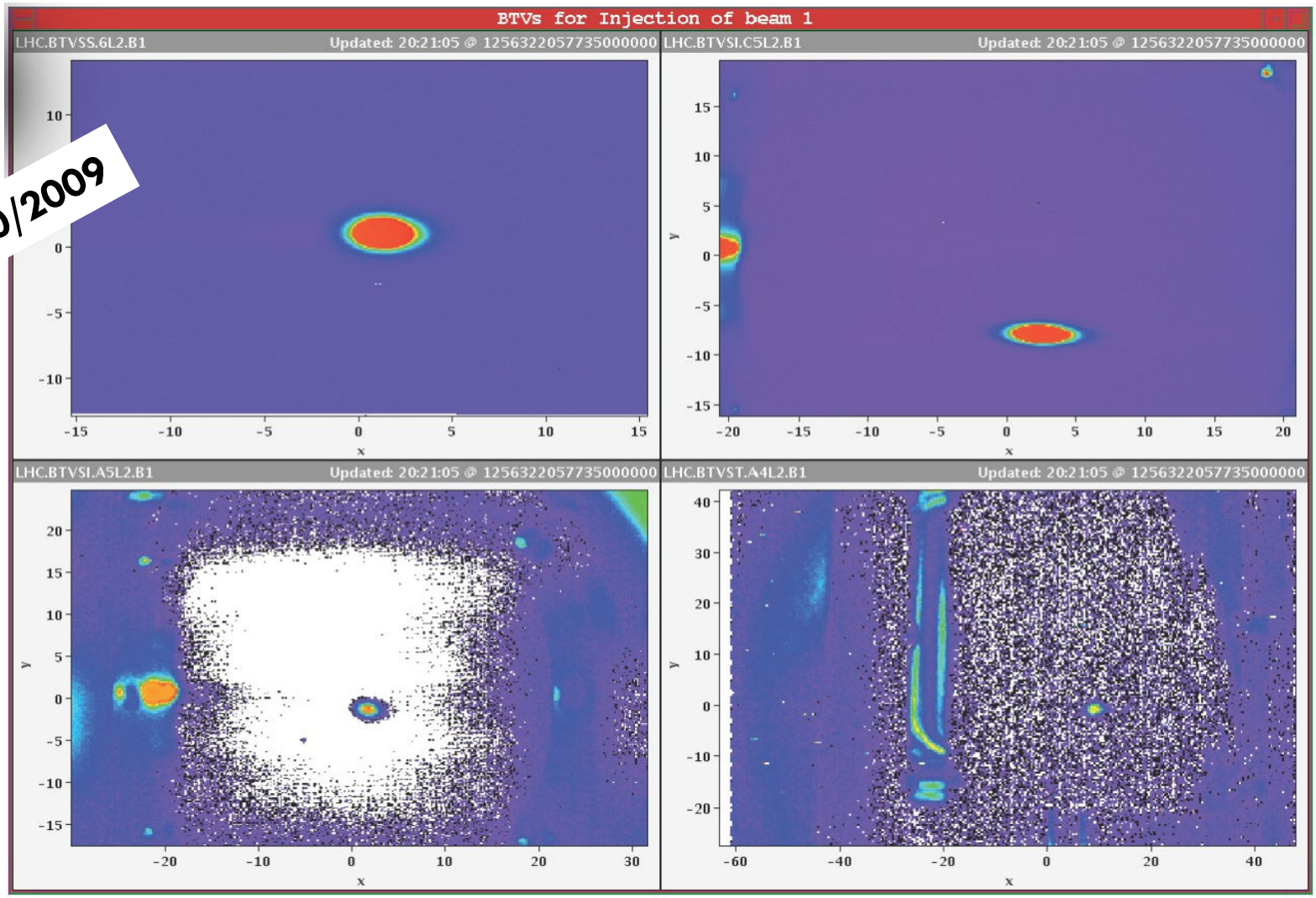
- Would need dedicated beam time to set up 'Nominal' long cycle (13 injections!) with ions in 2010.

Ions at the front door of ALICE!



27-28/09/2009

Ions in the LHC!



23/10/2009

Thanks to
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the tireless piquets and workers,
the machine supervisors and
the operators
for the successful 2009 run!