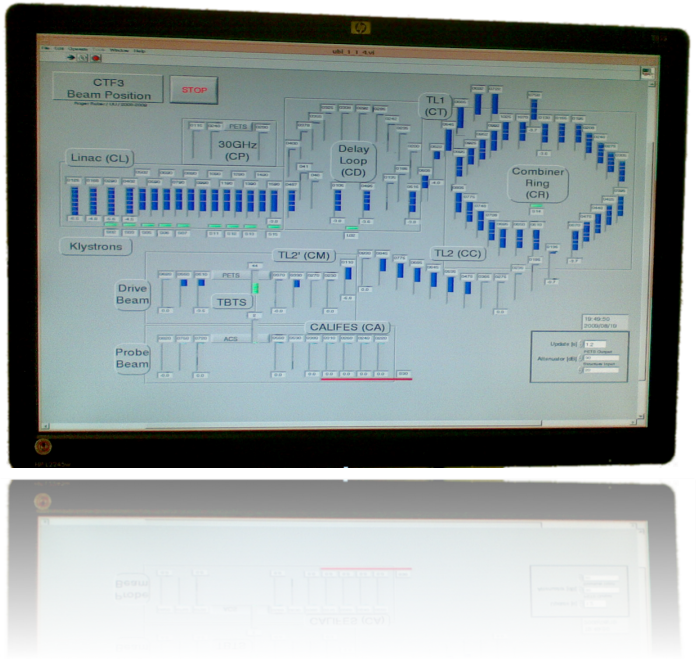
Progress in CTF3

Frank Tecker - BE/OP
for the CTF3 Team

- Introduction
- The achievements in 2009
- Conclusion

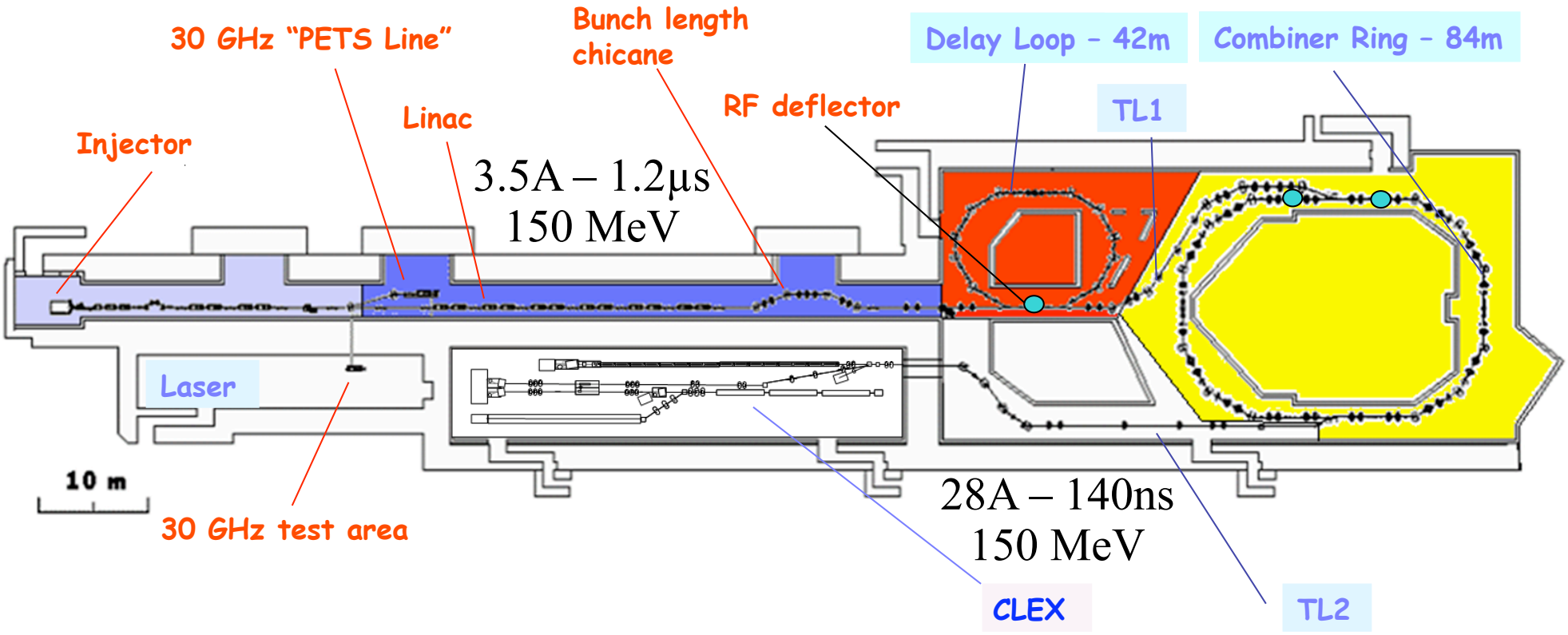


World-wide CLIC&CTF3 Collaboration

Aarhus University (Denmark)
Ankara University (Turkey)
Argonne National Laboratory (USA)
Athens University (Greece)
BINP (Russia)
CERN
CIEMAT (Spain)
Cockcroft Institute (UK)
Gazi Universities (Turkey)
Helsinki Institute of Physics (Finland)
IAP (Russia)
IAP NASU (Ukraine)
INFN / LNF (Italy)
Instituto de Fisica Corpuscular (Spain)
IRFU / Saclay (France)
Jefferson Lab (USA)
John Adams Institute (UK)
JINR (Russia)
Karlsruhe University (Germany)
KEK (Japan)
LAL / Orsay (France)
LAPP / ESIA (France)
NCP (Pakistan)
North-West. Univ. Illinois (USA)
Oslo University (Norway)
Patras University (Greece)
Polytech. University of Catalonia (Spain)
PSI (Switzerland)
RAL (UK)
RRCAT / Indore (India)
SLAC (USA)
Thrace University (Greece)
Uppsala University (Sweden)

CTF 3 – CLIC Test Facility

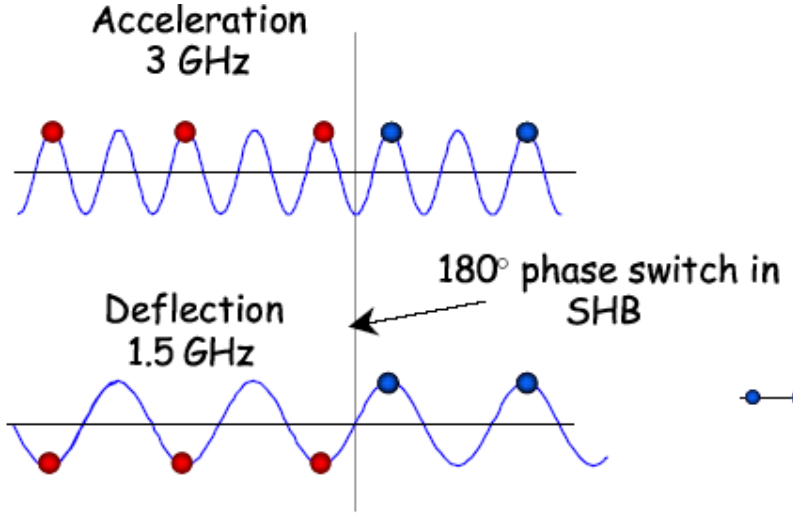
- demonstrate CLIC RF power source Drive Beam generation (fully loaded acceleration, bunch frequency multiplication 8x)
- Test CLIC accelerating structures
- Test power production structures (PETS)



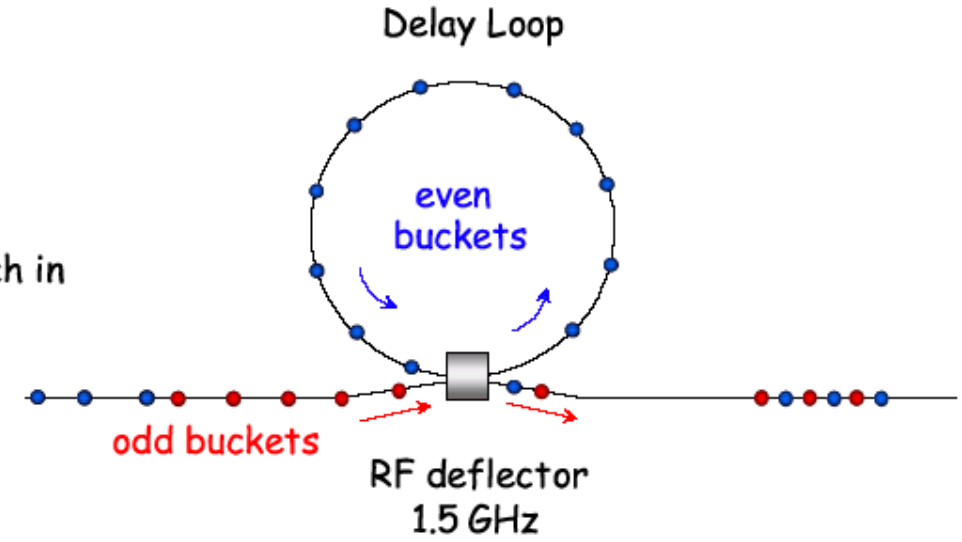
CTF3 Drive Beam generation

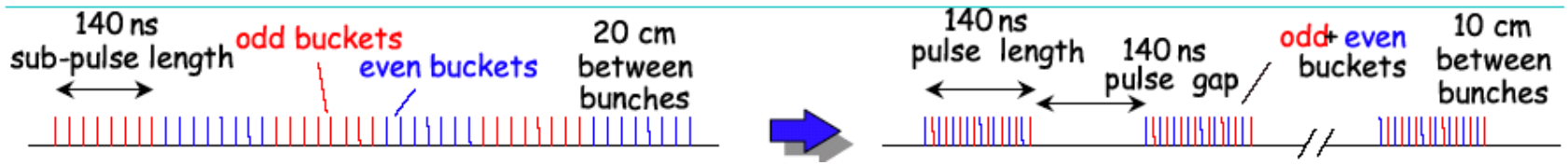
- Long, high-intensity bunch train (1.2μs) is accelerated with 3 GHz
- Bunch manipulations increase bunch repetition frequency and peak current

"phase-coding" of bunches



bunch interleaving with **Delay Loop**



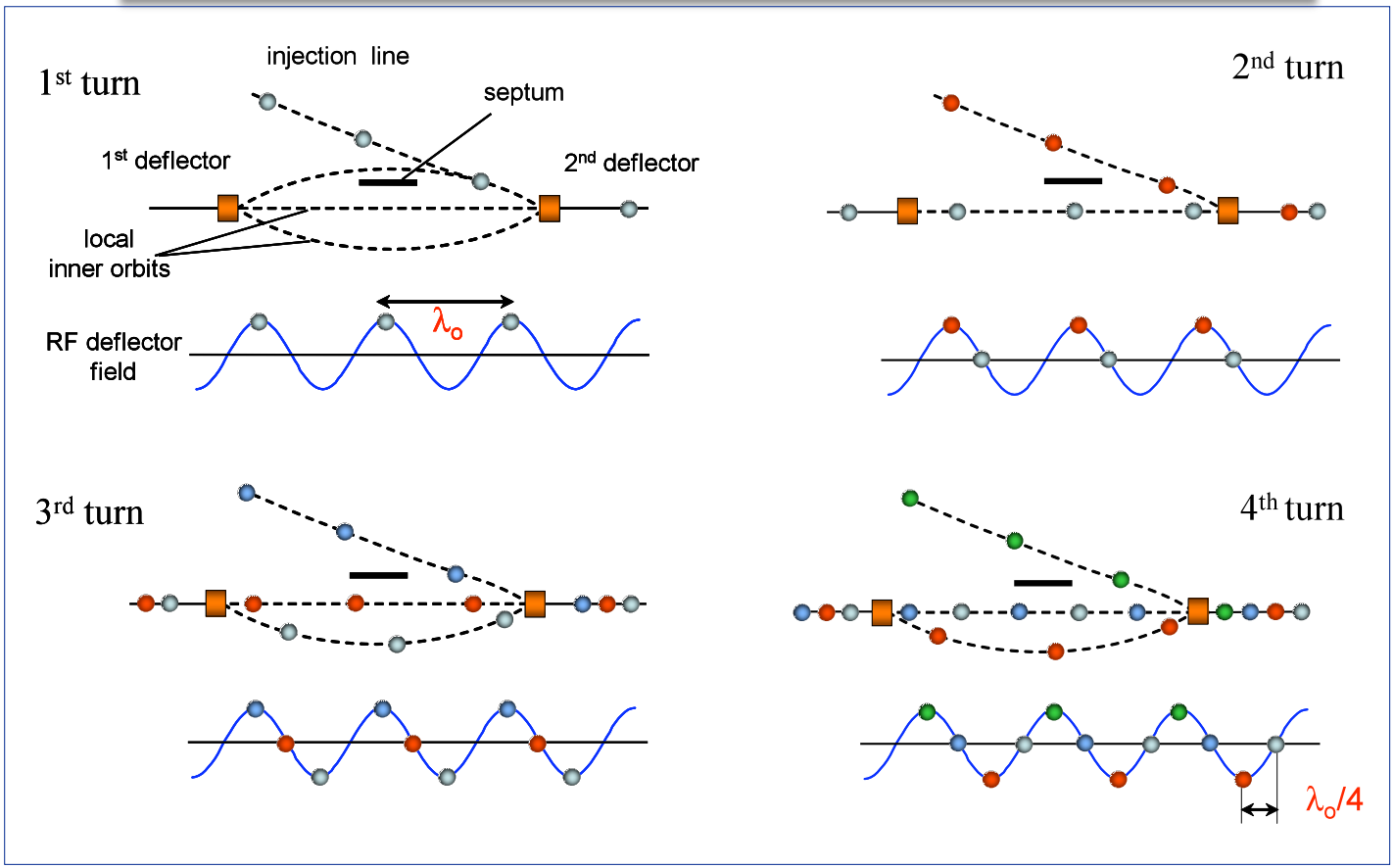


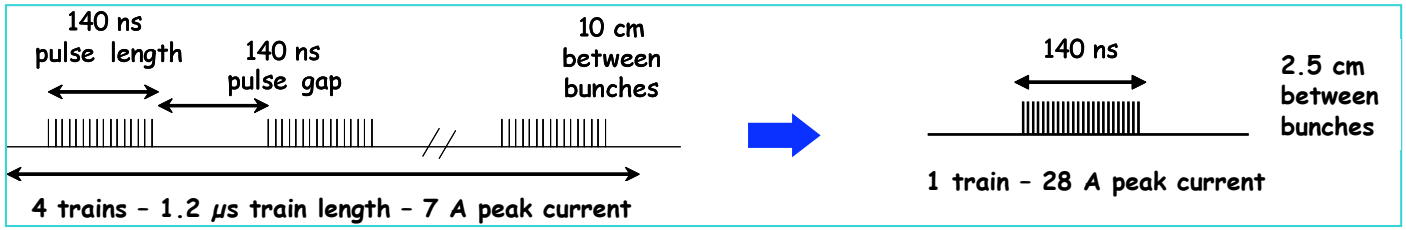
1.2 μs train length – 3.5 A current

1.2 μs train length – 7 A peak current

Combiner Ring principle

successive injection of 4 bunch trains into **Combiner Ring**





Comparison CLIC - CTF3

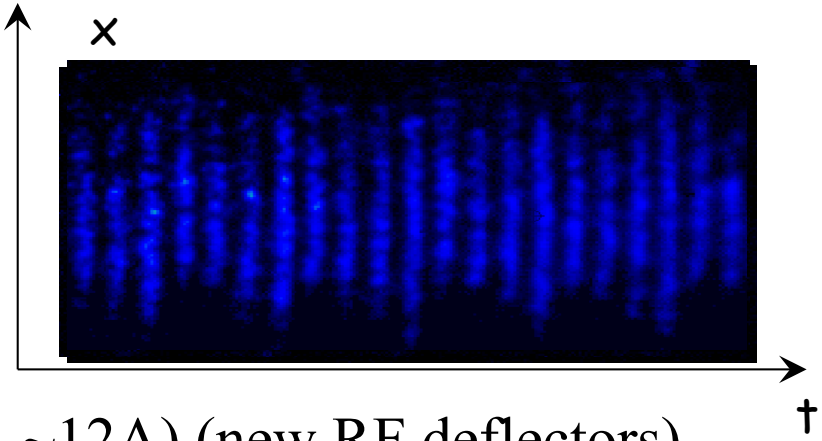
	CTF3	CLIC
Energy	0.150 GeV	2.4 GeV
Pulse length	1.2 µs	140 µs
Multiplication factor	2 x 4 = 8 (DL + 1 CR)	2 x 3 x 4 = 24 (DL + 2 CR)
Linac current	3.5 A	4.2 A
Final current	28 A	100 A
RF frequency	3 GHz	1 GHz
Deceleration	to ~50% energy	to 10% energy
Repetition rate	up to 5 Hz	50 Hz
Energy per beam pulse	0.7 kJ	1400 kJ
Average beam power	3.4 kW	70 MW

- CTF3 covers well the CLIC drive beam generation scheme
- Still considerable extrapolation to CLIC parameters
- Especially total beam power (loss management, machine protection)

=> WG5 - Thu

Previous demonstrations

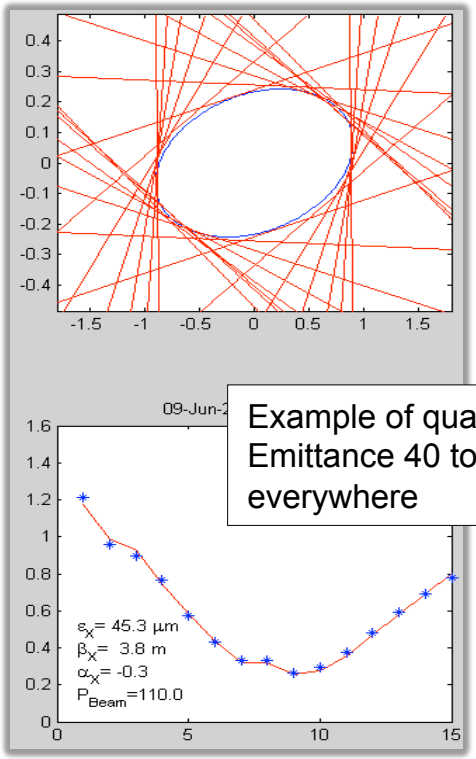
- Fully loaded acceleration: ~96% RF to beam efficiency!
- subharmonic bunching and phase coding: ~5ns phase flip
- Delay Loop principle, factor 2 current multiplication
- Combiner Ring principle, CTF3 Preliminary Phase (low current)
  - factor 4 and 5 combination
  - combination setup
  - isochronicity tuning
- present Combiner Ring
  - high current combination (without DL, ~12A) (new RF deflectors)
  - ring length control
- RF power generation (30 GHz)



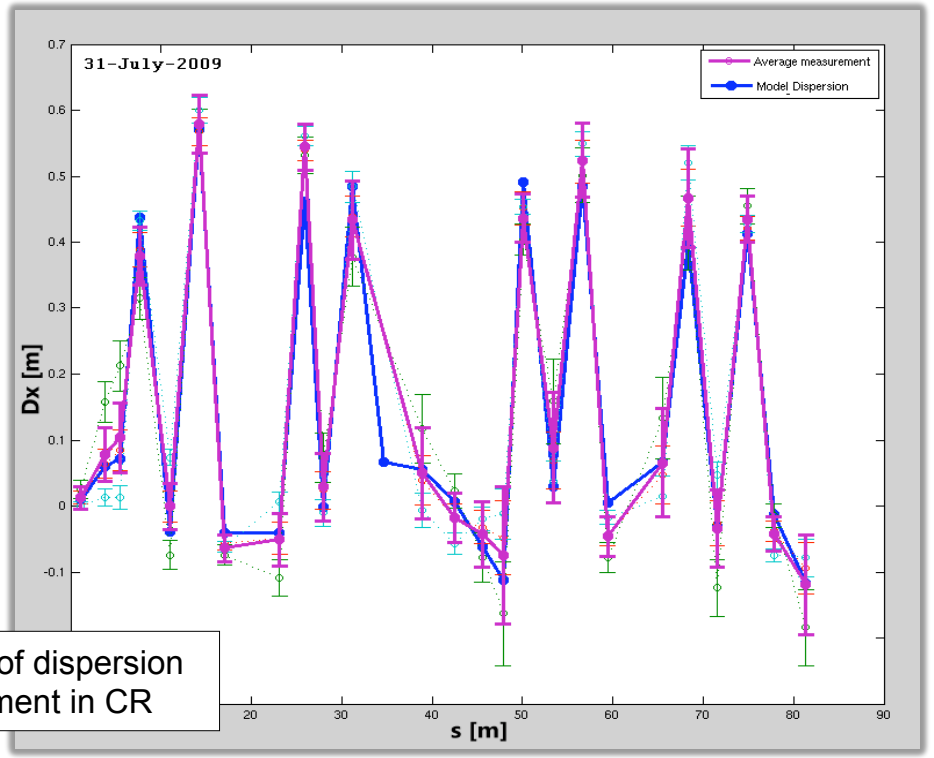
Optics measurements, DL, Ring

- Twiss parameters, emittance (quad scans): well established & coherent (up to TL2)
- Kick measurements, tune and dispersion measurements
  => model significantly improved, coherent with model (up to TL2, some doubts on DL)
- Ring length, closed orbit and combination procedure also well under control
- Still work needed for bunch length control and TL2 optics

Piotr Skowronski

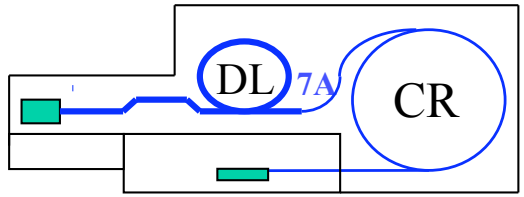


Example of quad scans in linac
Emittance 40 to 100 π mm mrad everywhere

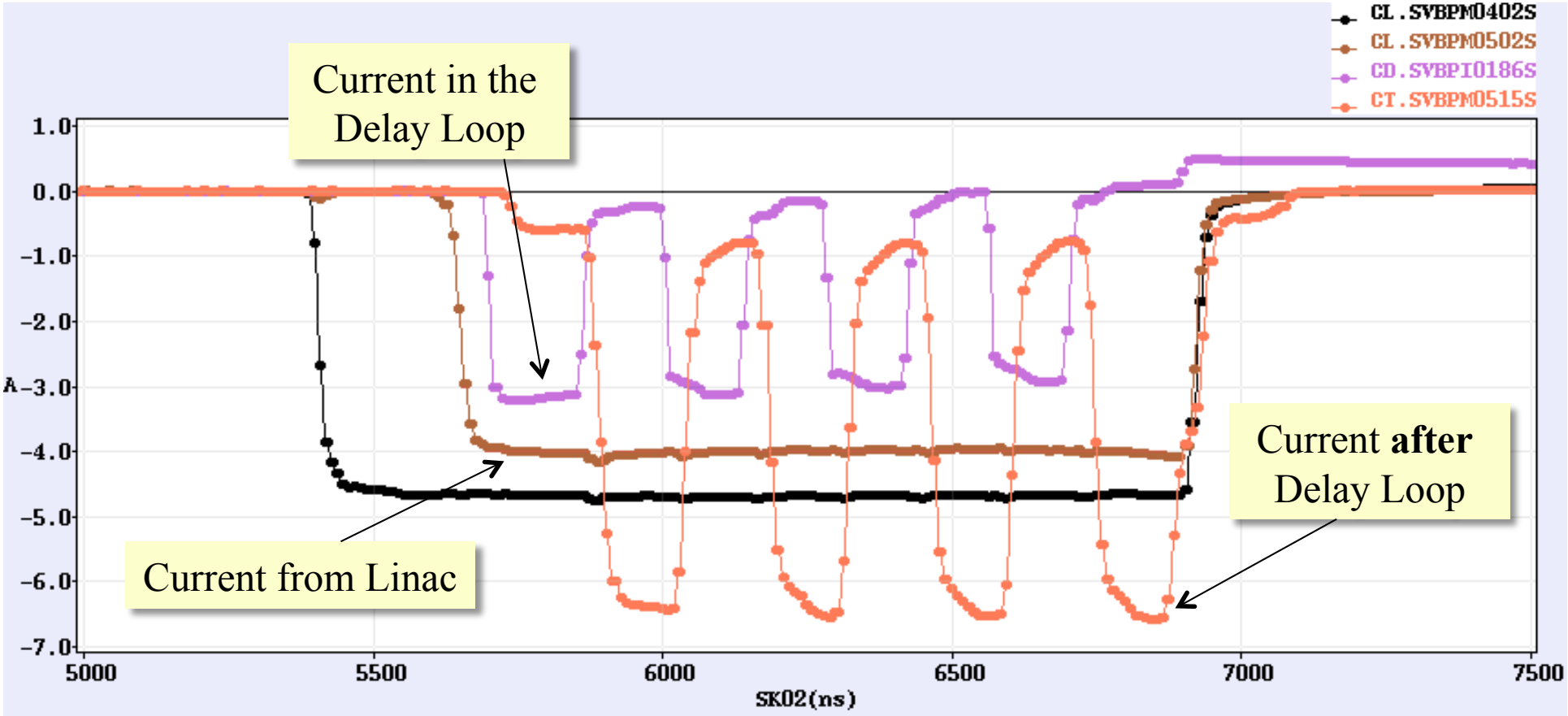


Example of dispersion measurement in CR

Delay loop status

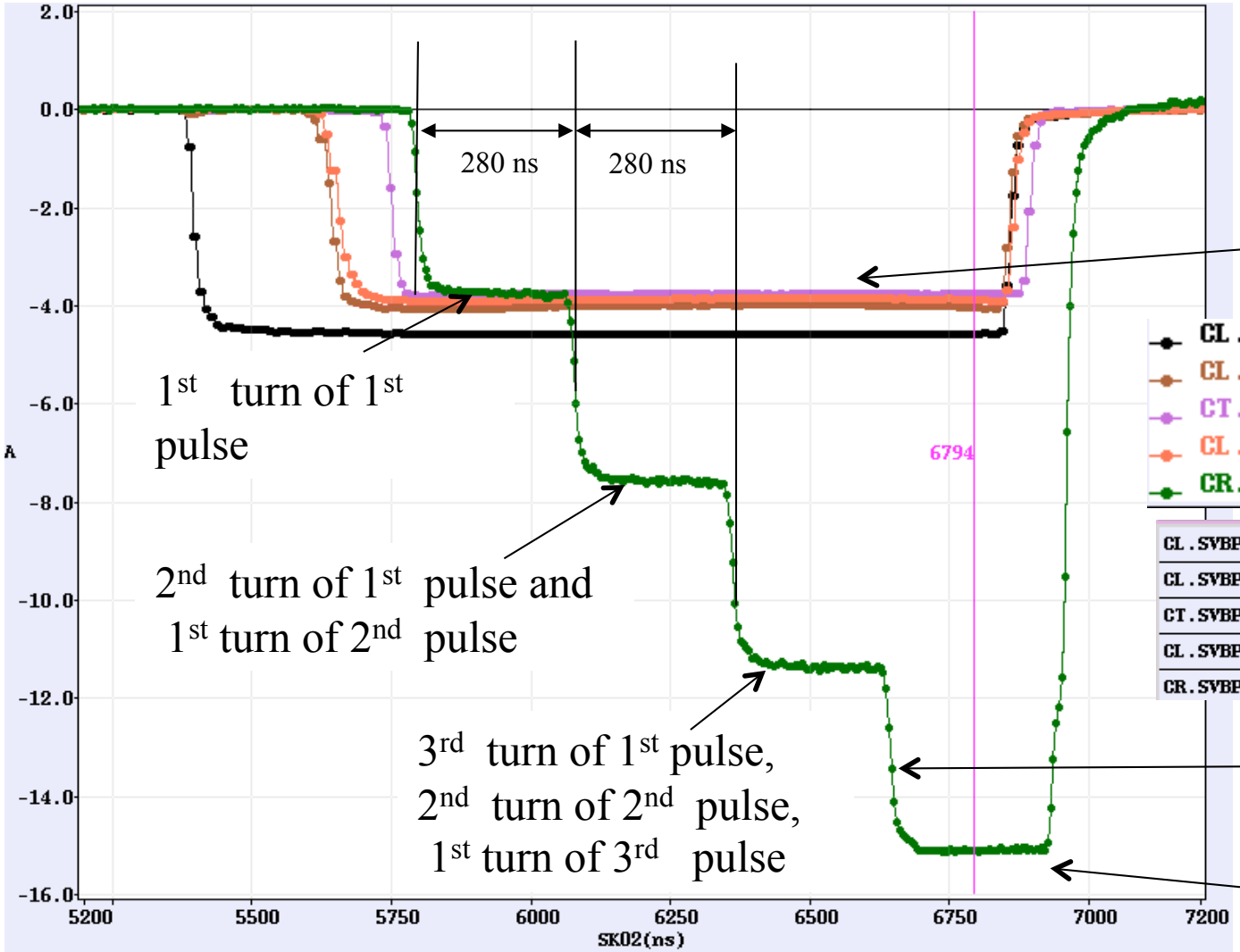


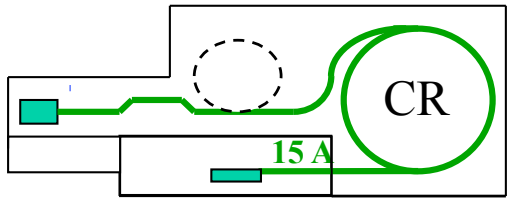
- factor 2 combination re-established after 2 years
- current about doubled, from ~3.5 A to ~6.5A (0.5 A in satellites)



Combiner ring status

- factor 4 combination achieved with 15 A, 280 ns (without Delay Loop)





Current from Linac

1st turn of 1st pulse

2nd turn of 1st pulse and 1st turn of 2nd pulse

3rd turn of 1st pulse, 2nd turn of 2nd pulse, 1st turn of 3rd pulse

CL.SVBPM0402S
CL.SVBPM0502S
CT.SVBPM0515S
CL.SVBPM1590S
CR.SVBPI0130S

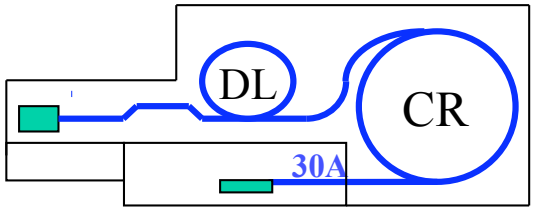
CL.SVBPM0402S	-4.56877
CL.SVBPM0502S	-4.03190
CT.SVBPM0515S	-3.74760
CL.SVBPM1590S	-3.87000
CR.SVBPI0130S	-15.09200

Current in the ring

All 4 pulses

Factor 8 combination (DL+CR)

- ~26 A combination achieved, nominal 140 ns pulse length
- detailed studies still to be done

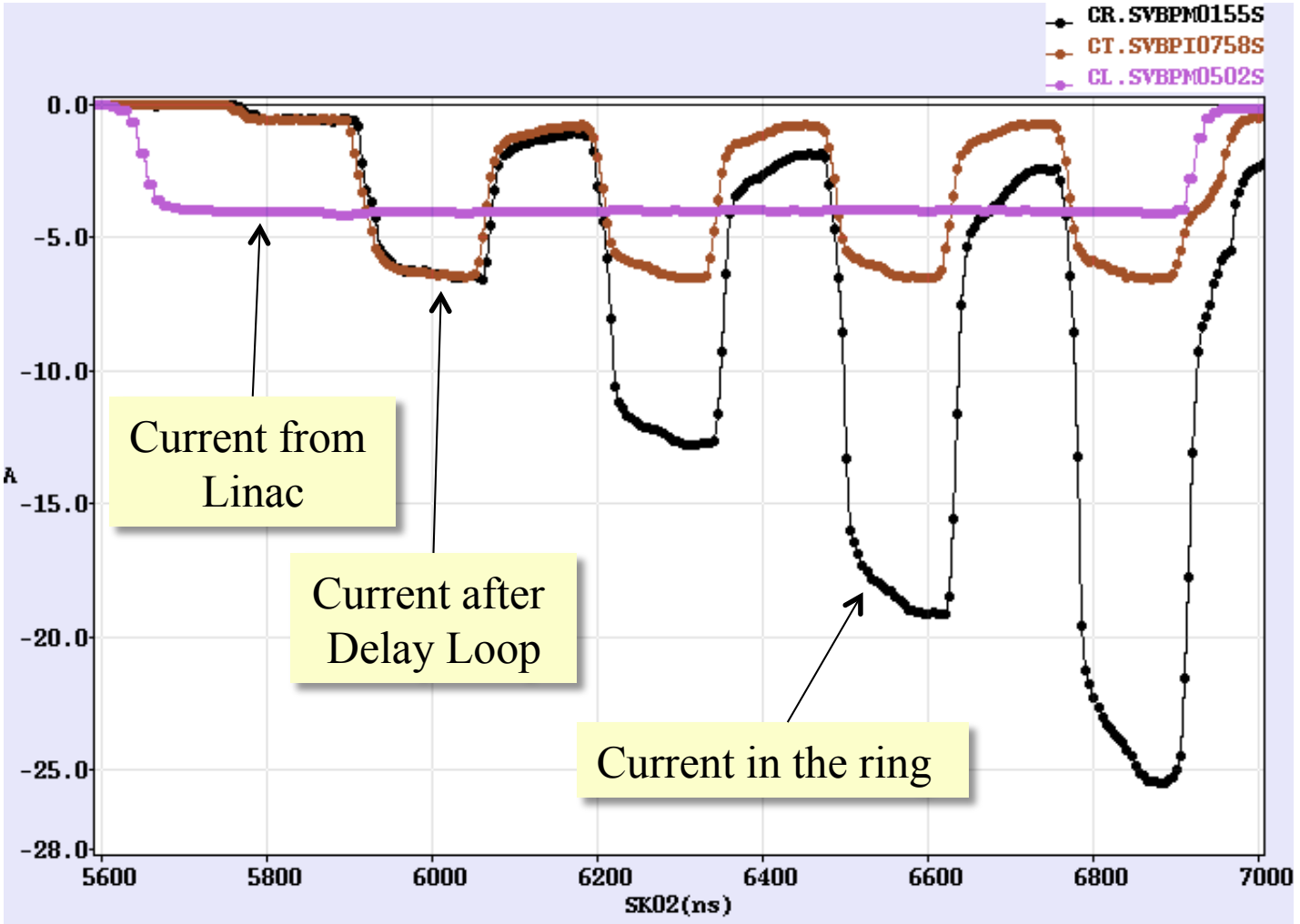


- much more in talk by

Simona Bettoni

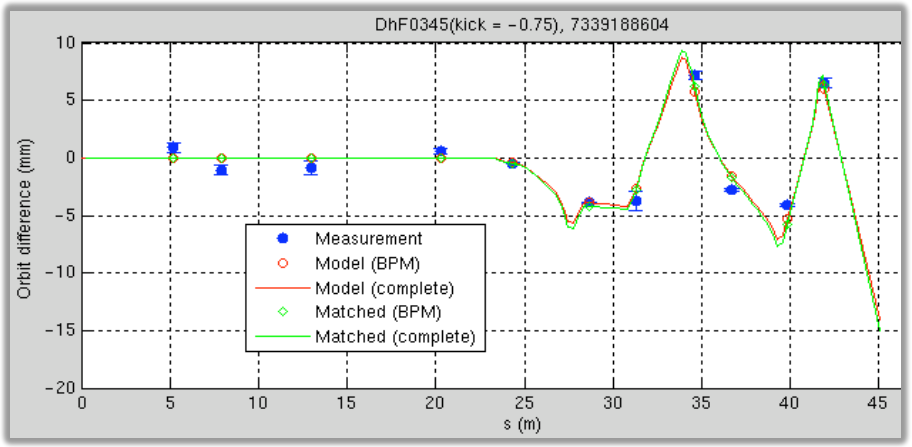
in WG3

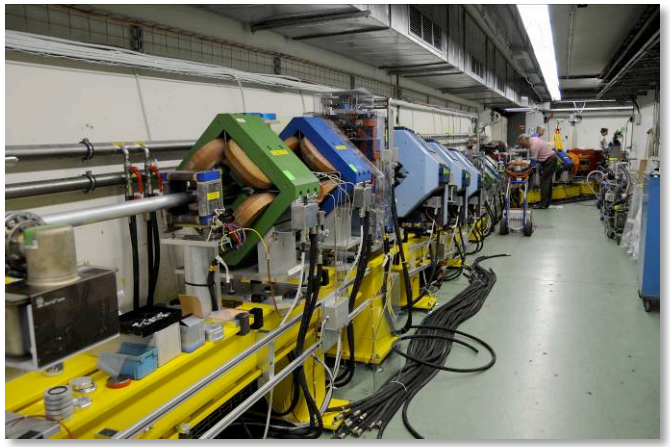
on Thu 16:30

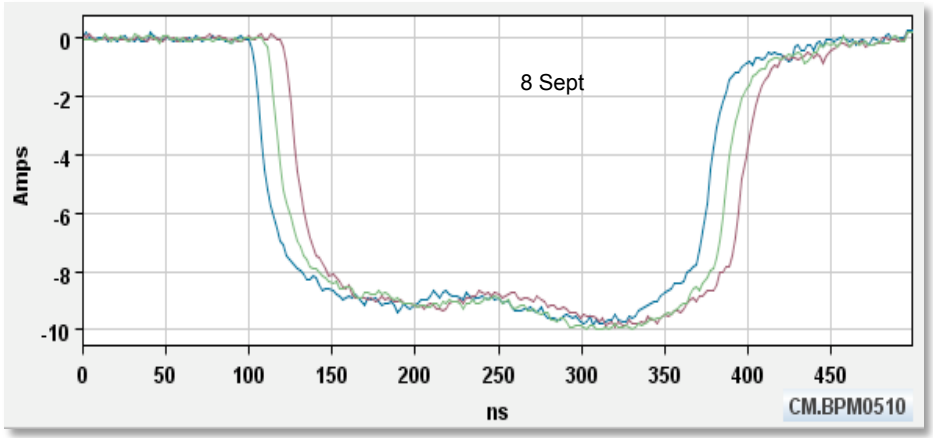


TL2, TL2', TBTS beamlines

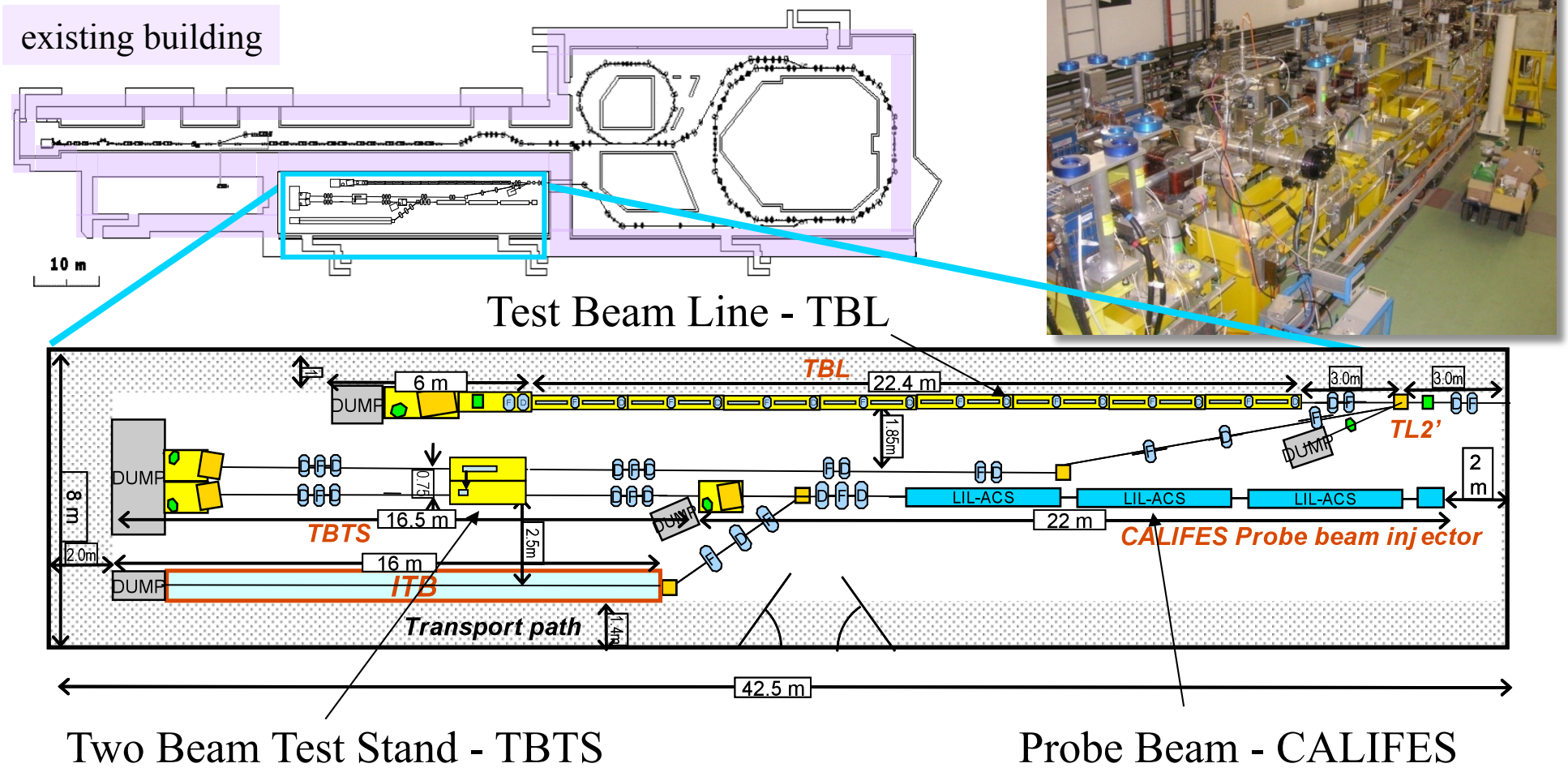
- line optics seems OK (kick measurements) but difficult matching identified one possible error (20% strength in a quad, under investigation)
- beam transported to TBTS and through PETS
  - Non-combined beam with small losses (less that 10%)
  - Combined beam with some losses (from 12 A to ~10 A, no local losses in PETS)
- Tail Clipper (CIEMAT, Spain) strip-line kicker working well







CLEX (CLIC Experimental Area)

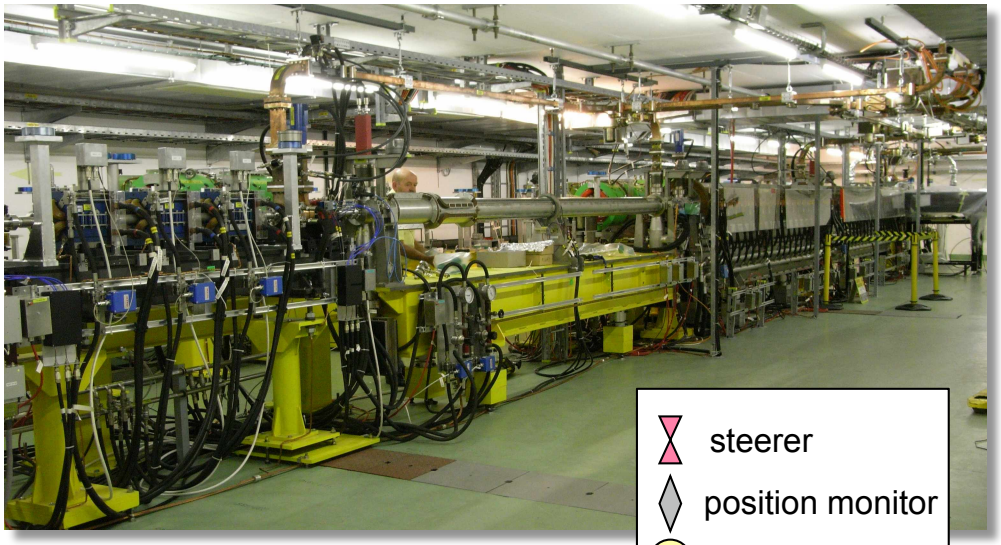


- tests for power production, deceleration and two-beam studies
- all beam lines installed – TBL to be filled with PETS

Probe Beam - CALIFES

Responsibility of IRFU (DAPNIA), CEA, Saclay, France

180 MeV
bunch charge 0.6 nC
number of bunches 1 – 32, 226

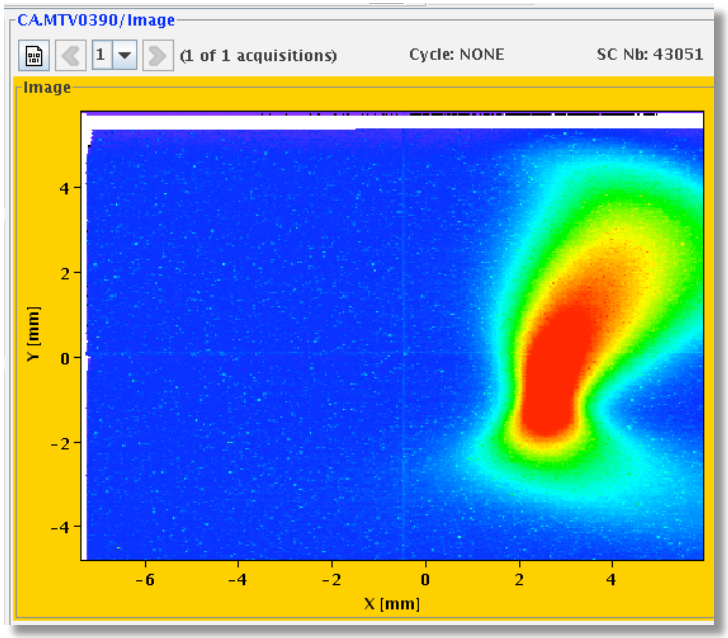


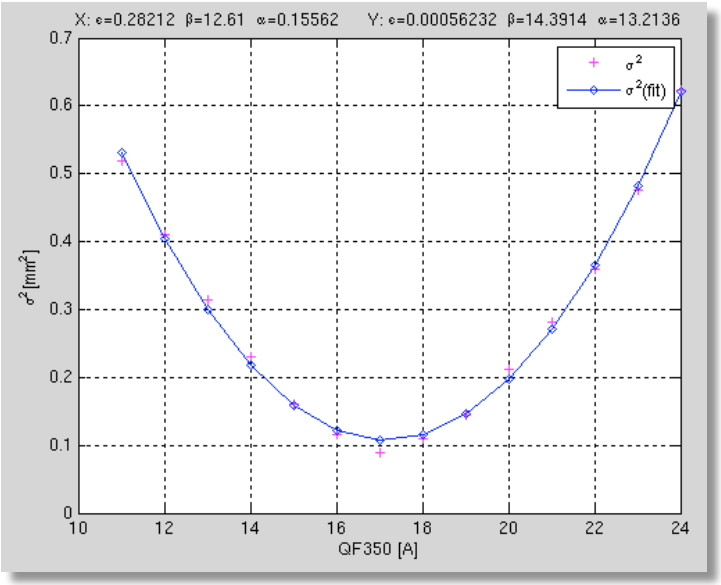
CALIFES

A. Mosnier, CEA Dapnia

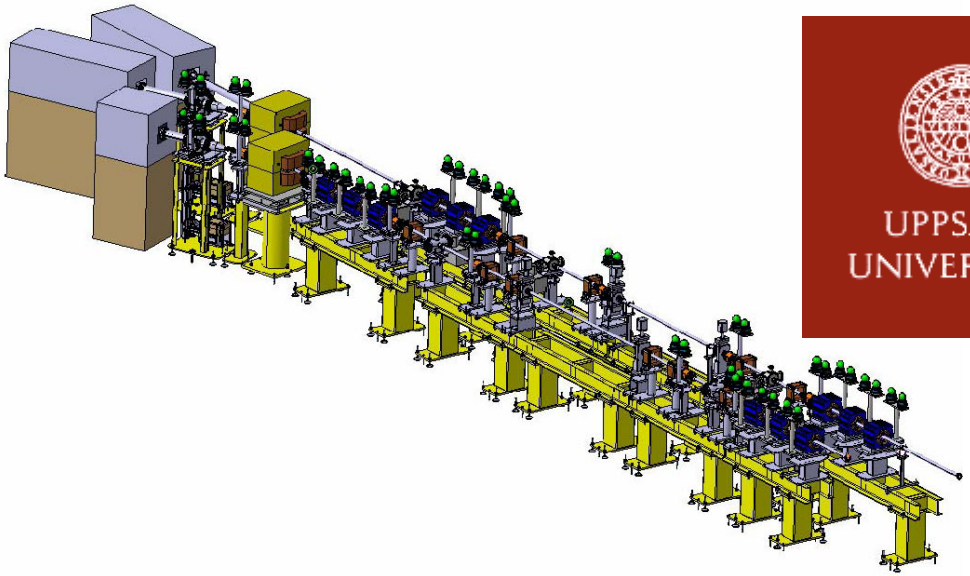
CALIFES results

- 31 March: beam at end of linac
- First optics checks OK
- Reached ~140 MeV, 0.3 nC / bunch, 10 ns
- almost perfect transmission
- many measurements, bunch length, beam characterization, RF optimization,…
- allowed to transport beam through TBTS (09 Apr.)
- Beam emittance optimization under way (Initial measurements 66/82 => 43/69 π mm mrad)
- details in talk of Wilfrid Farabolini

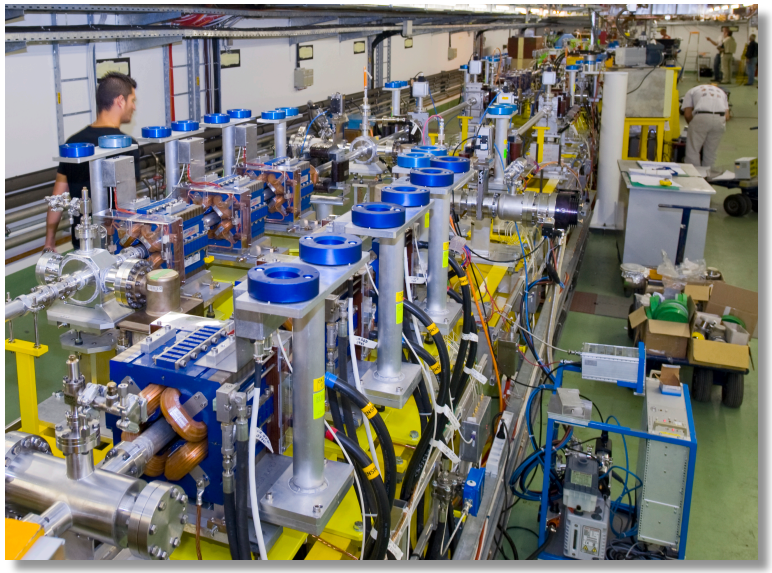




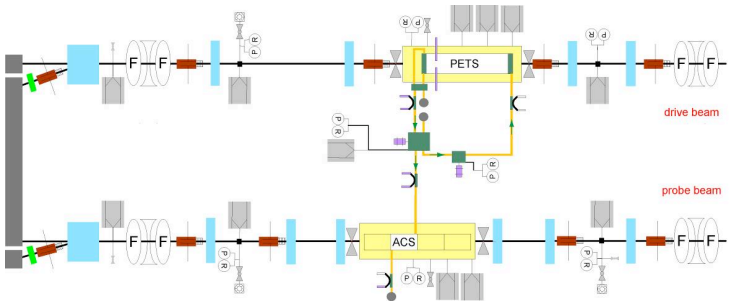
Two-Beam Test Stand - TBTS



UPPSALA UNIVERSITET



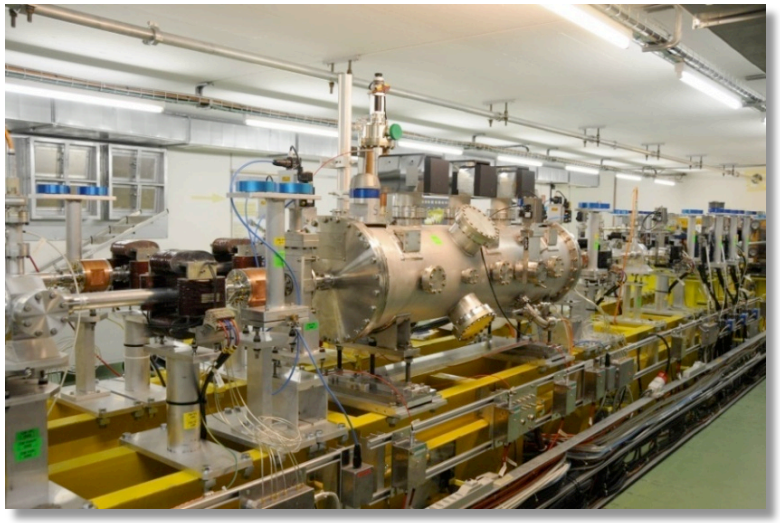
- Beam to the end, both Drive Beam and Probe Beam
- Optics studies performed
- RF power generated by beam in PETS structure
- Two-beam acceleration not yet covered

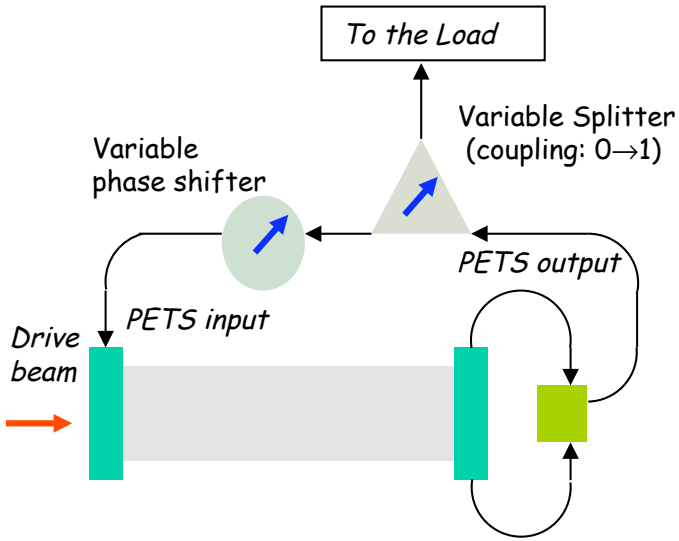


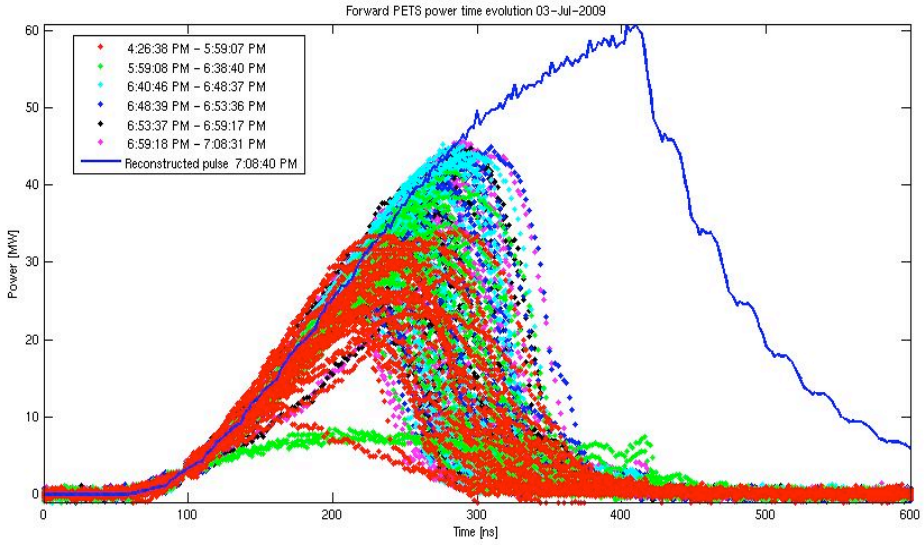
- details in talk of Roger Ruber

TBTS, PETS conditioning

- PETS operated with recirculation:
  part of generated power is reinjected into PETS
- Lots of breakdowns (pulse shortening) most likely variable power splitter (outside PETS) – replaced now
- Rapid (a bit aggressive) conditioning
- Max power reached 140 MW (peak)
  total pulse length ~200 ns – no flat top

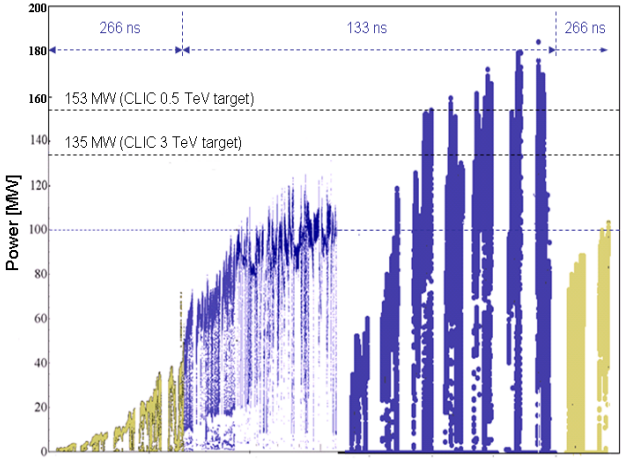


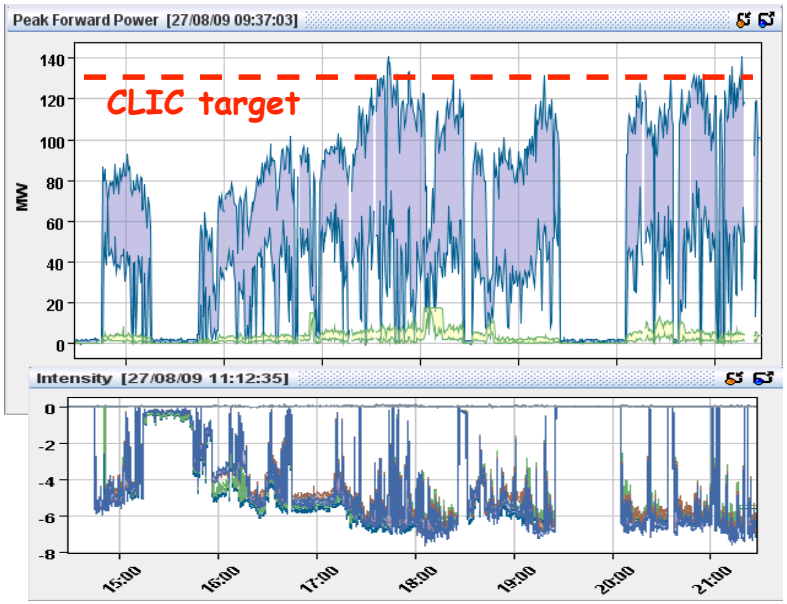


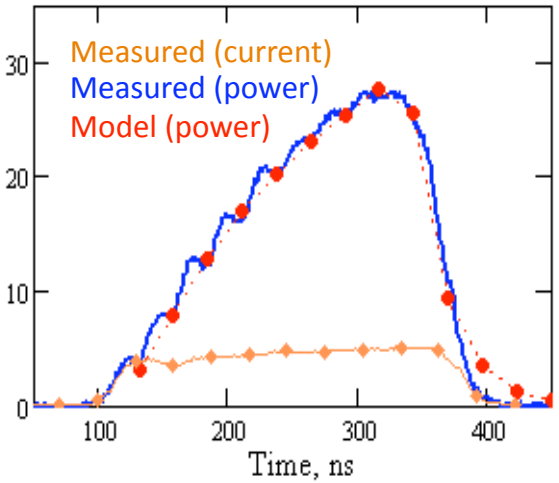


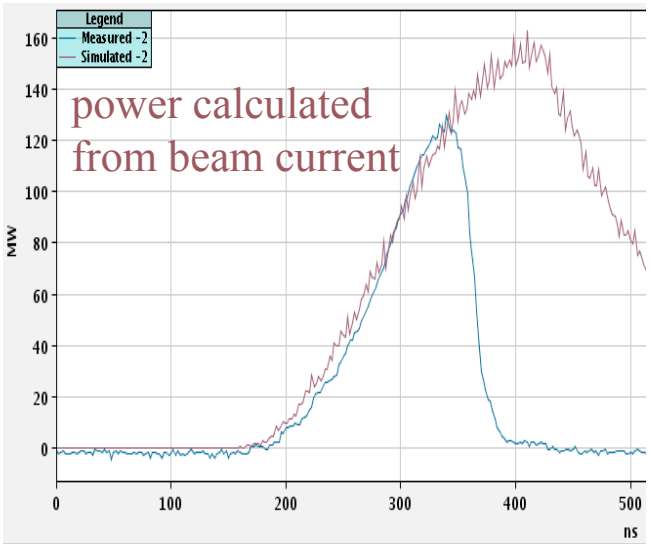
Present PETS status (12 GHz)

- achieved 125 MW @ 266ns in RF driven test at SLAC
- up to ~140 MW peak power beam driven at CTF3 (6A beam current, recirculation) (still breakdowns)
- model well understood
- more in talk by Roger Ruber (WG4 – Thu 09:50)



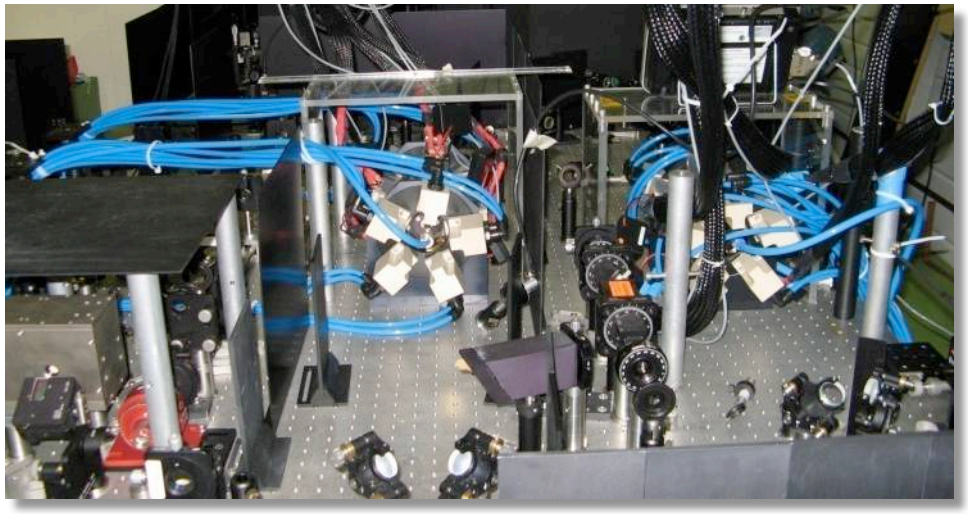






Laser system status

…to fulfill PHIN photo injector requirements		
micro bunches repetition rate	ns	0.667
Synch to external rf @ 1.5GHz	ps	<1
micro bunch width (FWHH)	ps	<10
micro bunch energy (@ cathode)	nJ	370
laser pointing stability std	mm	0.5

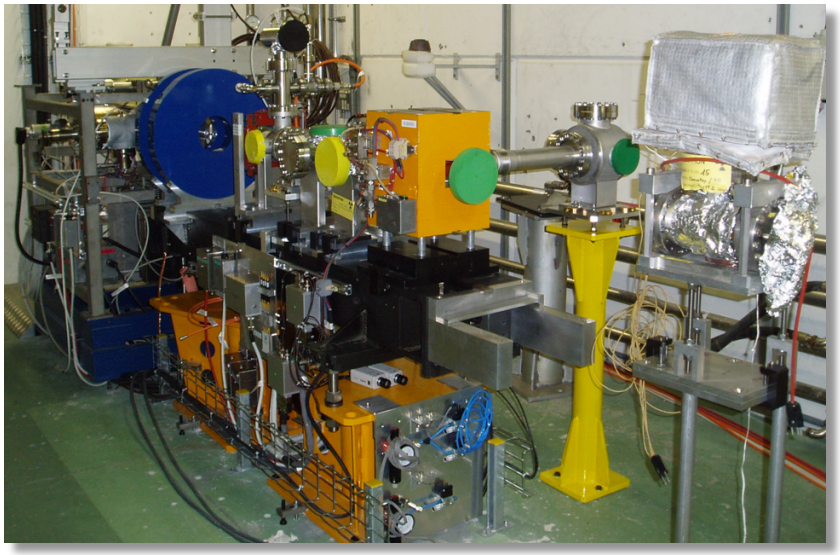


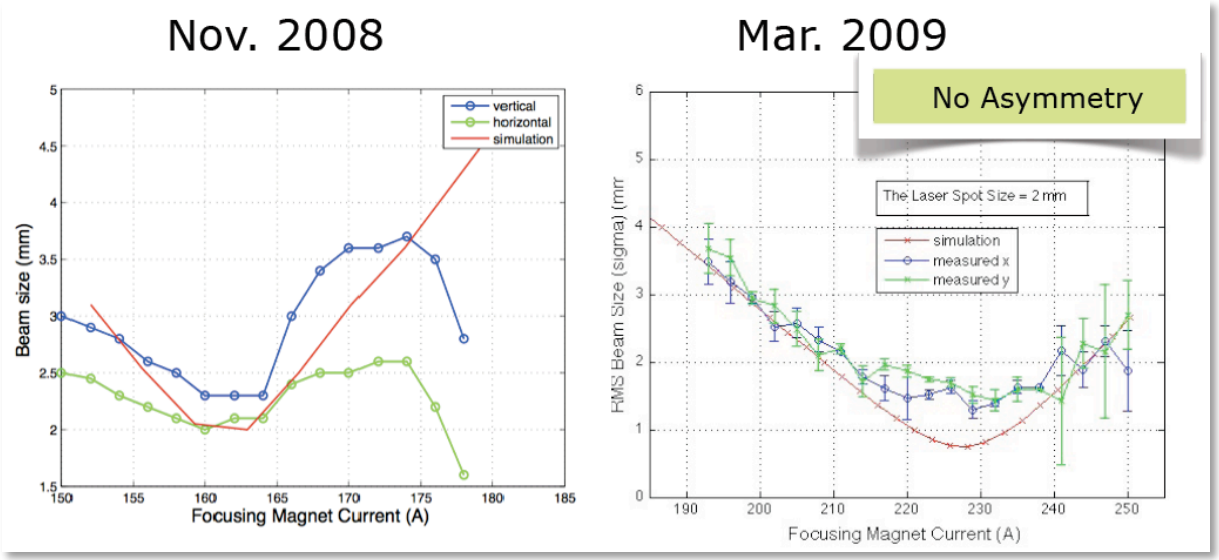
- Laser for both CALIFES and PHIN (photoinjector)
- setup significantly improved (beam path, optical crystal,…)
- For PHIN all laser main target parameters fulfilled !!!
- stable laser beam @ nominal energy sent to cathode

- details in talk of Massimo Petrarca (WG2 - Thu 17:30)

PHIN - photoinjector

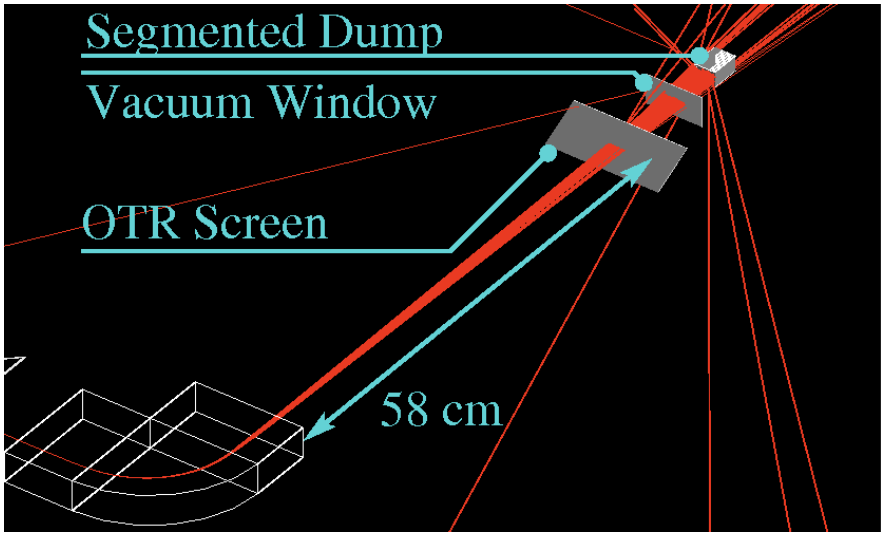
- Two runs in 2009 (March, now)
- First run already very successful
- Bunch charge up to 2.5 nC, above nominal!
- Beam energy ~ 5-6 MeV
- Emittance measured ~7 π mm mrad
- Very good agreement with simulations
- Several potential improvements identified, were implemented for next run (last weeks)
- Aims for next run: stability (short and long term)

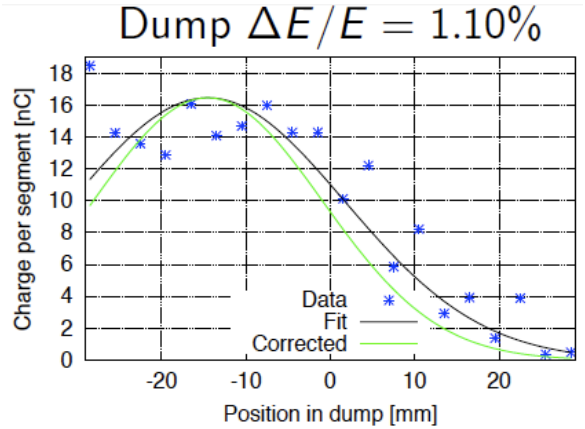


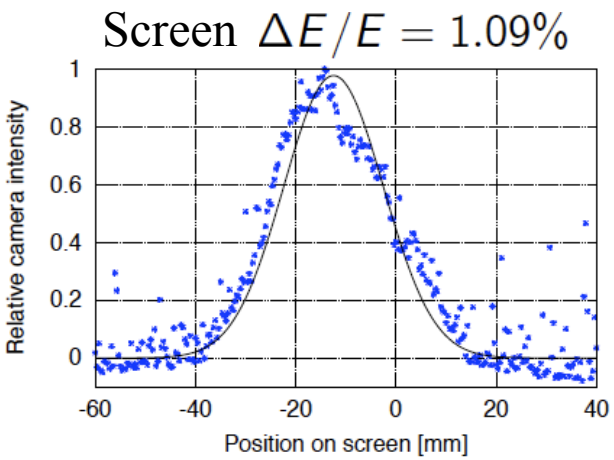


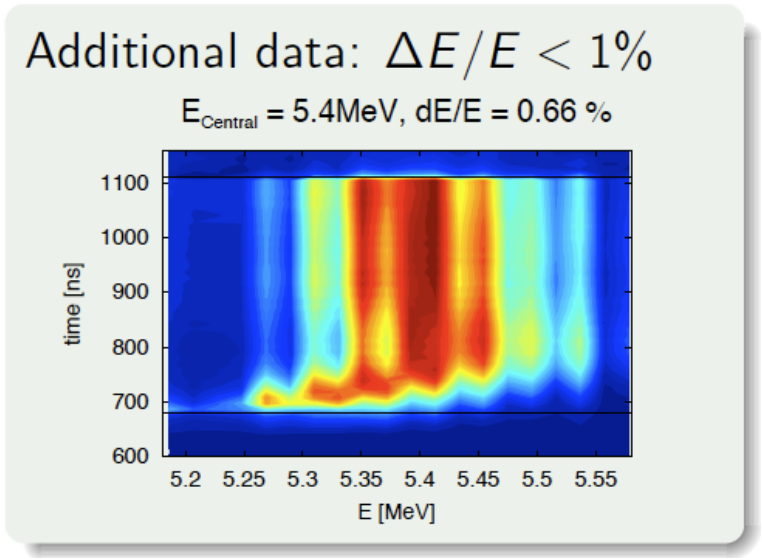
PHIN

- Energy spread measurement
- screen improved
- dump: resolution 0.35% (segmentation)
- consistent measurement from screen and segmented dump



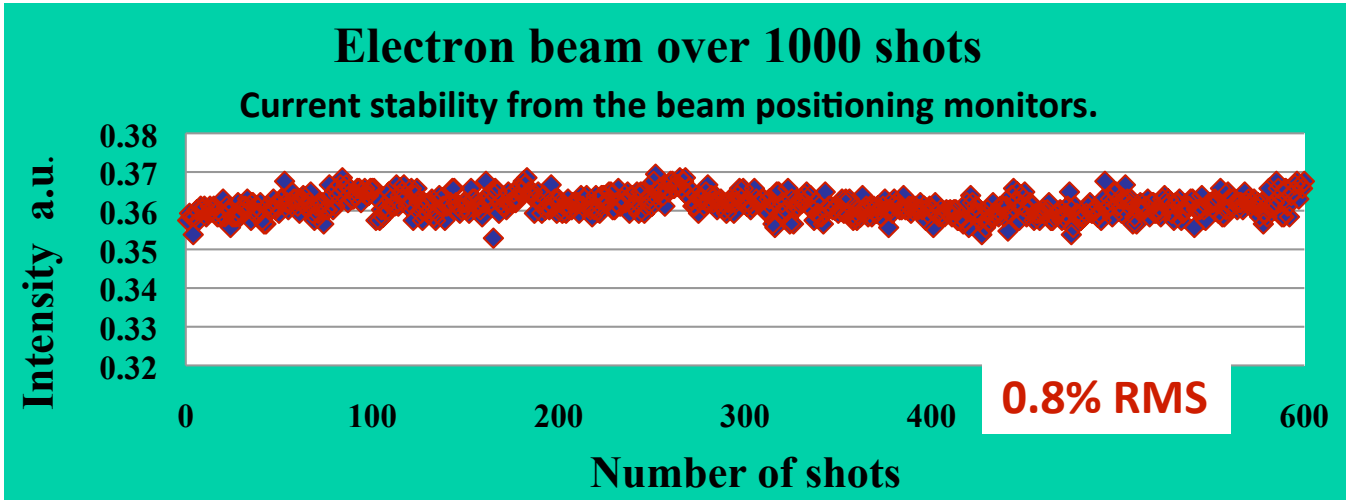


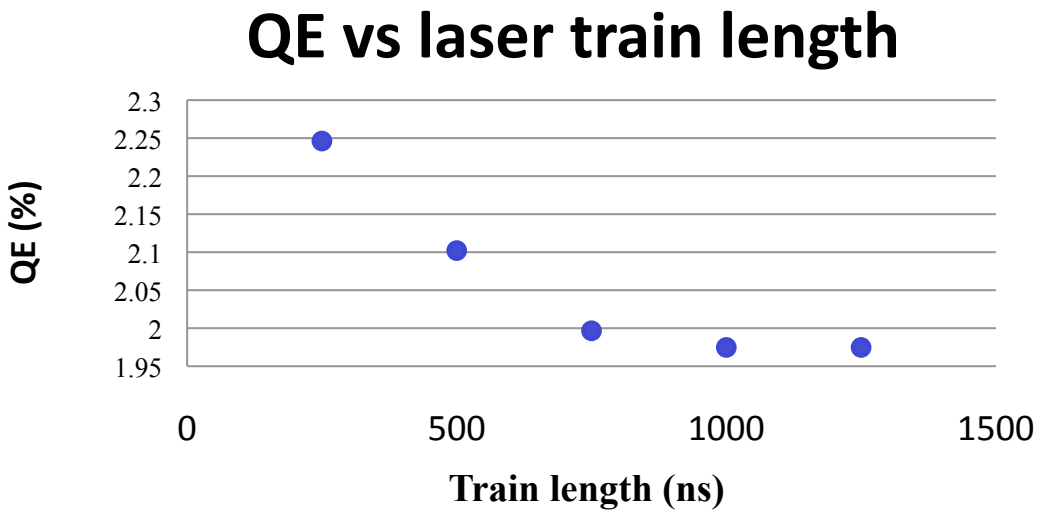




Daniel Egger

PHIN: Stability/Qe

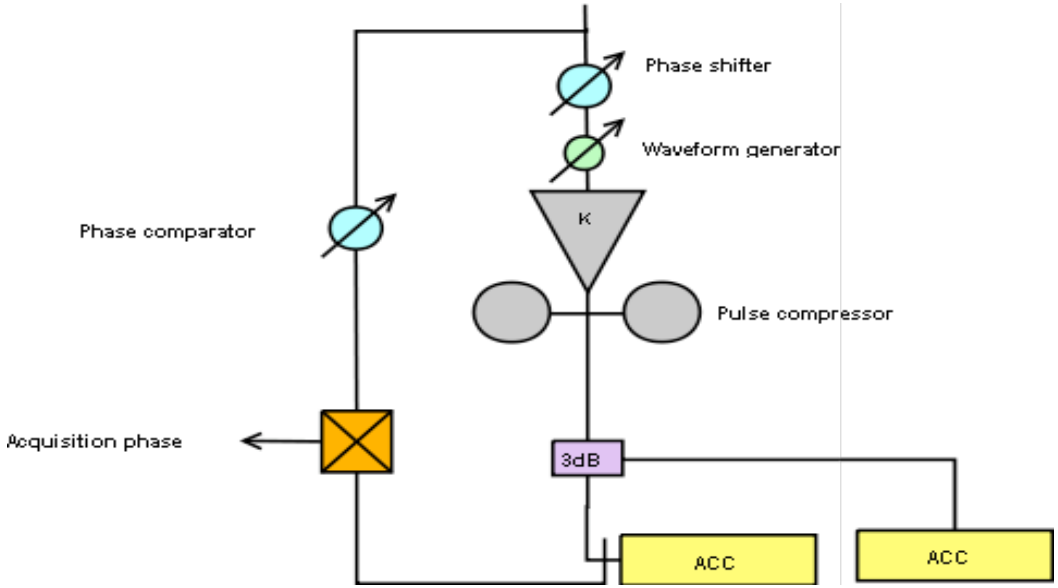


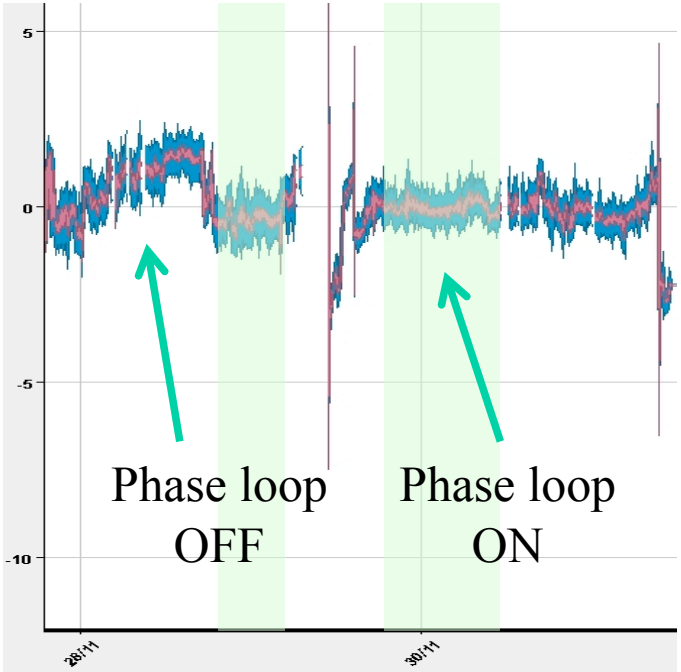


- more in talk by Öznür Mete (WG2 - Thu 17:30)

Stability and Reproducibility

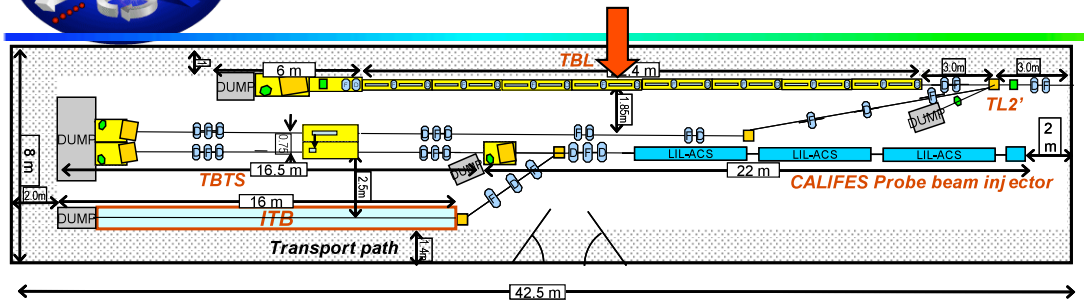
- Operation more complex and more demanding
- Extensive use of reference signals (RF, BPMs, etc.)
- Jitter and slow drifts render operation very difficult
- RF pulse compression sensitive to small temperature variation
- RF phase feed-back significantly improved operation





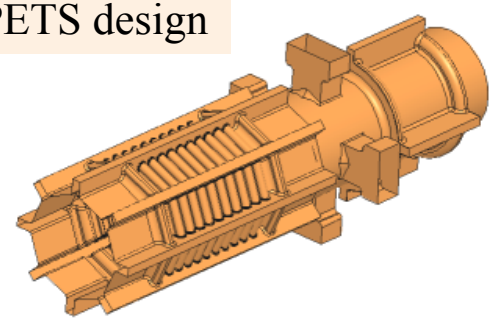
Alexey Dubrovskiy

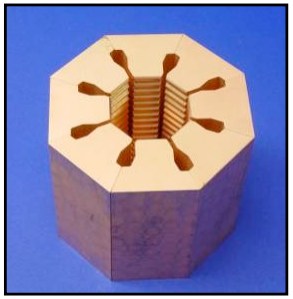
Test Beam Line TBL



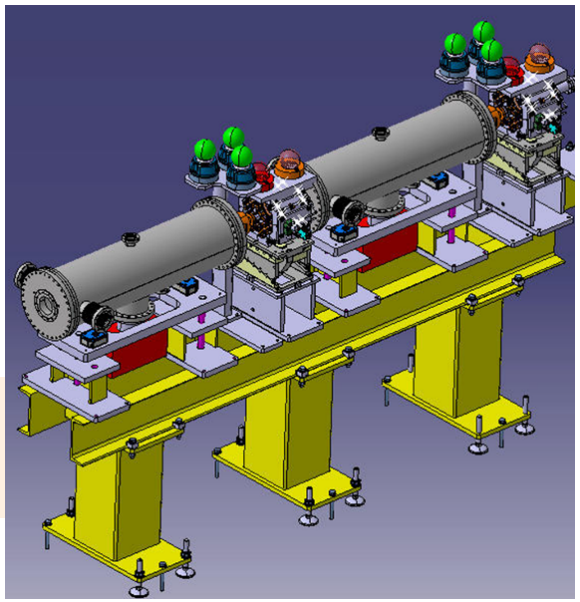
- High energy-spread beam transport decelerate to 50 % beam energy
- Drive Beam stability
- Stability of RF power extraction total power in 16 PETS: 2.5 GW
- Alignment procedures

PETS design

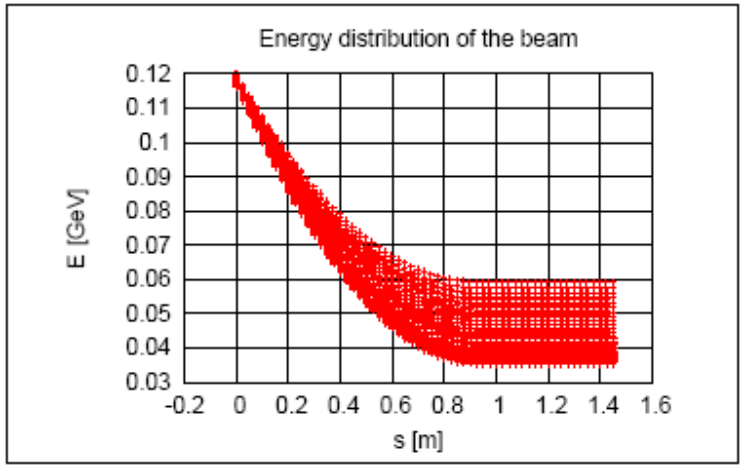




5 MV/m deceleration (35 A)
165 MV output Power



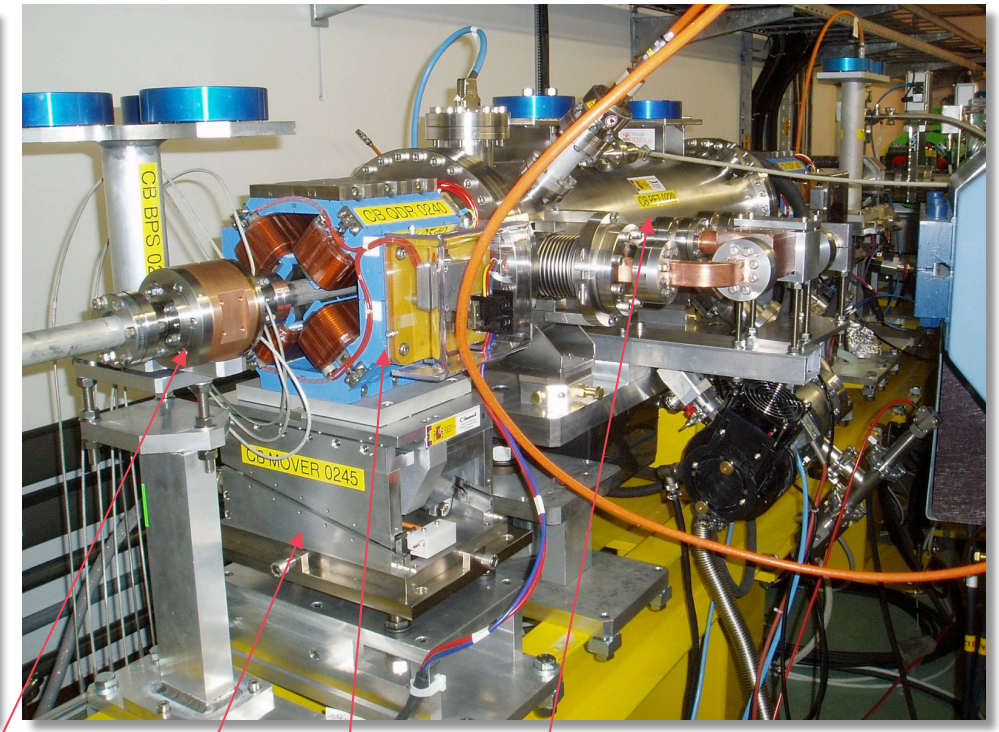
2 standard cells,
16 total



PETS development: CIEMAT
BPM: IFIC Valencia
and UPC Barcelona

TBL prototype beam line spring 2009

- PETS prototype from CIEMAT installed in spring

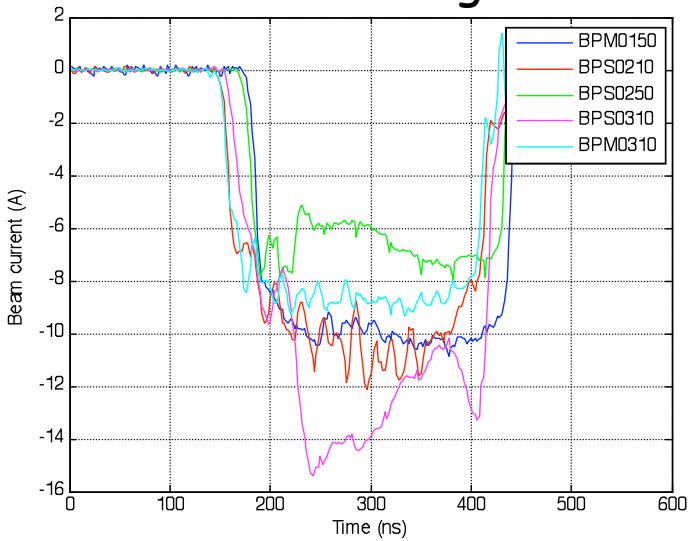


BPM, Quad Mover, Quad, PETS-tank

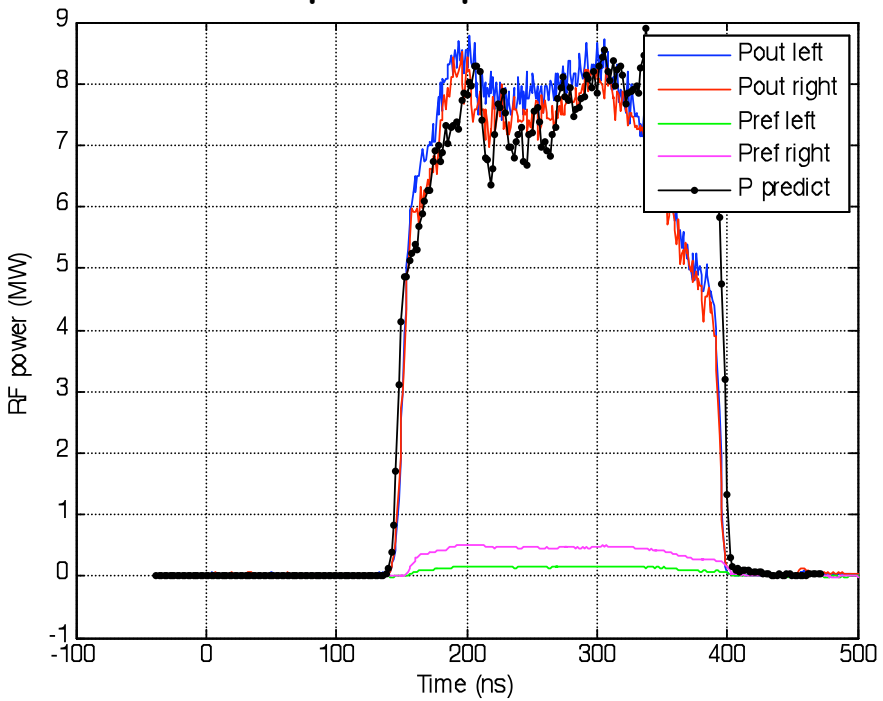
TBL Commissioning Status

- 10 A through PETS
- 20 MW max produced
- Form factor 0.9

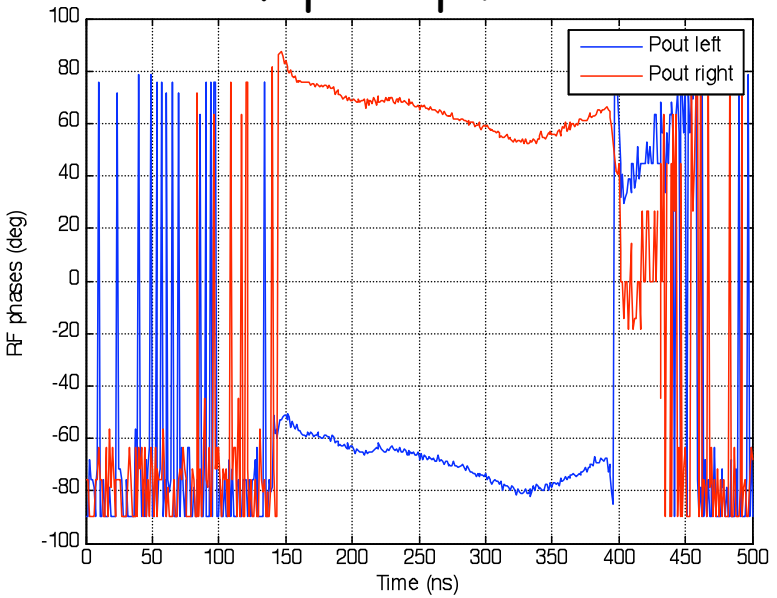
Beam current along the line



RF power produced

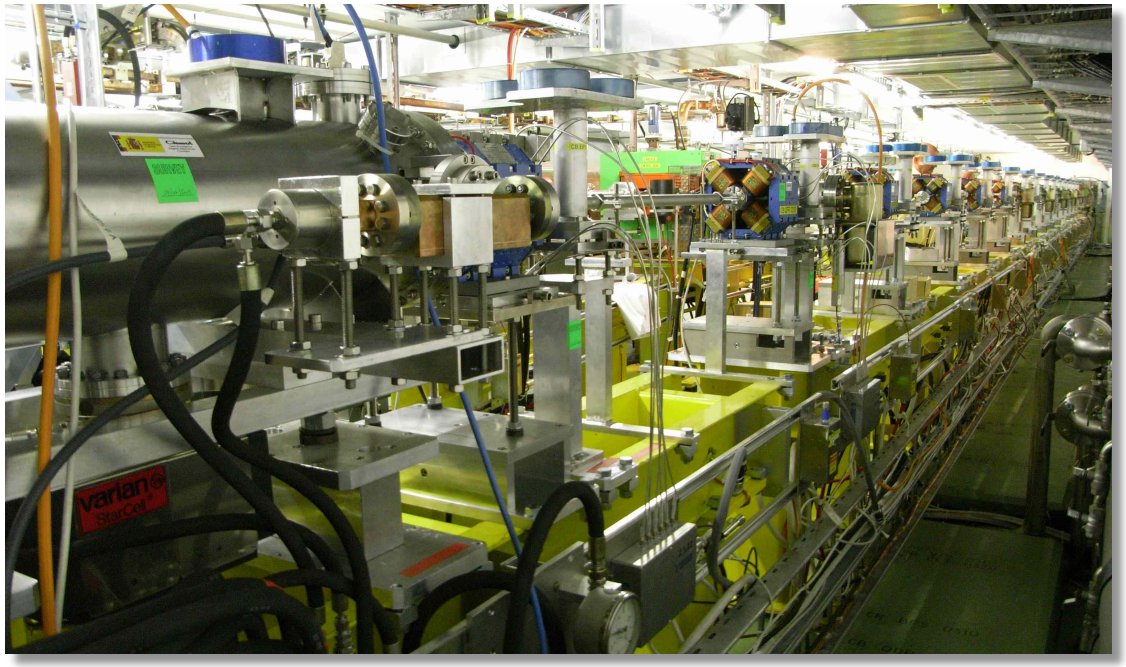


RF pulse phase

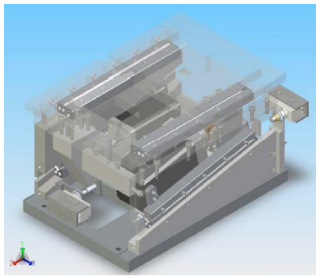


TBL Status

- up to 10 A through PETS
- 20 MW max produced at a pulse length of 280 ns
- Power production consistent assuming a form factor of 0.9
- RF diagnostics working well
- Noise problems on BPM signals

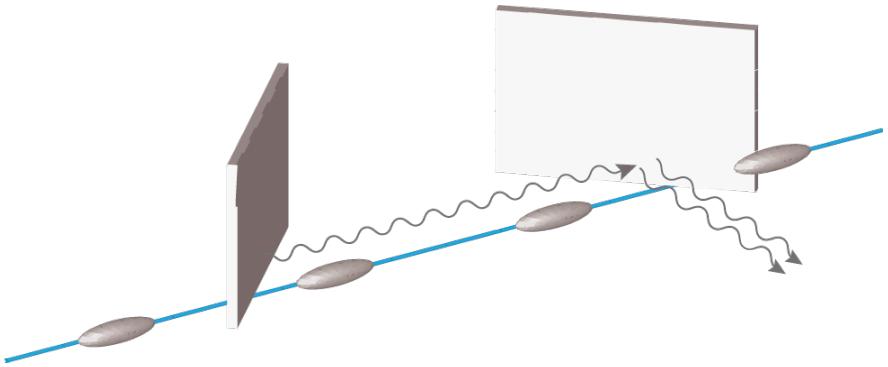


- Detailed Commissioning of BPS's and Quad movers not yet done
- Complete beam line including diagnostic section installed (finishing this week)
- 3 magnet movers (CIEMAT) installed, rest by December
- PETS series production launched together with CIEMAT (series of 8) => more details in talk by David Carillo (WG4 Wed 16:10)

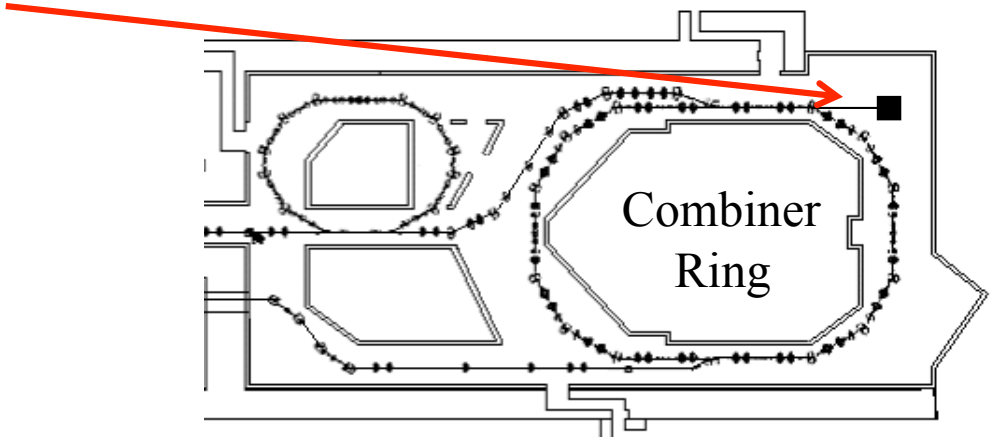


CDR Experiment

- John Adams Institute at Royal Holloway, London

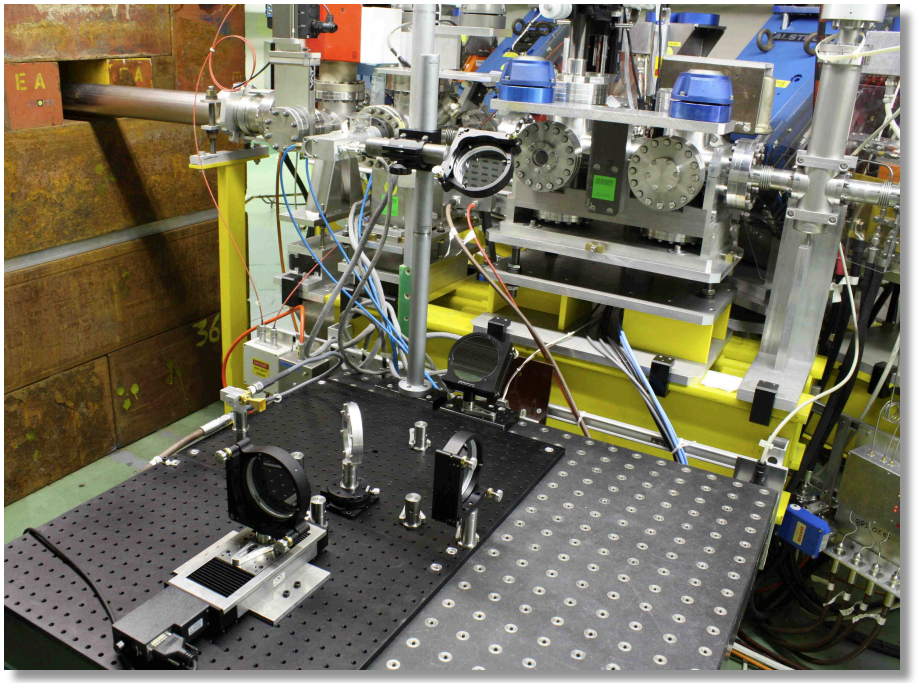


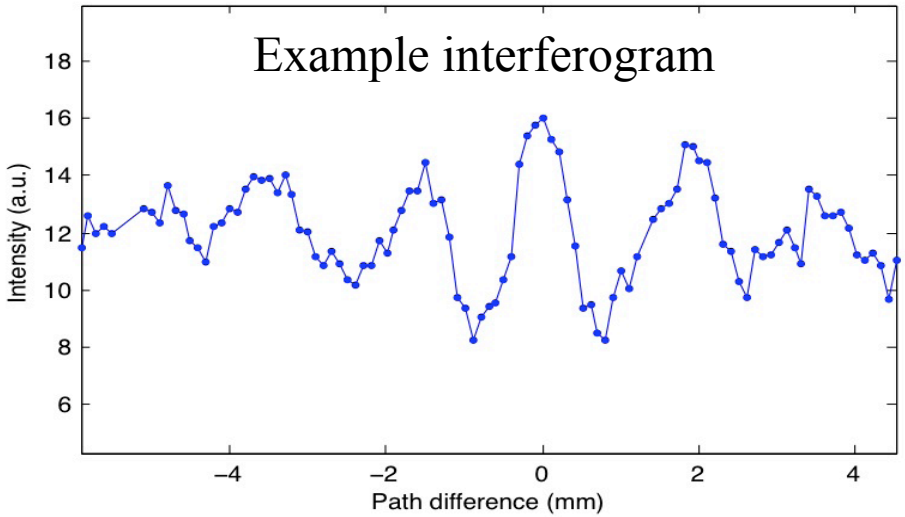
- Diffraction radiation when a charged particle moves close to a medium
- Interferometric measurements extract information on longitudinal beam profile
- installed in the CRM line at the Combiner Ring

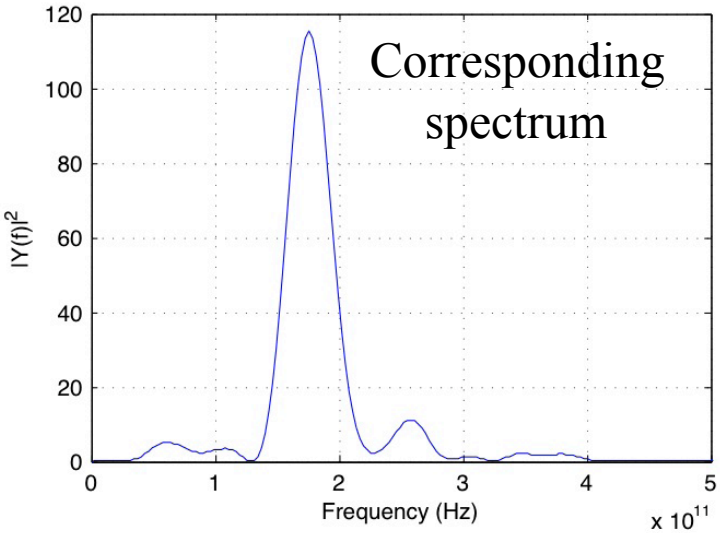


CDR (Coh. diffraction Radiation)

- Both CSR and CDR signals observed
- checks of spatial distribution
- Observed first CSR interferogram and obtained the spectrum
- identified some background contributions being solved presently
- more data expected shortly
- see Anne Dabrowski (WG5- Thu 12:05)







2009 CTF3 experimental program

Goals

- 30 GHz: One structure test (TM02) + breakdown studies
- PHIN: Beam characterization, reach ½ of nominal bunch charge ?
- CALIFES: Beam characterization, beam to TBTS (most likely still reduced current)
- Delay Loop: Back in operation, retrieve combination x 2 (~ 7 A)
- Combiner Ring: Final optics checks, isochronicity, put together with DL (> 24 A)
- TL2: Complete commissioning (tail clipper), bunch length control, > 20 A to users
- TBTS: PETS to nominal power/pulse length (15 A, recirculation)
  Beam commissioning of probe beam line
  First accelerating structure tests (one structure ? – CLIC G)
  Two-beam studies (deceleration/acceleration), initial breakdown kicks studies
- TBL: PETS validation (100 MW, need > 20 A), beam line studies (2-3 PETS ?)
- Others: CDR studies in CRM, beam dynamics benchmarking, stability studies, control of beam losses…

Conclusion

- Collaboration has been growing
- Major parts of CTF3 not only installed but operated by collaboration members
- Main objective - full Drive Beam generation achieved
- Beam Driven RF power generation as expected
- Many other points well covered
- On a good way to the CDR

- Many Thanks to everyone who made this possible!!!