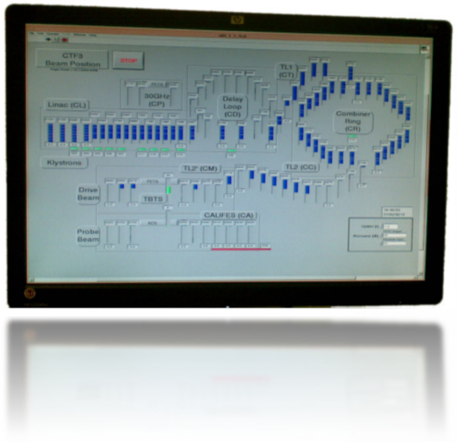

Experimental Verification of the CLIC Two-beam Scheme, Status and Outlook

R. Corsini for the CLIC Collaboration

Talk Outline:

1. Status of CLIC feasibility benchmarks in the CLIC test facility CTF3 (including last year's highlights)

2. Plans for CTF3 in 2013 and beyond

3. Further steps towards CLIC

CLIC Feasibility Issues

Main linac gradient	– Accelerating structure
Drive beam scheme	– Drive beam generation – PETS (power extraction and transfer structures) – Two beam acceleration – Drive beam deceleration
Luminosity	– Main beam emittance generation, preservation and focusing – Alignment and stabilisation
Operation and Machine Protection System (robustness)	
Detector (experimental conditions)	

CLIC Feasibility Issues

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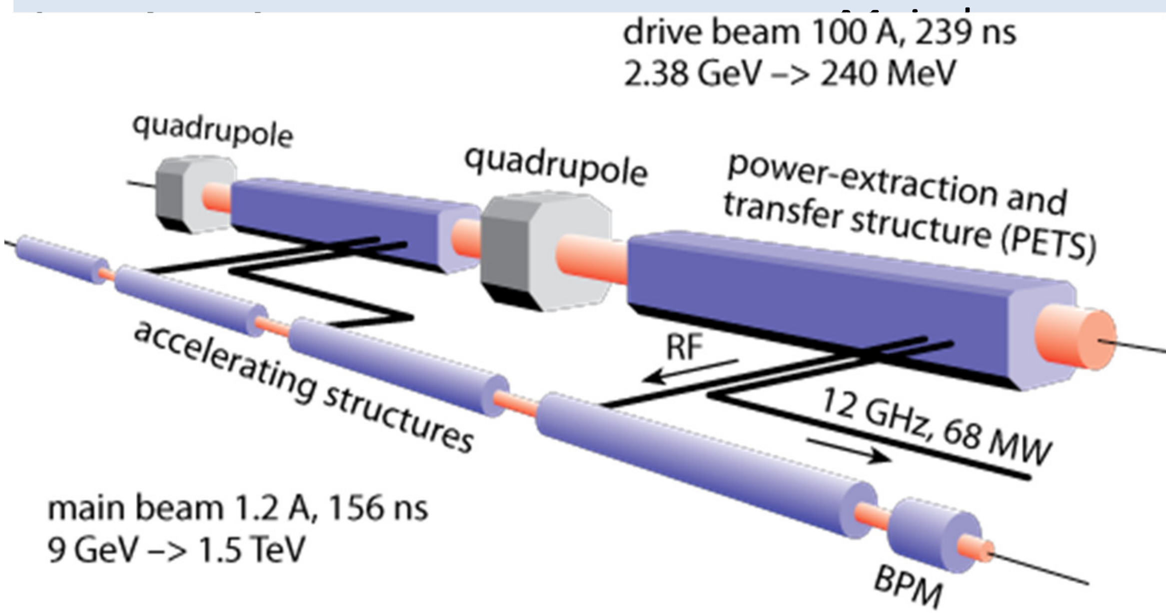
	–	PETS (power extraction and transfer structures)
	–	Two beam acceleration
	–	Drive beam deceleration
		ttance generation,
		d focusing
		stabilisation
		robustness)



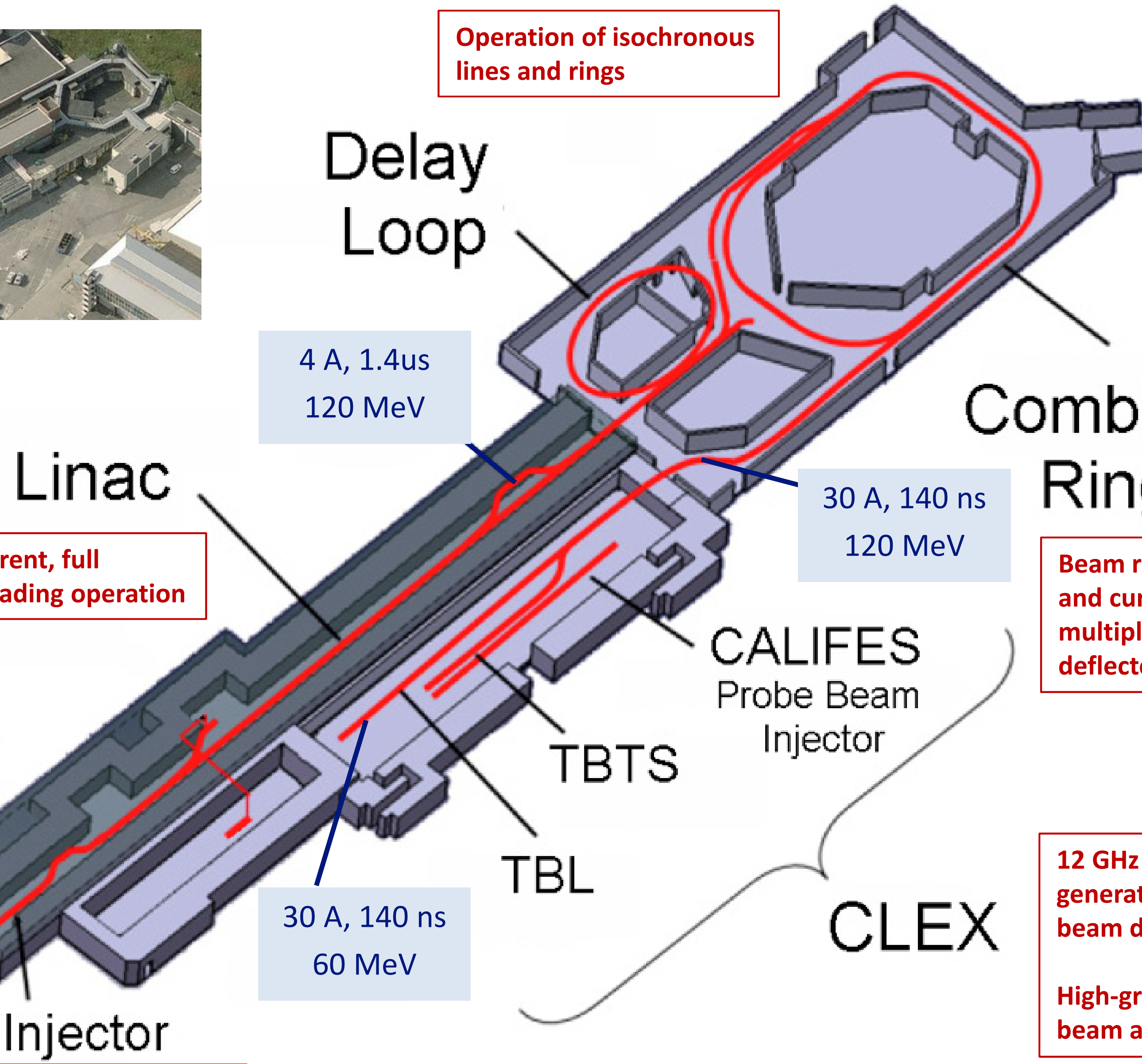
CLIC Feasibility Issues

S. Stapnes -WEYA01

Main linac gradient	– Accelerating structure	(CTF3)
Drive beam scheme CTF3	– Drive beam generation – PETS (power extraction and transfer structures) – Two beam acceleration – Drive beam deceleration	
Luminosity	– Main beam emittance generation, preservation and focusing – Alignment and stabilisation	(CTF3)
Operation and Machine Protection System (robustness)		(CTF3)
Detector (experimental conditions)		

CTF3 layout and CLIC Feasibility Issues

Operation of isochronous lines and rings



High current, full beam-loading operation

Beam recombination and current multiplication by RF deflectors

12 GHz power generation by drive beam deceleration

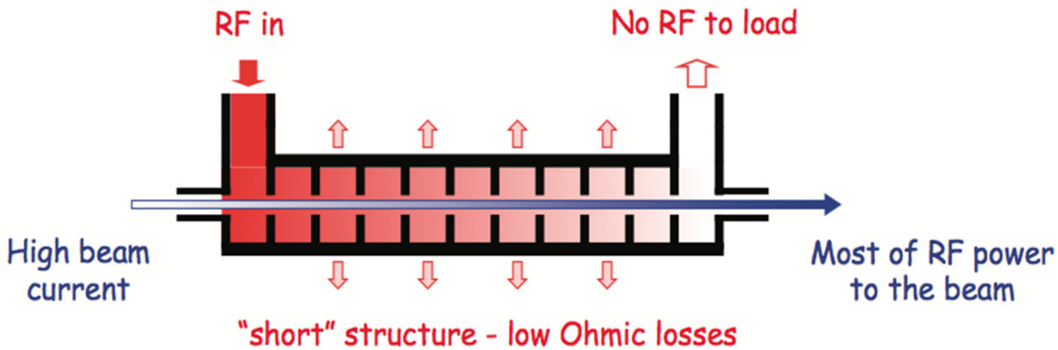
High-gradient two-beam acceleration

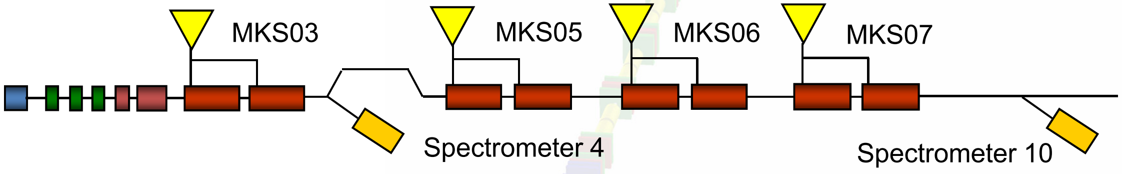
Bunch phase coding

Achievements – Drive Beam Generation

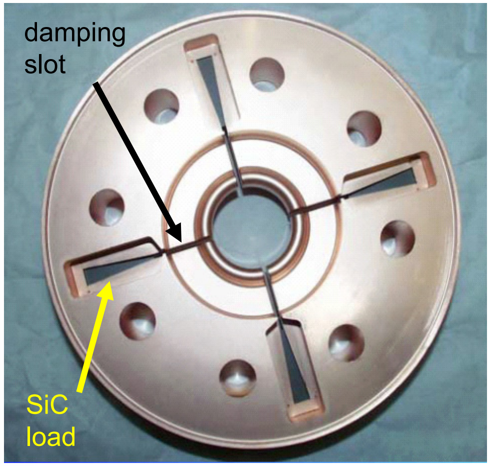
High current, full-loaded linac operation

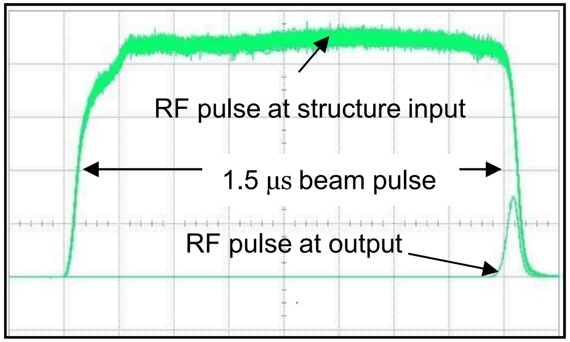
- 95 % RF to beam efficiency measured
- No instabilities





Dipole modes suppressed by slotted iris damping (first dipole's Q factor < 20) and HOM frequency detuning

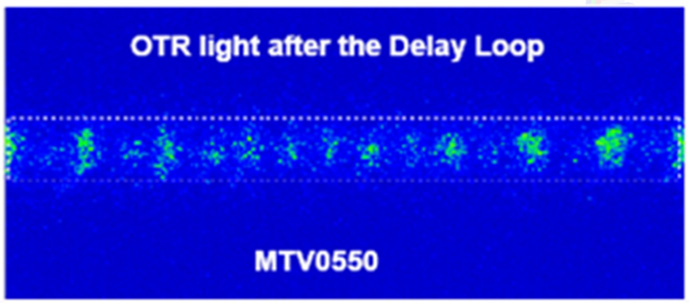


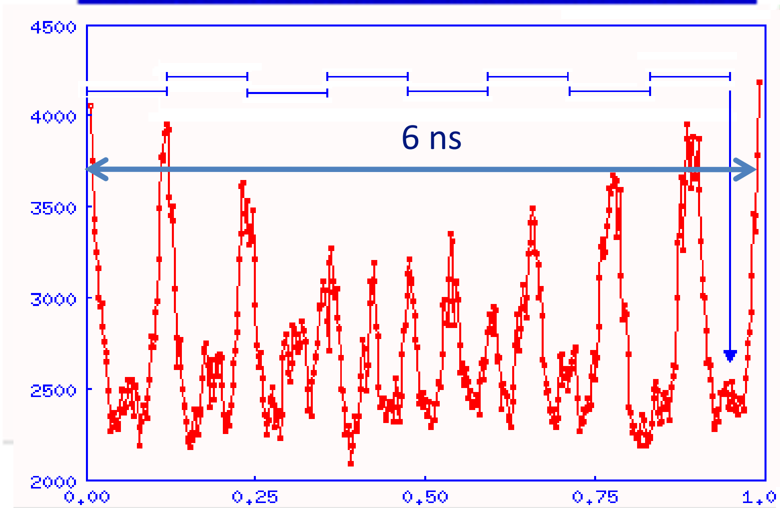


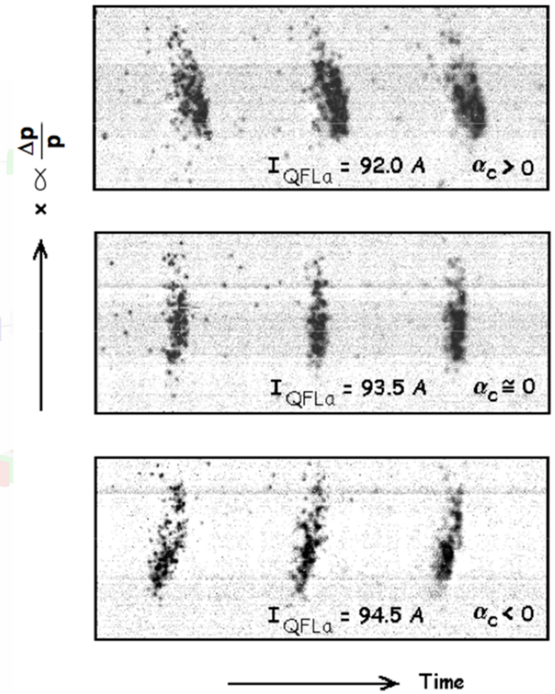
Achievements – Drive Beam Generation

Beam recombination

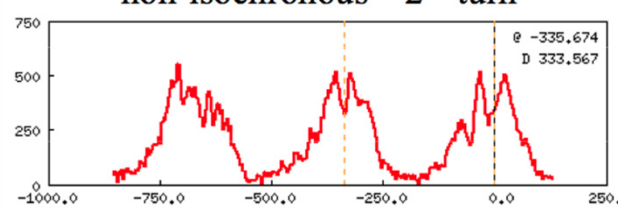
- Fast bunch phase switch in SHB system
- Operation of isochronous rings and beam lines



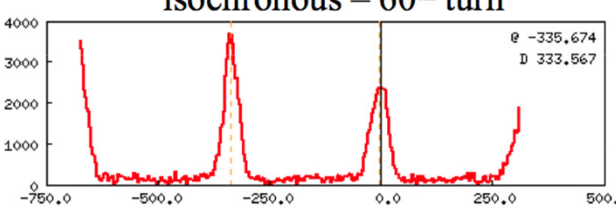




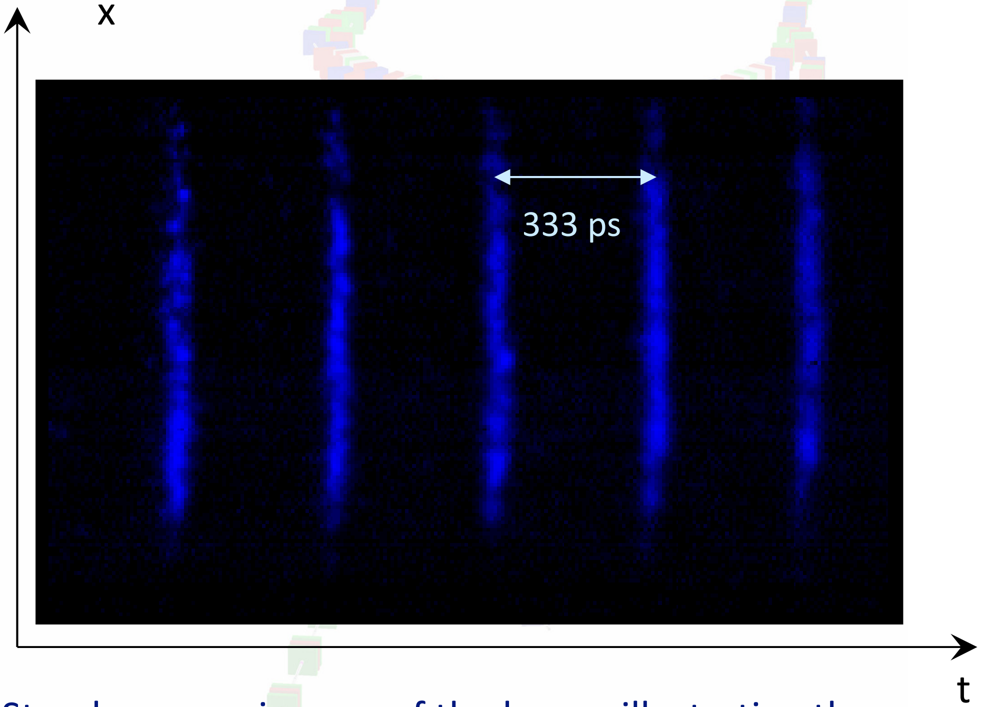
non-isochronous – 2nd turn



isochronous – 60th turn

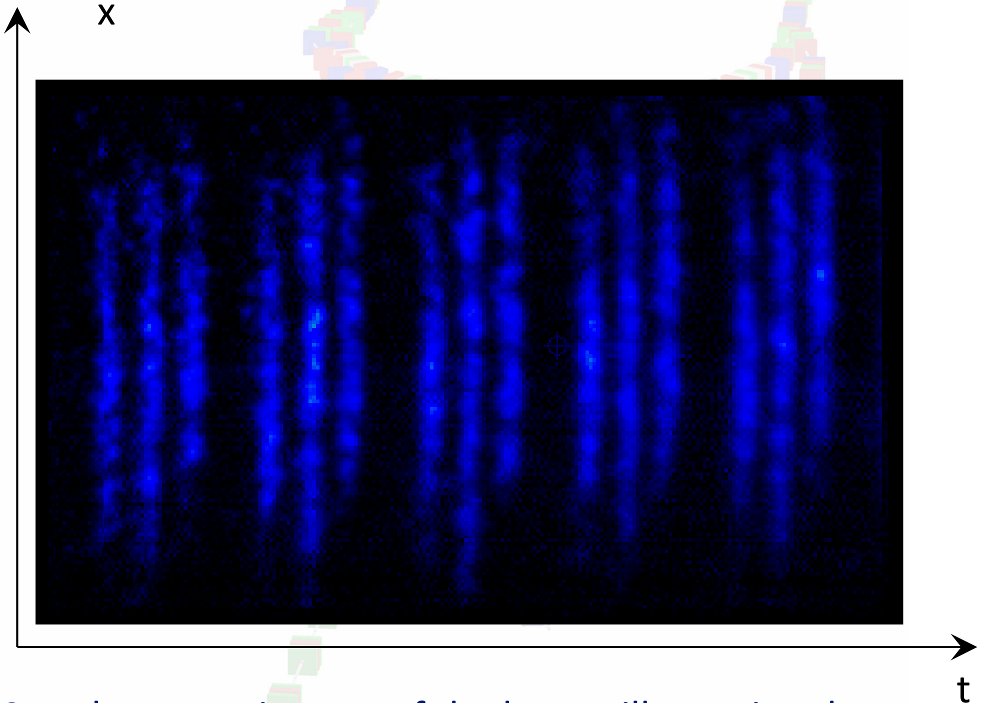


Achievements – Drive Beam Generation



Streak camera images of the beam, illustrating the bunch combination process in the ring

Achievements – Drive Beam Generation



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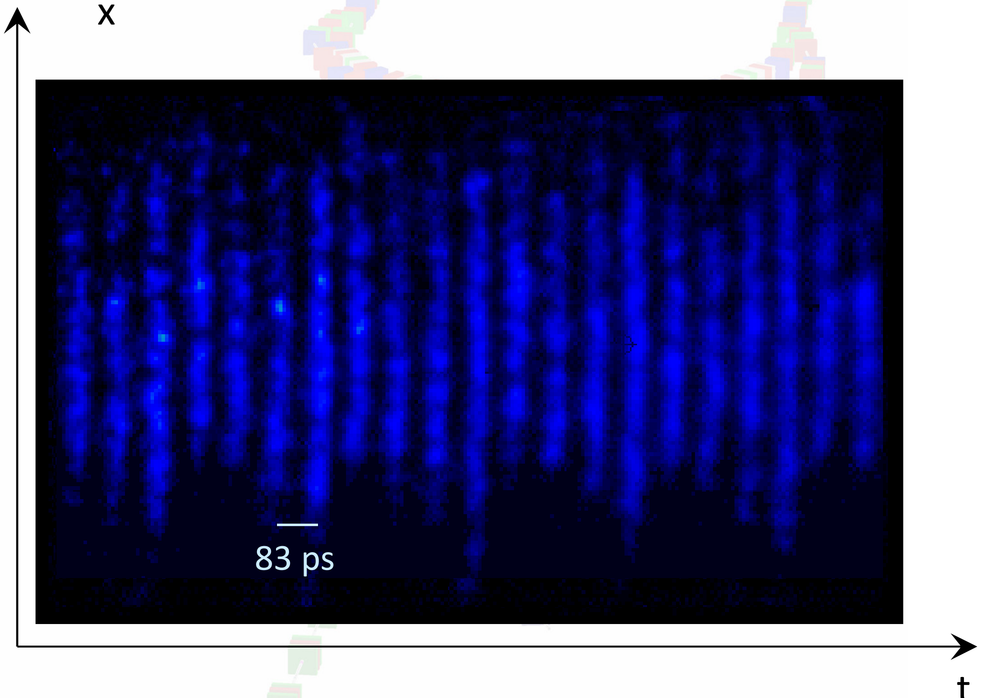
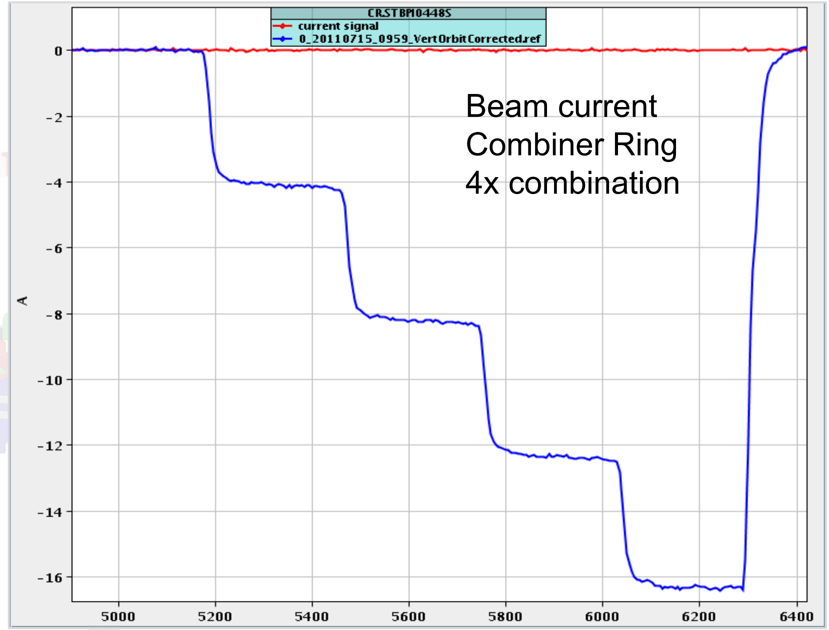


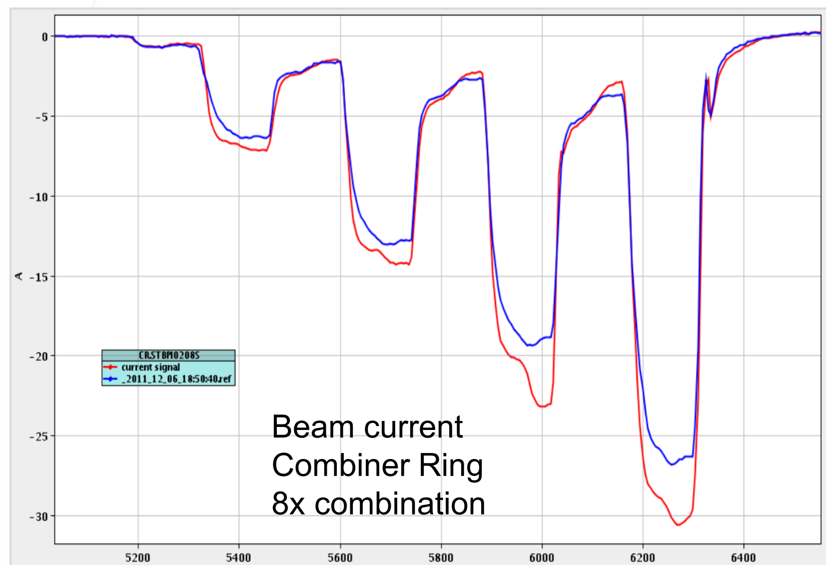
Streak camera images of the beam, illustrating the bunch combination process in the ring

Achievements – Drive Beam Generation

Beam recombination

- Factor 4 - OK
- Factor 8
  - basic principle demonstrated
  - need improvement (pulse shape, stability, losses, emittance)





Beam recombination - Emittance

Best results in CLEX
for factor 4: ε_H= 250 um ε_V= 140 um
for factor 8: ε_H= 640 um ε_V= 170 um

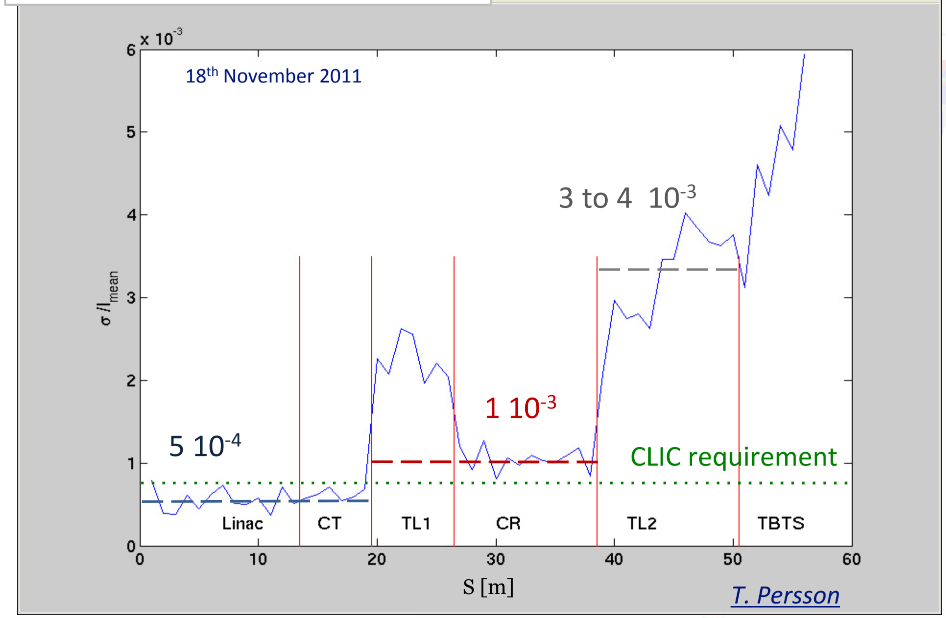
Different turns are ~ ok, no unknown effects
Emittance increase due to non perfect orbit

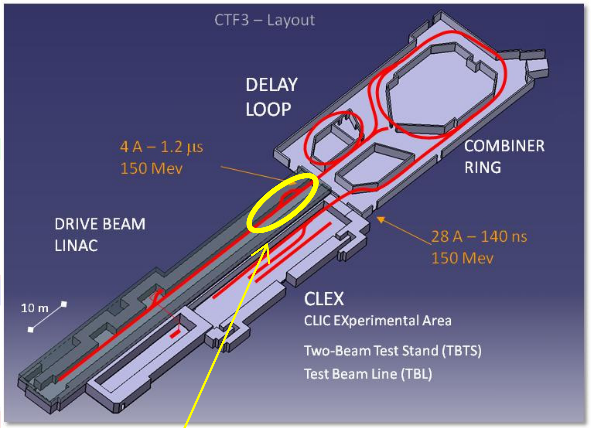
2011 Highlights - Beam Stability

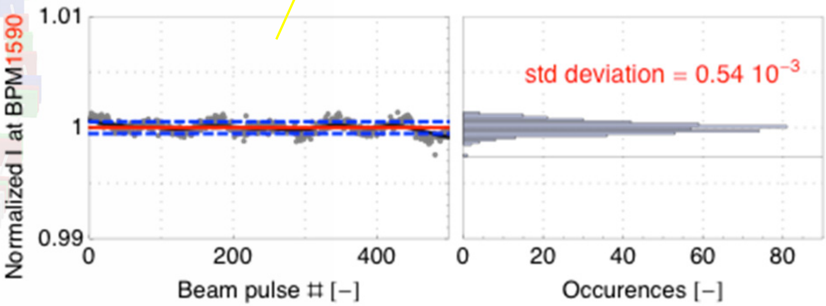
Repeatability and long term current stability improved

Pulse charge stability measured at end of the linac better than CLIC requirements

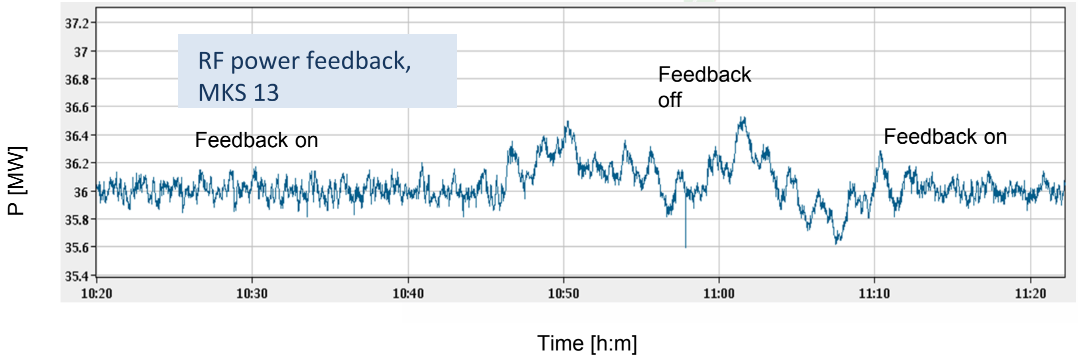
Charge stability – Factor 4







G. Sterbini



Several feed-back loops operational, for temperature, RF phase and power and gun current.

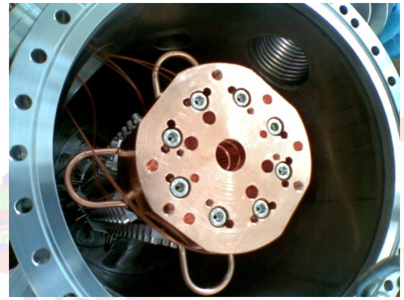
T. Persson, P. Skowronski -TUPPR032

2011 Highlights - Test Beam Line (TBL)

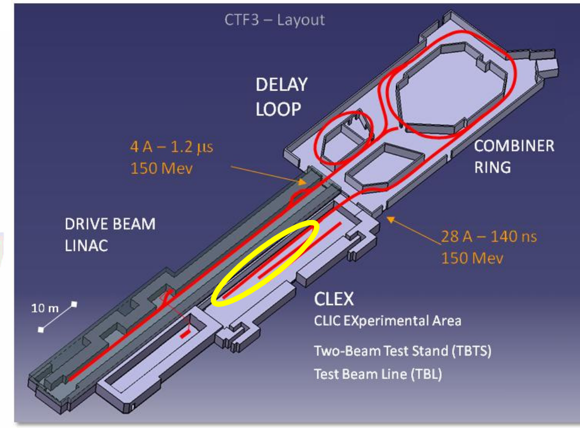
Nine Power Extraction & Transfer Structures (PETS) installed and commissioned in 2011 (13 PETS installed in 2012)

Full beam transport to end-of-line spectrometer, stable beam

Power produced (70 MW/PETS) fully consistent with drive beam current (21 A) and measured deceleration.



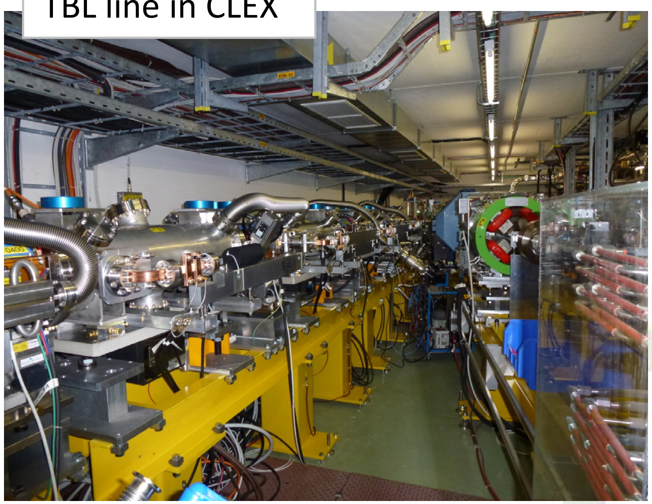
PETS tank during installation

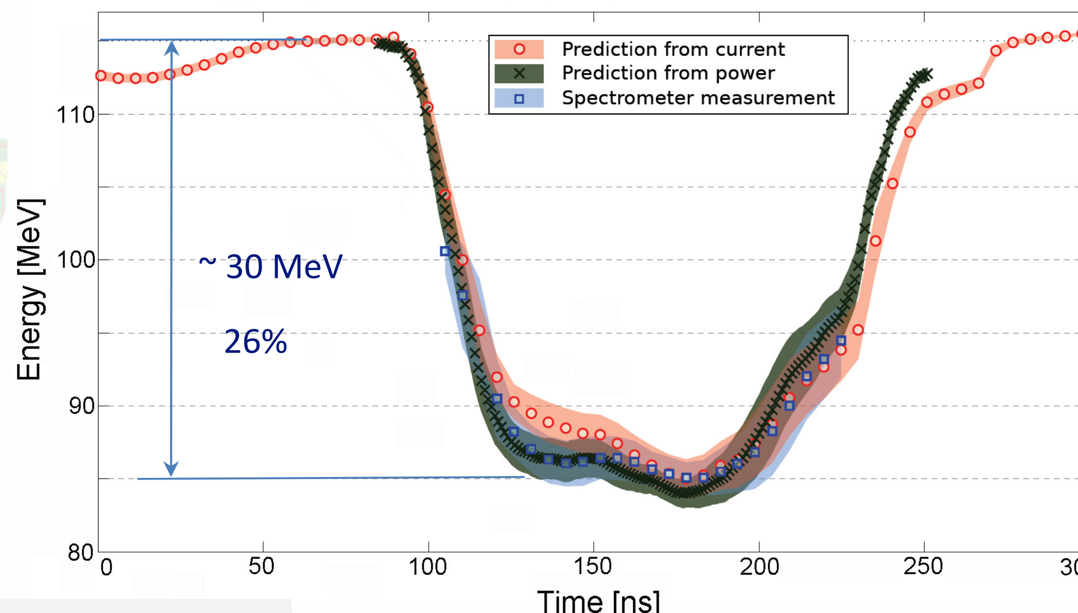


More than half a GW of 12 GHz power!

Beam deceleration, measured in spectrometer and compared with expectations

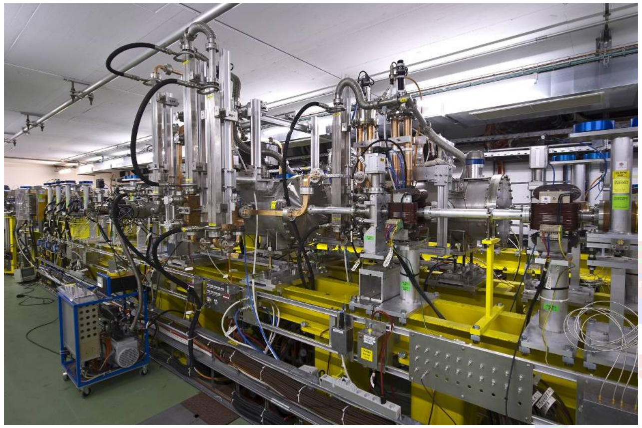
TBL line in CLEX

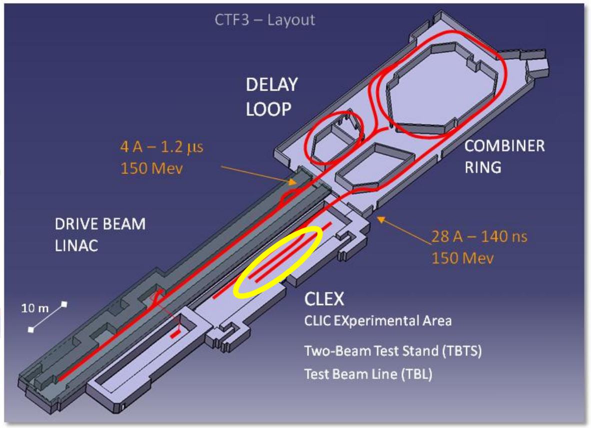




R. Lillestol, S. Doebert, M. Olvegaard, A. Rabiller, G. Sterbini, E. Adli - TUPPR031

2011 Highlights - Power production in Two-Beam Test Stand



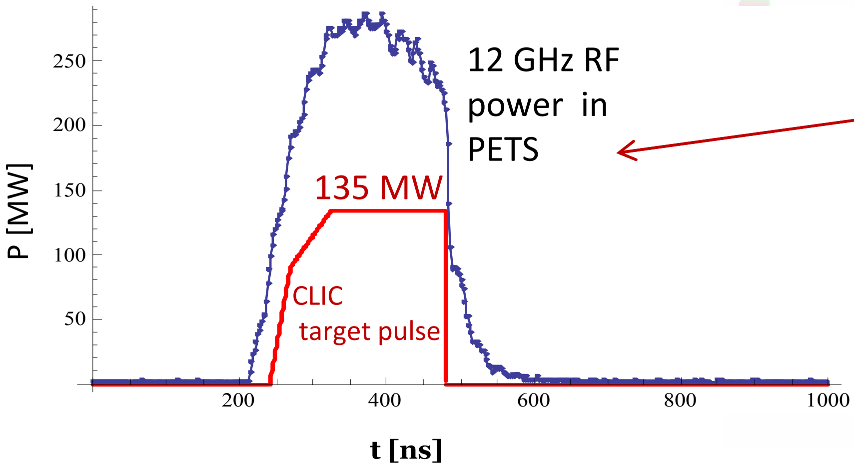


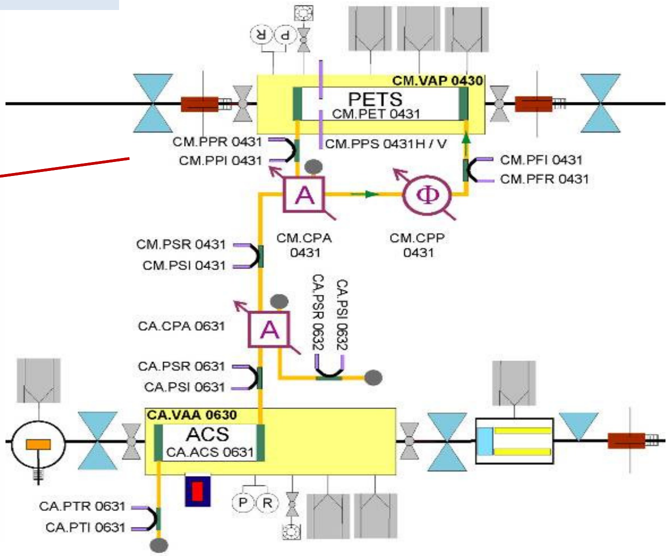
PETS operated routinely above **200 MW** peak RF power

providing reliably pulses ~ 100 MW peak to accelerating structure.

About twice the power needed to demonstrate 100 MV/m acceleration in a two-beam experiment with TD24 structure.

Two-Beam Test Stand (TBTS) Layout





R. Ruber, I. Syratchev

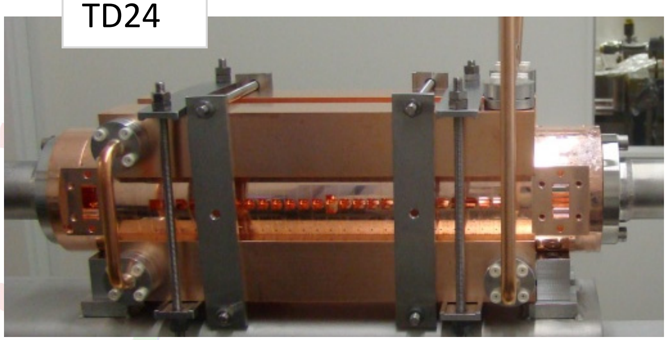
2011 Highlights – Two-beam acceleration in TBTS

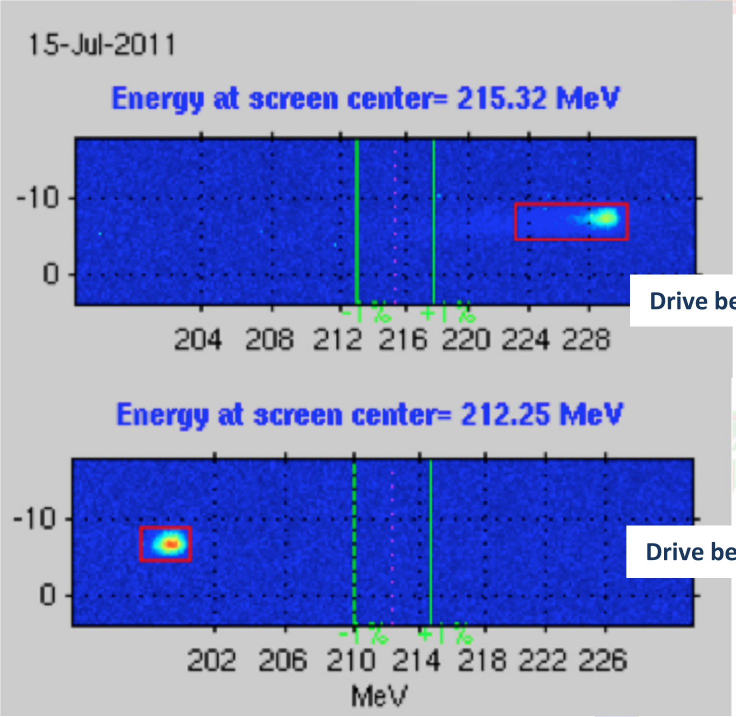
Two-Beam Acceleration demonstration in TBTS

Up to 145 MV/m measured gradient

Good agreement with expectations (power vs. gradient)

TD24



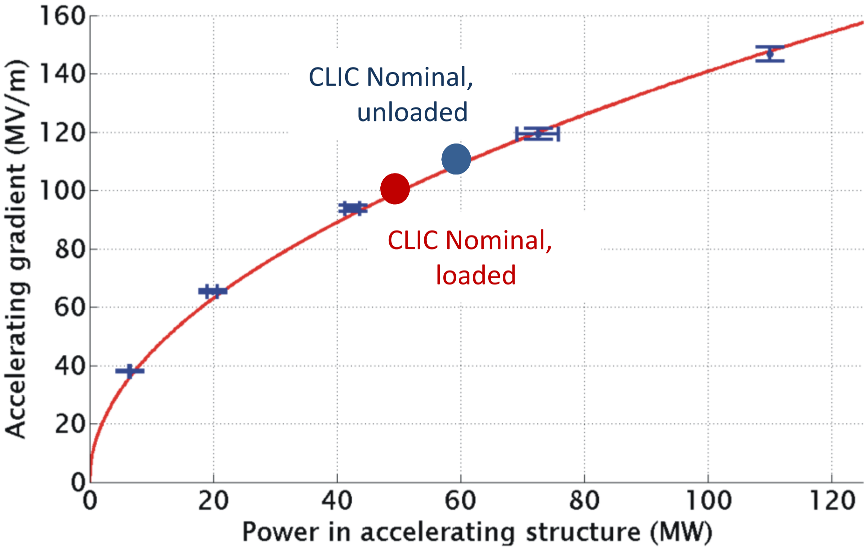


Drive beam ON

Drive beam OFF

Maximum stable probe beam acceleration measured: 31 MeV

⇒ Corresponding to a gradient of **145 MV/m**



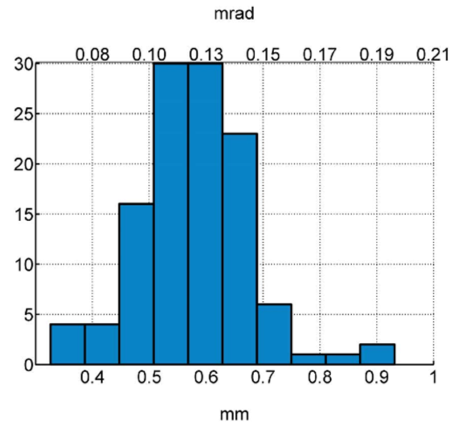
W. Farabolini, J. Barranco

TBTS – Two-beam tests & high gradient studies

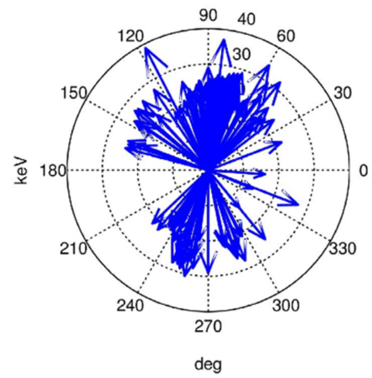
Break-down kicks
&
Break-down physics/statistics

A. Palaia, M. Jacewicz, T. Muranaka, R. Ruber, V.Ziemann , W. Farabolini - MOEPPB001

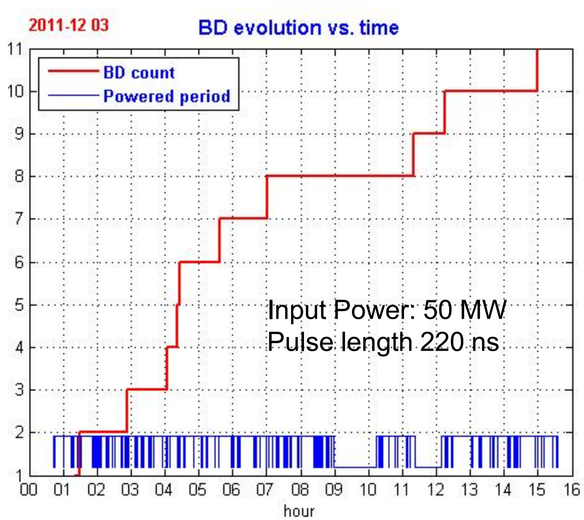
kick magnitude
(typically 0.13 mrad)

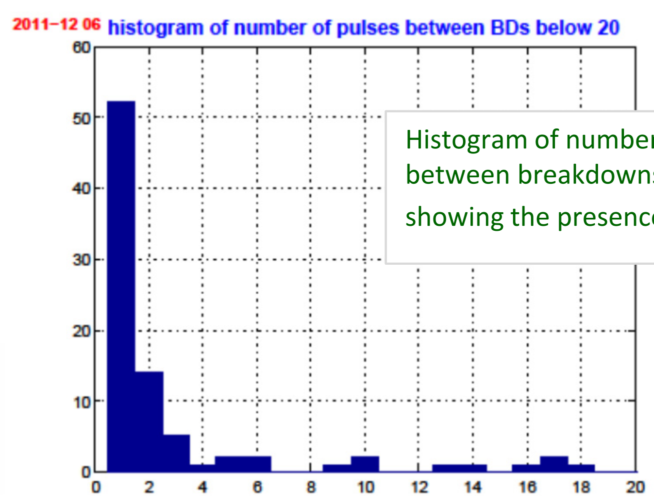


transverse electric field
(typically 25 keV)



- kicks on horizontal and vertical planes between 0.02 and 0.2 mrad;
- kicks corresponding to a transverse momentum between 10 and 40 keV/c
  (measurements at NLCTA within 30 keV/c, Dolgashev et al., LINAC 2004);

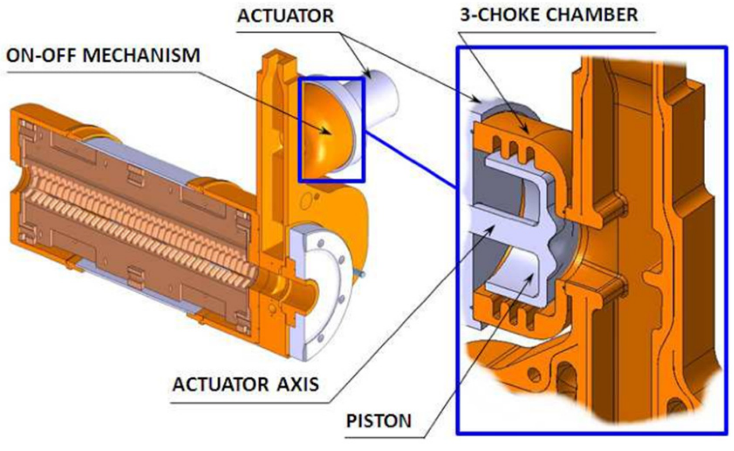


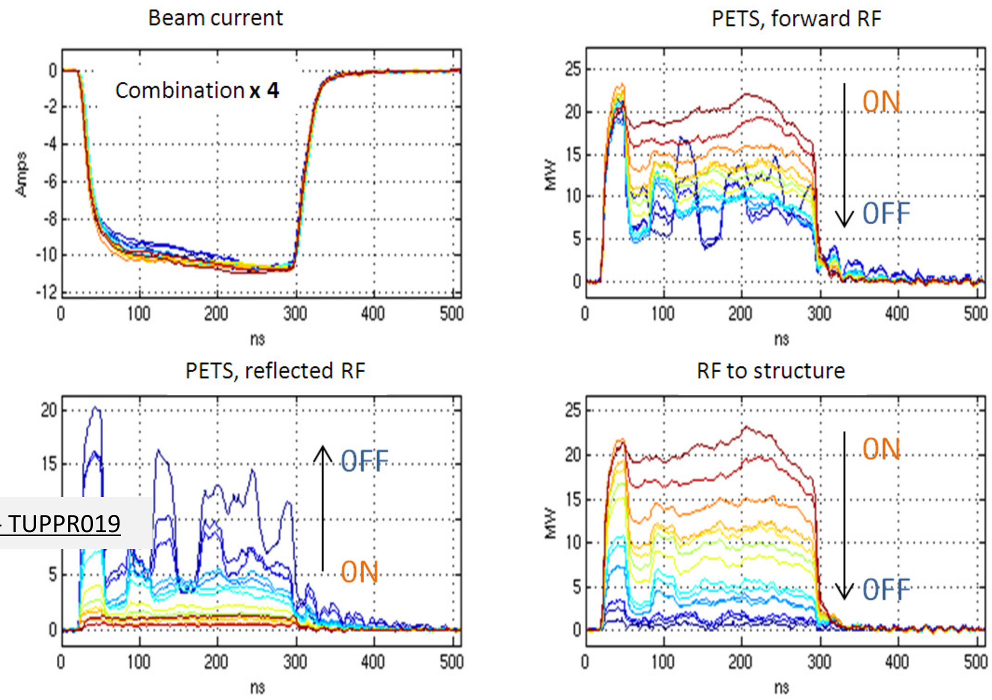


Histogram of number of pulses between breakdowns,
showing the presence of clusters.

Farabolini, A. Palaia

TBTS – PETS On-off mechanism





R. Corsini, I. Syratchev, A. Dubrowski, R. Ruber, P. Skowronski - TUPPR019

Demonstration of PETS of-off mechanism

- Considered a feasibility issue
- Ability to:
  - Switch off power from individual PETS to accelerating structure in case of breakdown
  - Reduce substantially power in PETS, to cope with PETS breakdowns
- PETS on-off principle fully tested
- Conditioned at high power (135 MW - nominal) by recirculation

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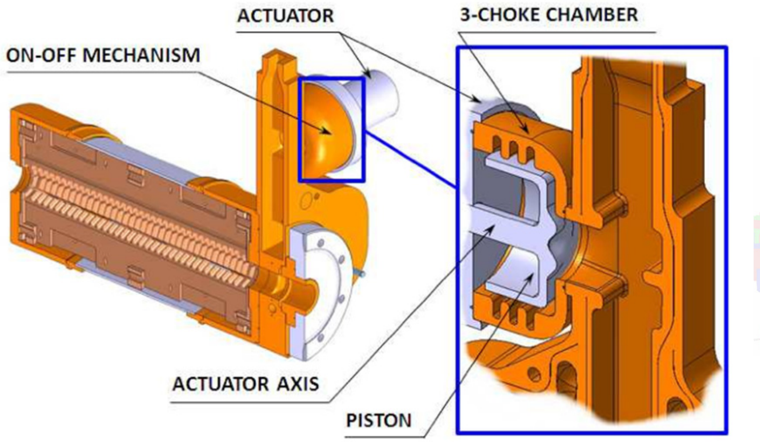

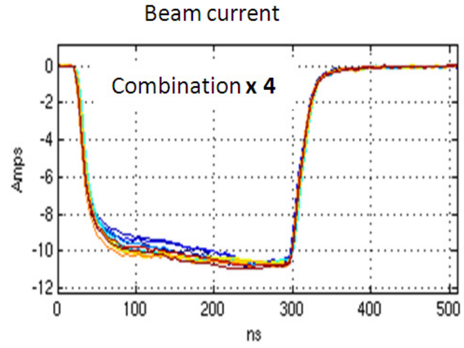

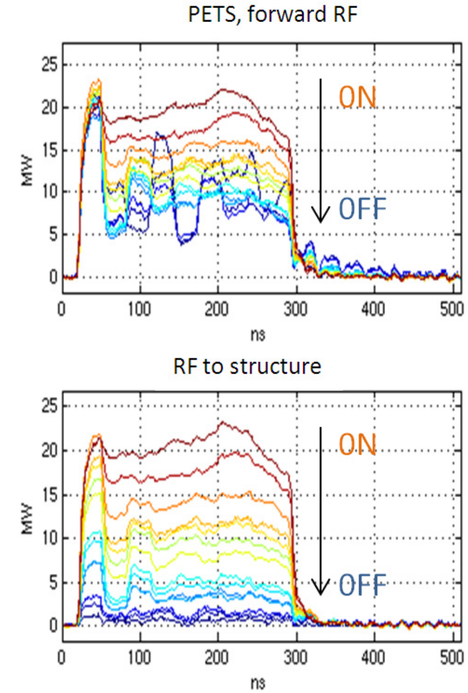

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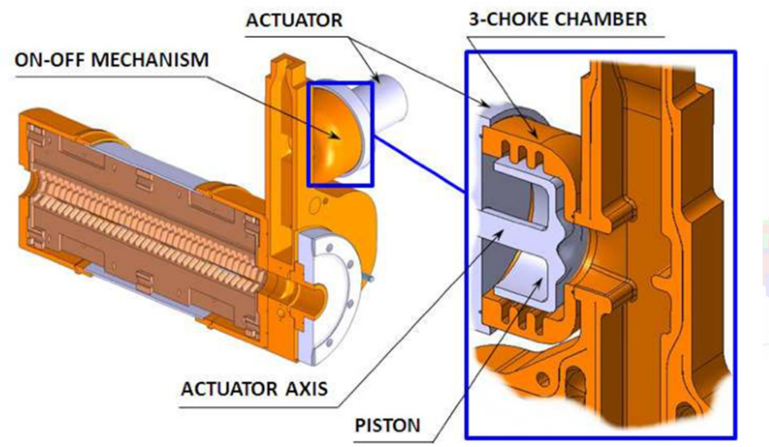

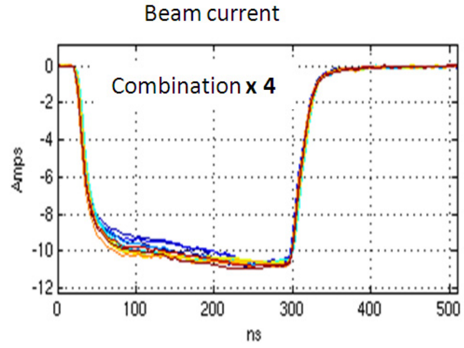

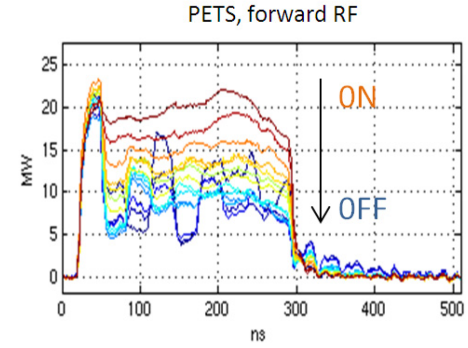

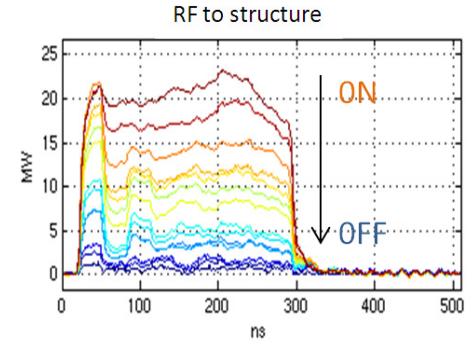

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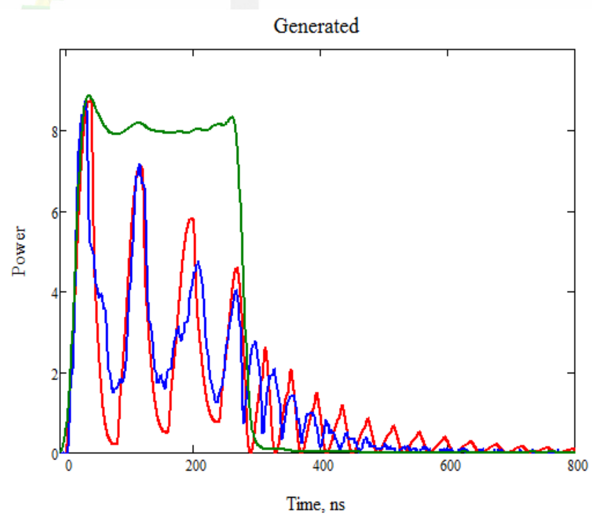

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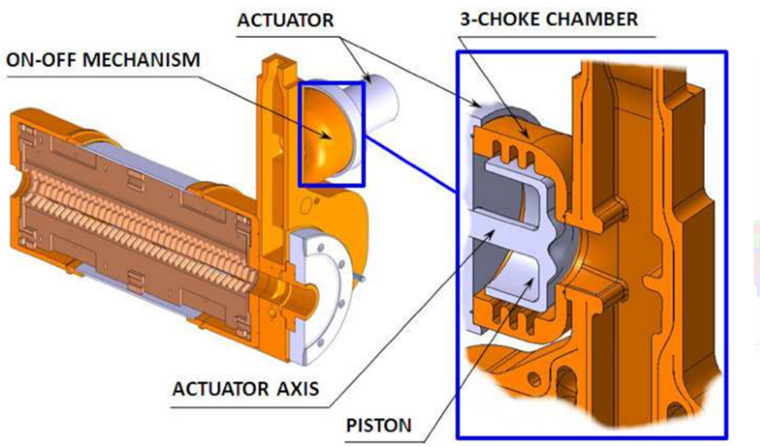

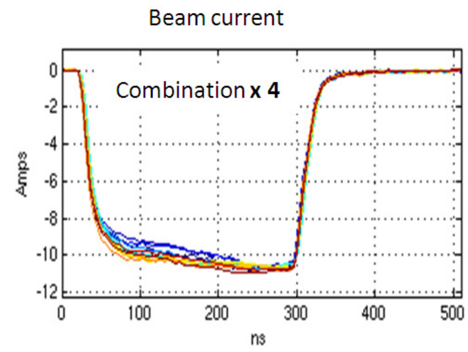

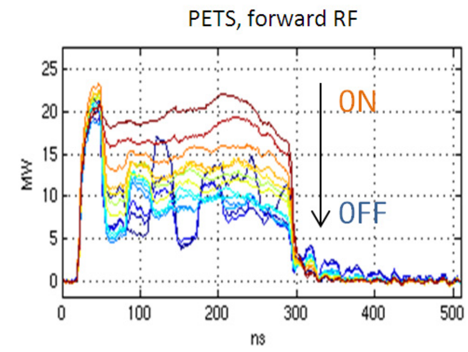

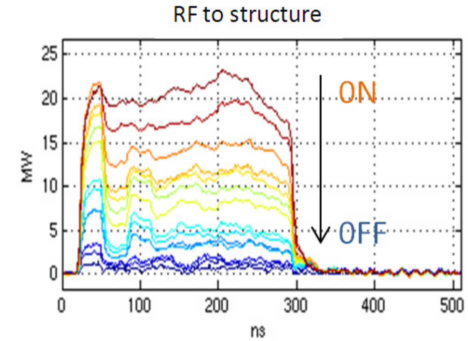

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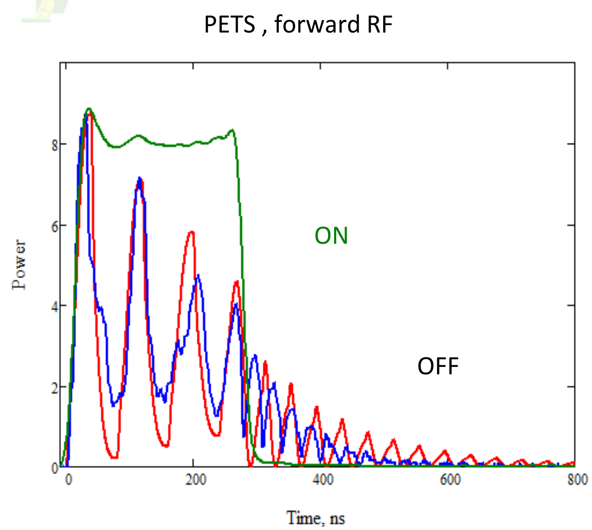
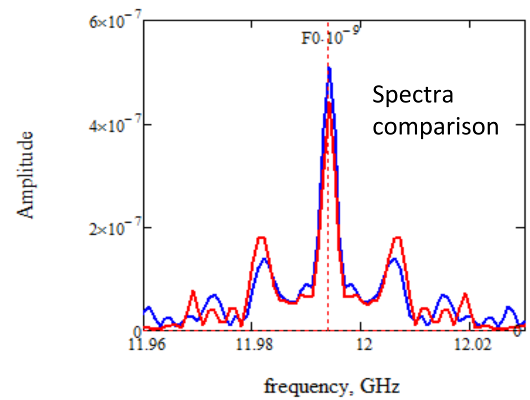
Simulation vs. experiment





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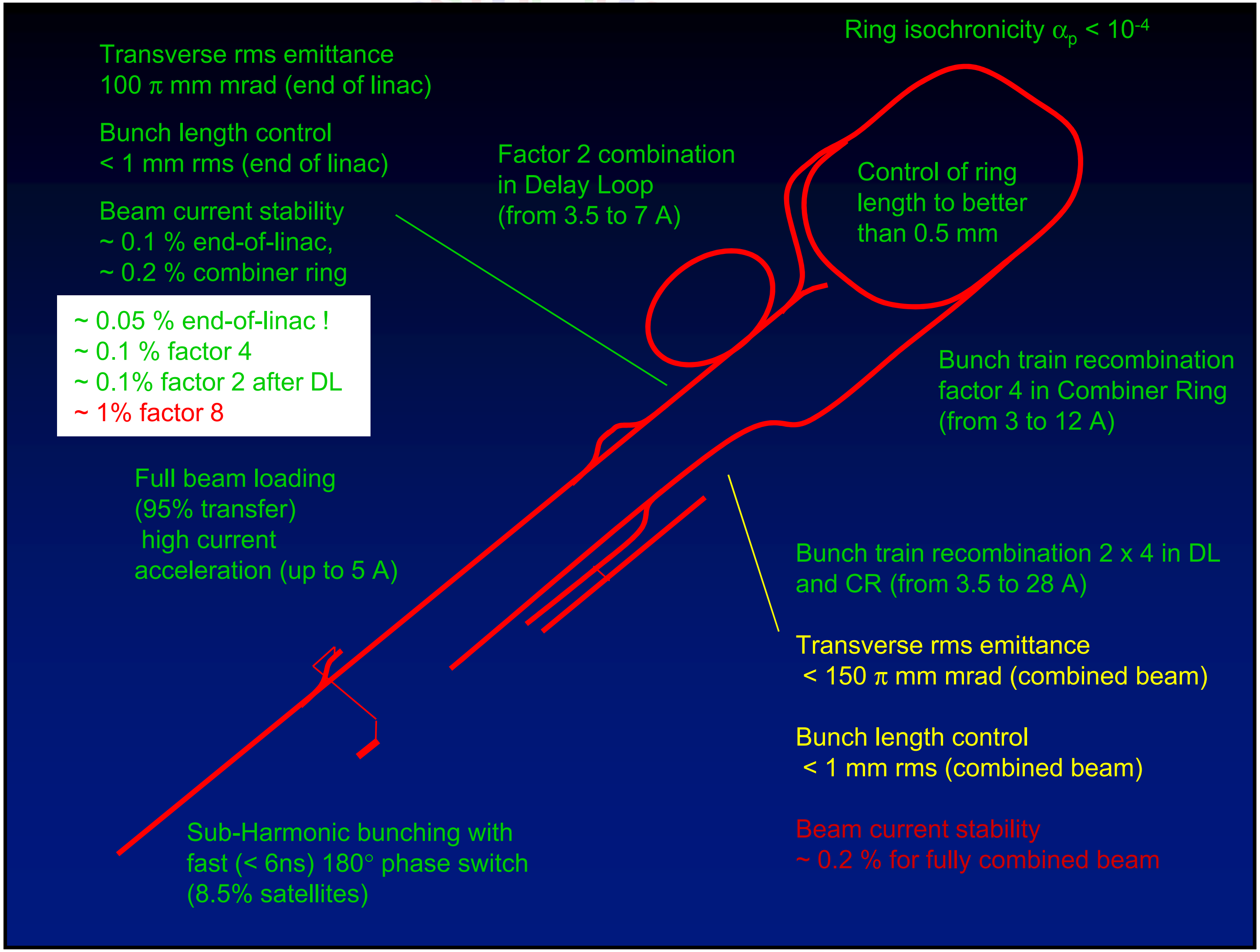
CTF3 Achievements – What is still missing for feasibility studies – Drive Beam Generation



DB generation , 2012:

Improve beam quality for factor 8 beam

(emittance, bunch length, stability)

CTF3 Achievements – Two-Beam issues

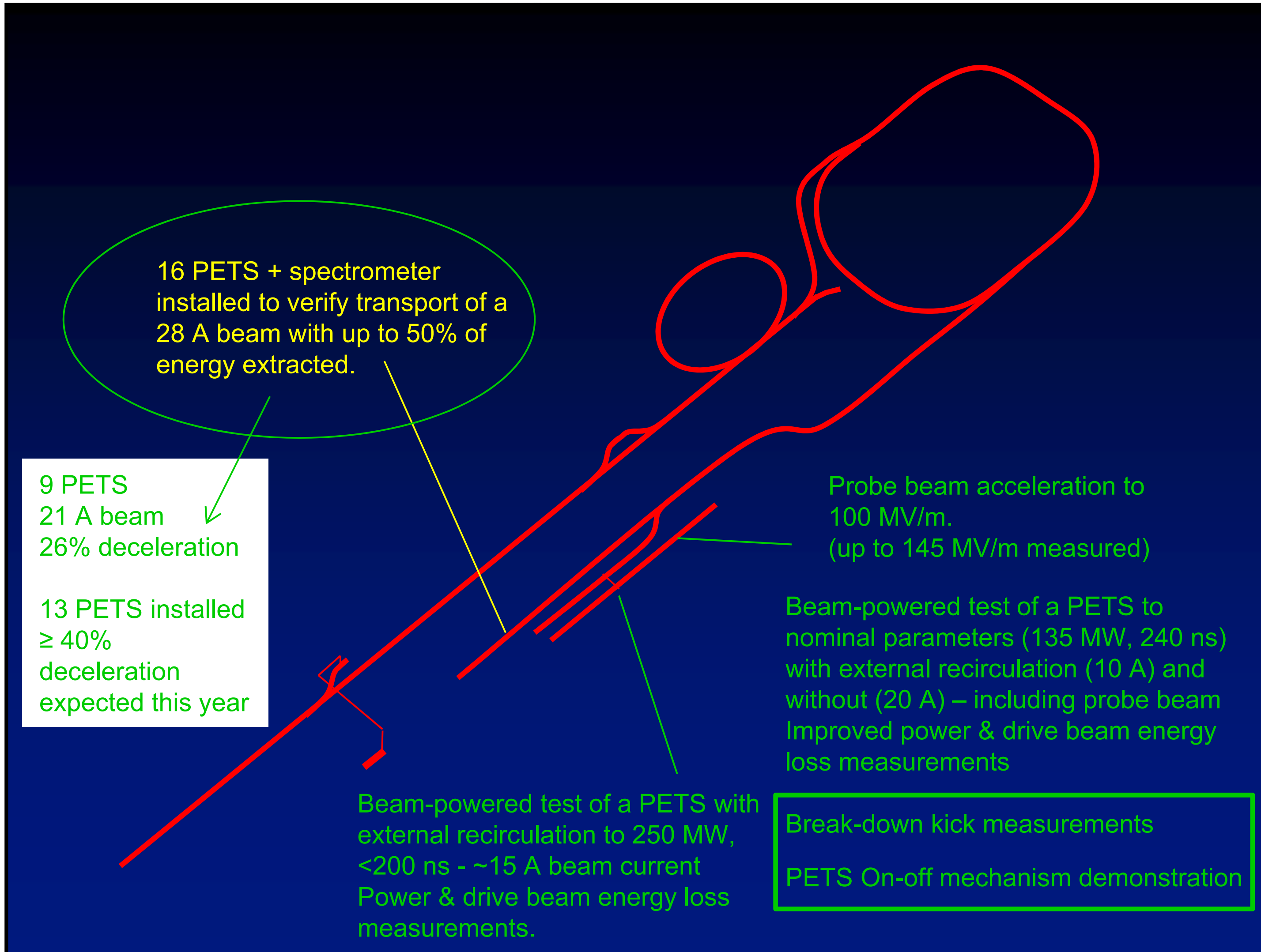
CTF3 Achievements – What is still missing for feasibility studies – CLEX

TBL:

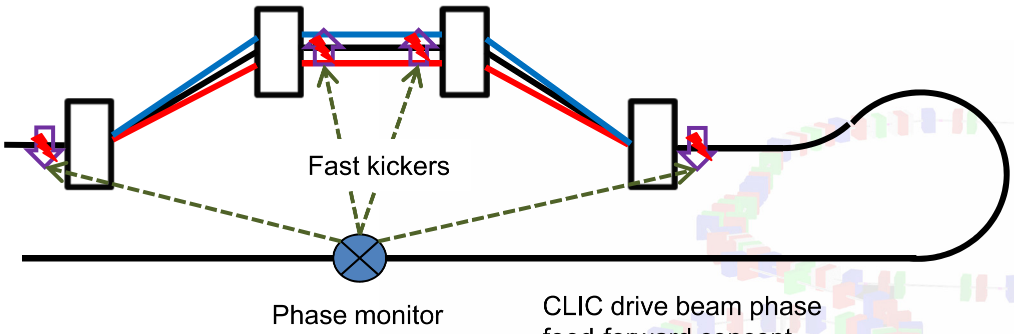
- 13 PETS start 2012
- 14 or more PETS end 2012 ?

TBTS, 2012:

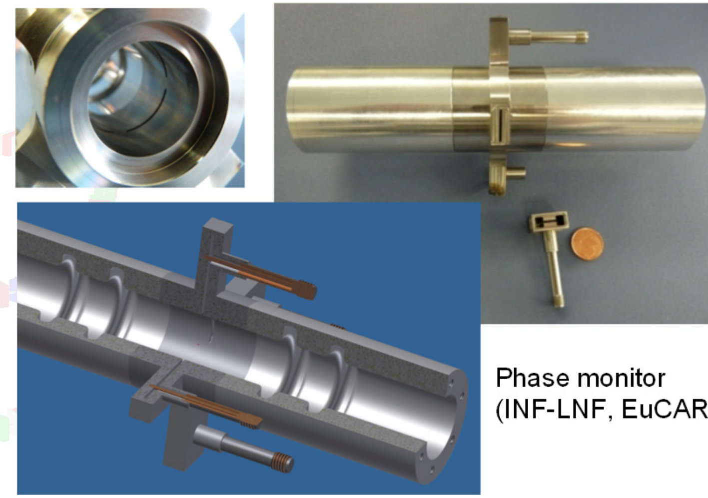
- Continue studies with two new structures
- Wakefield monitors



CTF3 beyond 2012 – Drive Beam feed-forward & feedback



CLIC drive beam phase
feed-forward concept



Phase monitor
(INF-LNF, EuCARD)

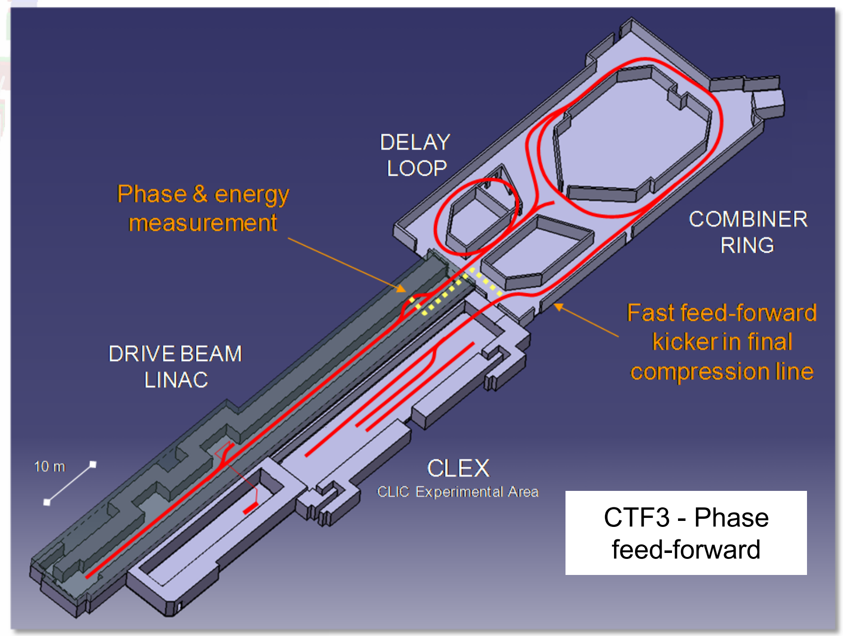
P. Skowronski, P. Burrows, A.Ghigo

Not just a single experiment – series of related studies:

- Measure phase and energy jitter, identify sources, devise & implement cures, extrapolate to CLIC
- Show principle of CLIC fast feed-forward

Close link to collaborating partners:

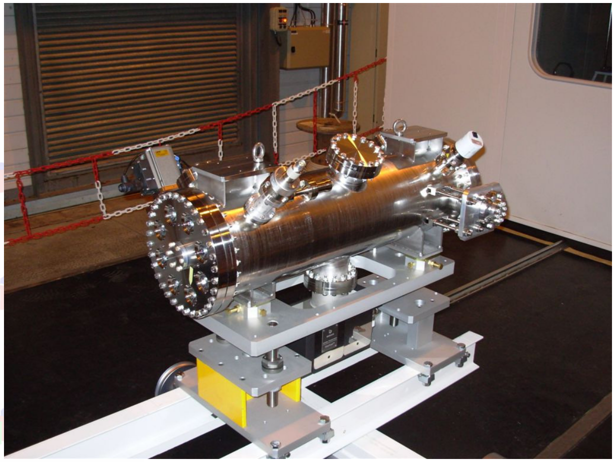
- INFN-LNF: Phase monitors, stripline kickers
- Oxford University/JAI: feedback electronics, amplifiers



A. Gerbershagen, P. Burrows, D. Schulte - WEPPP066

CTF3 beyond 2012 – TBL

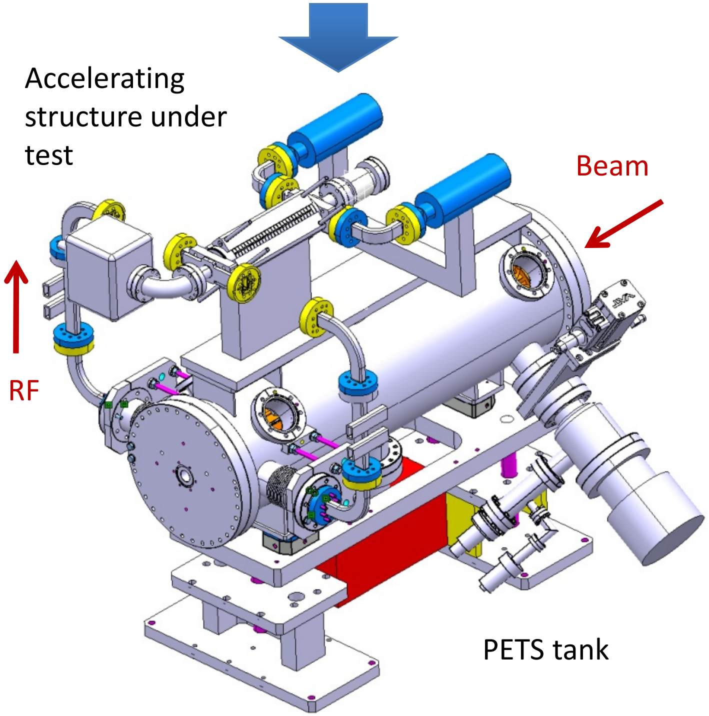
Upgrade TBL to a test facility relevant for future CLIC program

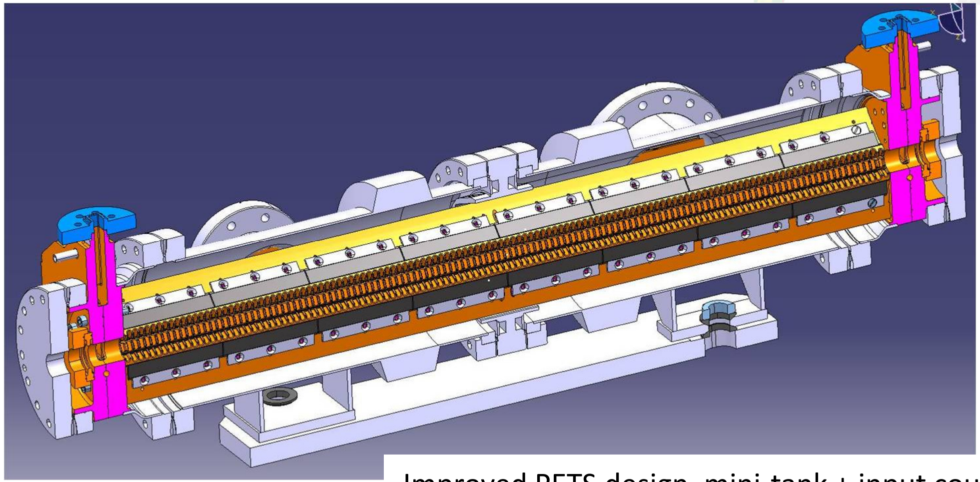


- 12 GHz power production for structure conditioning
    - Working experience with a real decelerator
    - Beam dynamics studies, pulse shaping, feedbacks, etc

Timeline:

- Last batch of PETS will be adapted to high-power testing (using internal recirculation)
- One (or two slots) tested at beginning of 2013
- Gradual increase of slots to 4-8 slots and rep rate to 25-50 Hz



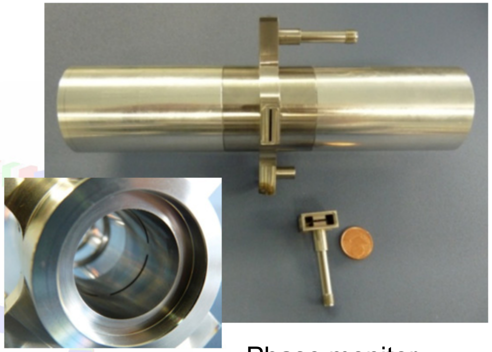


Improved PETS design, mini-tank + input coupler

S. Doebert

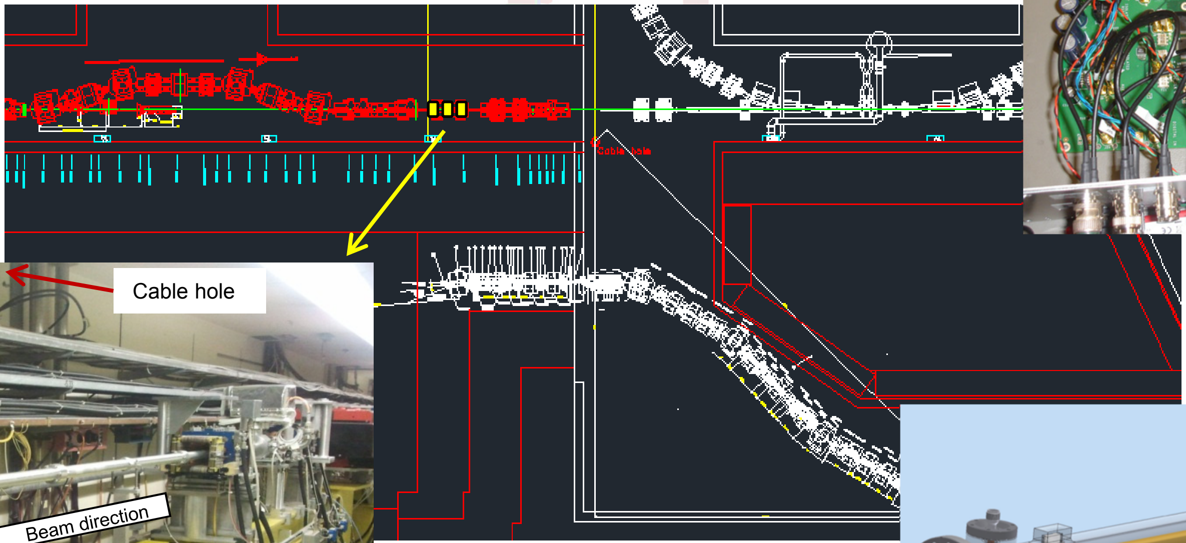
CTF3 beyond 2012 – Drive Beam feed-forward & feedback

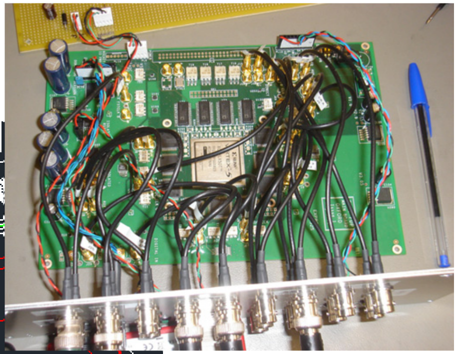
- Phase monitor tests – 3 monitors installed in summer 2012
- First system tests planned in summer 2013



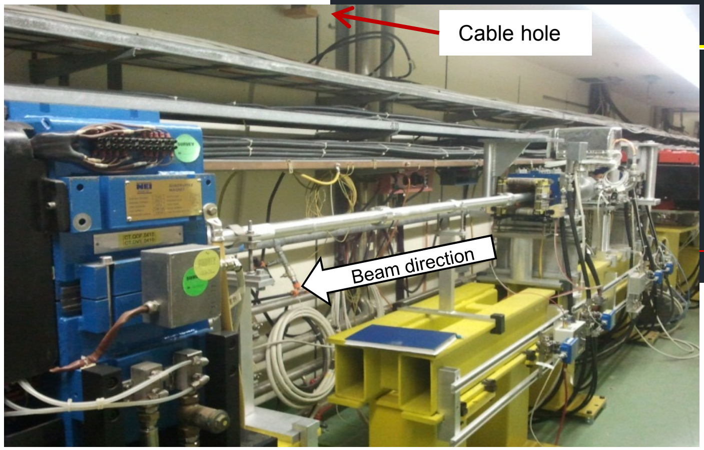
Phase monitor
(INF-LNF, EuCARD)

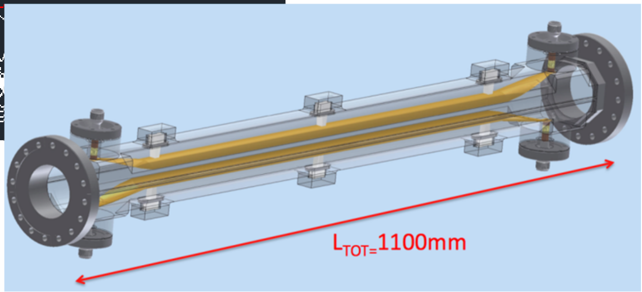
P. Skowronski, P. Burrows, A.Ghigo





FONT5 board
(Oxford)



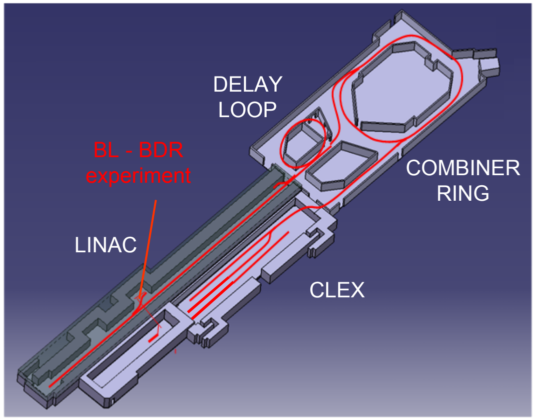


Stripline kicker
(INFN-LNF)

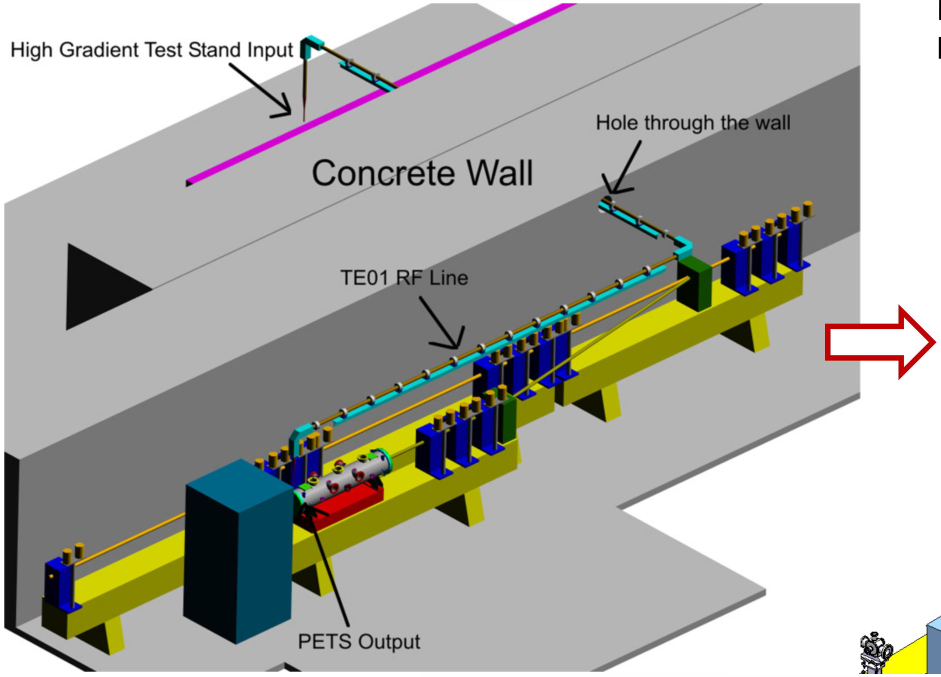
CTF3 beyond 2012 – Beam-Loading experiment

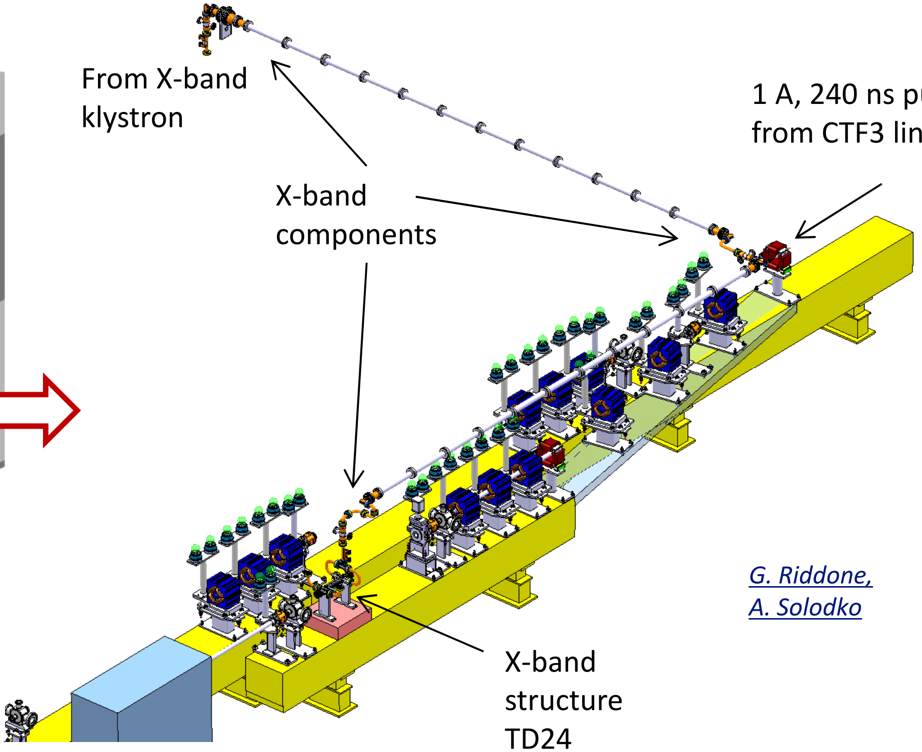
Beam loading reduces field locally in the structure
⇨ is it the break-down rate lower (or higher)?

- CLEX probe beam has only limited current/pulse length, CLEX Drive beam has limited rep rate
  ⇨ use CTF3 drive beam and klystron driven X-band structure
- Reactivate the old '30 GHz PETS' line, lower DB current, can reach 50 Hz
- Measure BDR with/without beam to get a direct comparison



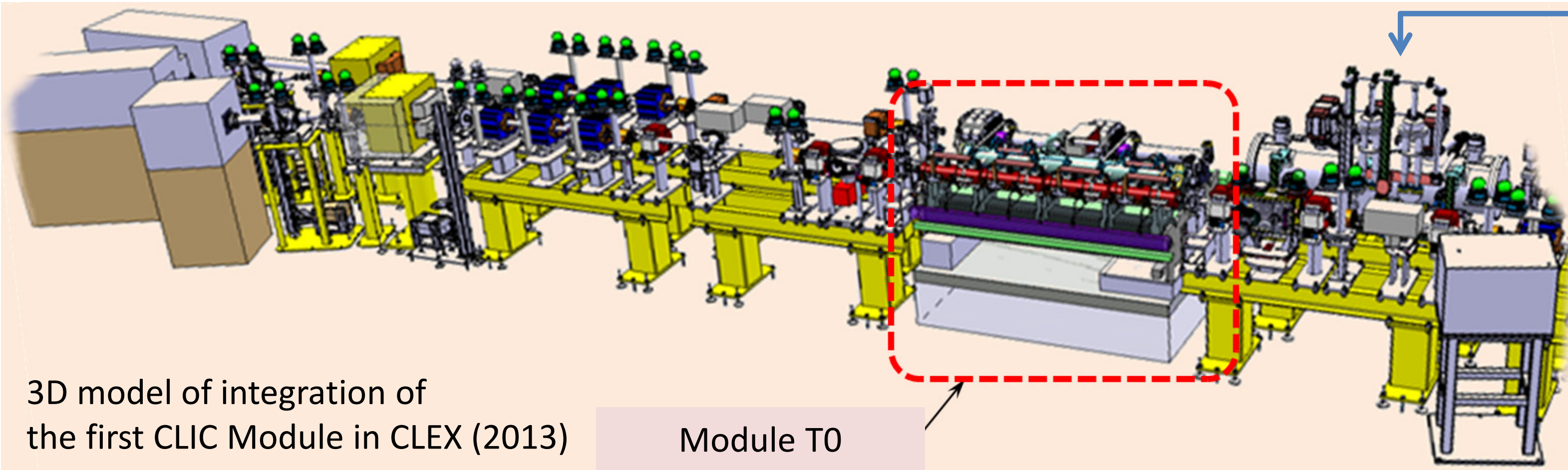
Present schedule: Install in winter shutdown 2012-2013
Run experiment in 2013





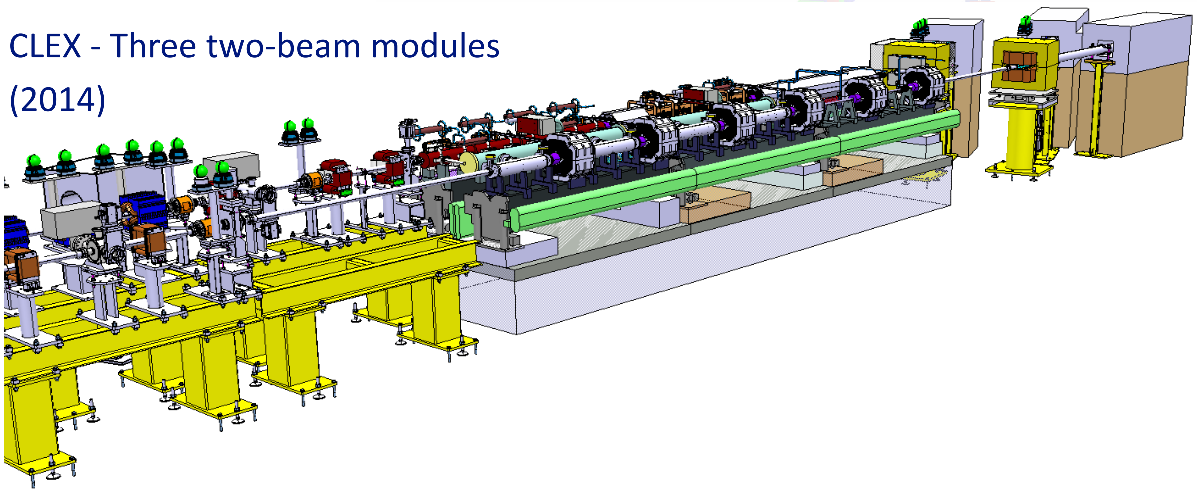
G. Riddone, A. Solodko

CTF3 beyond 2012 – Two Beam Modules in CLEX



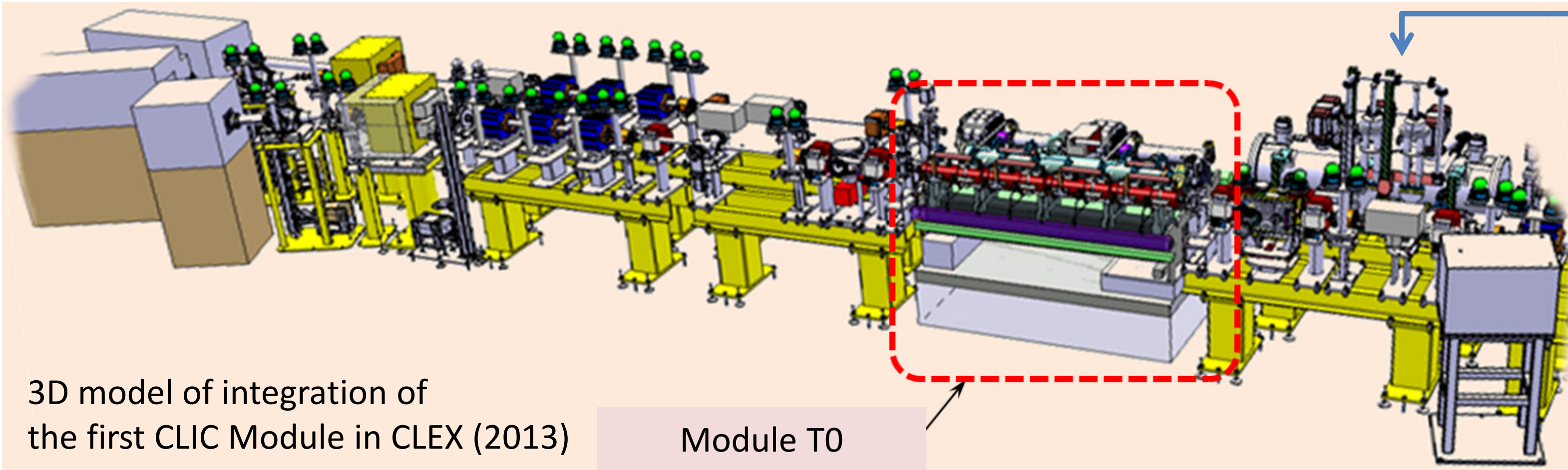
TBTS PETS tank

CLEX - Three two-beam modules (2014)

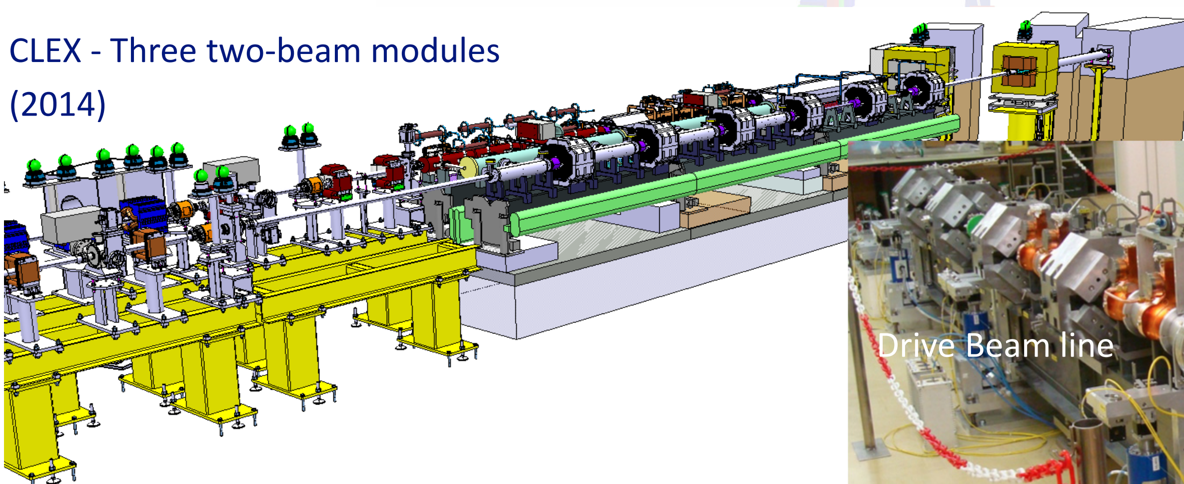


G. Riddone

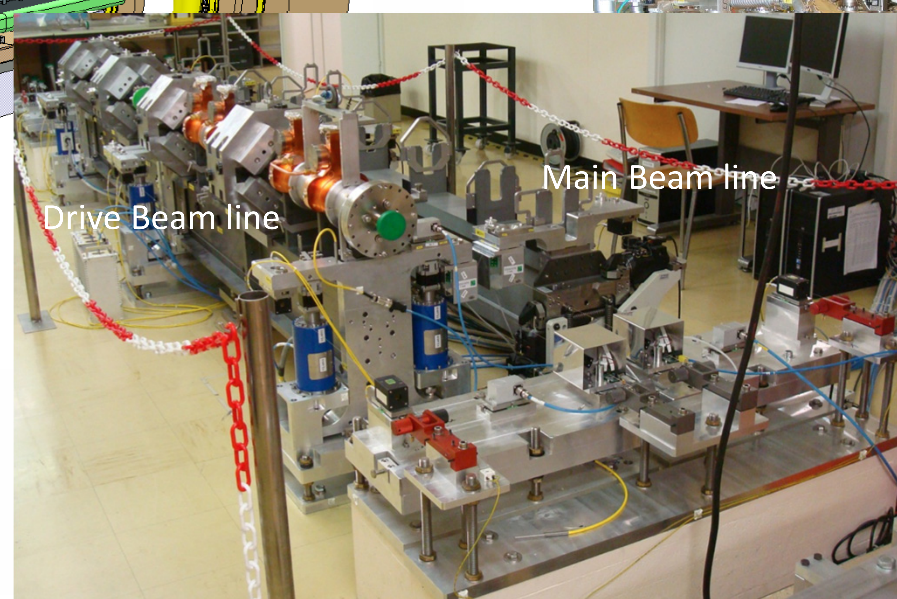
CTF3 beyond 2012 – Two Beam Modules in CLEX



CLEX - Three two-beam modules (2014)

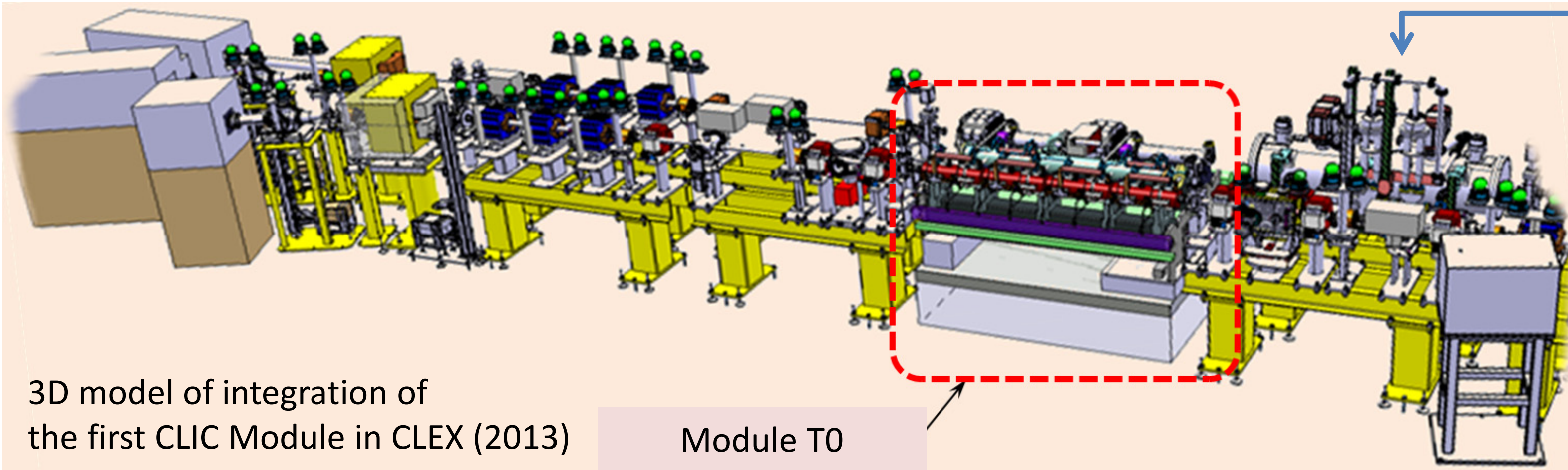


TBTS PETS tank



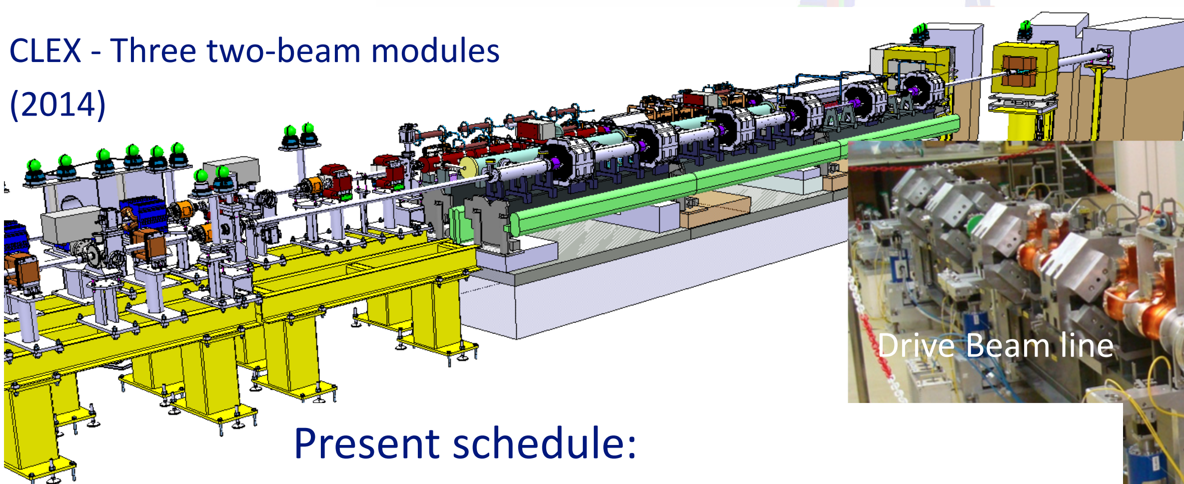
G. Riddone

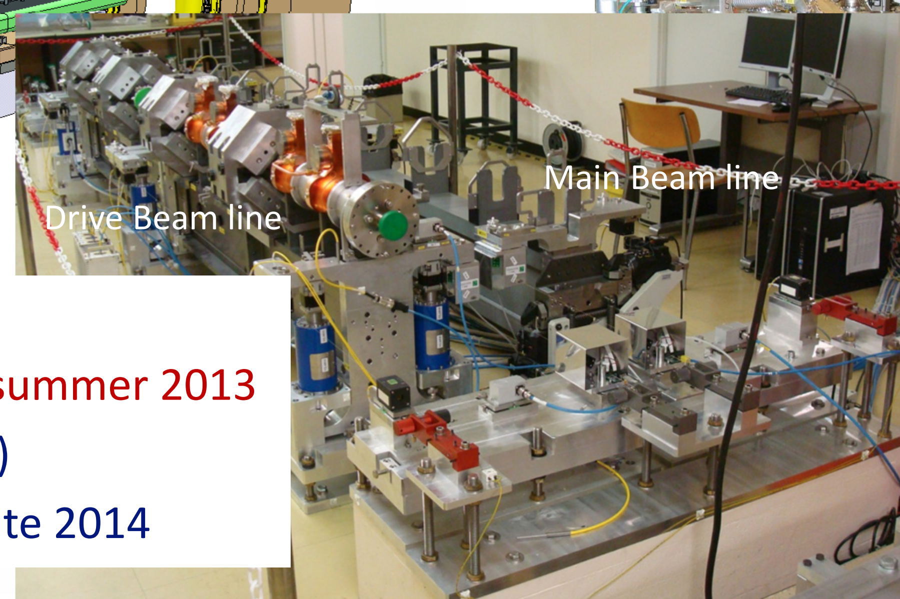
CTF3 beyond 2012 – Two Beam Modules in CLEX



TBTS PETS tank

CLEX - Three two-beam modules (2014)





Present schedule:

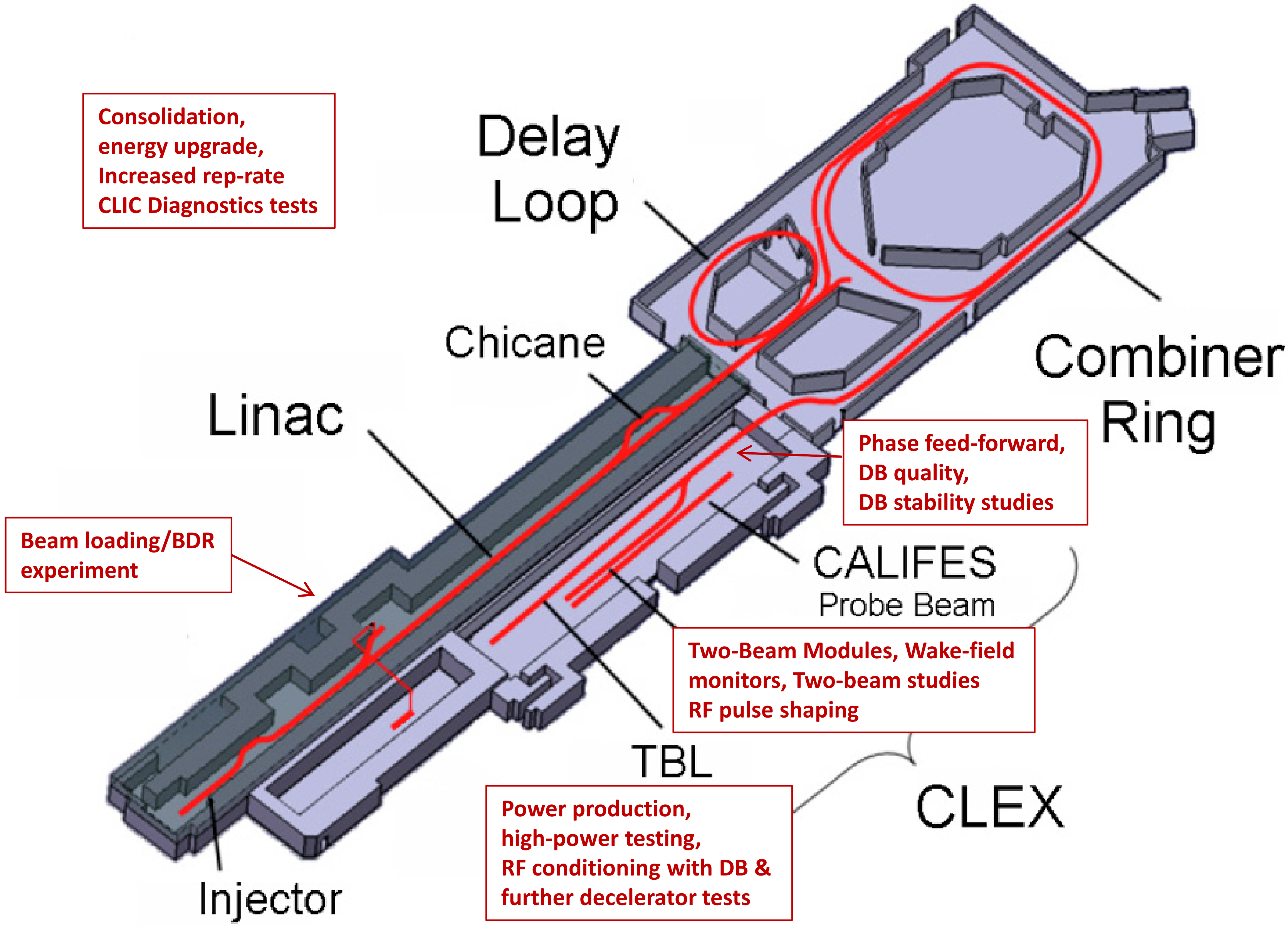
First module installation in summer 2013

(At least one year of testing)

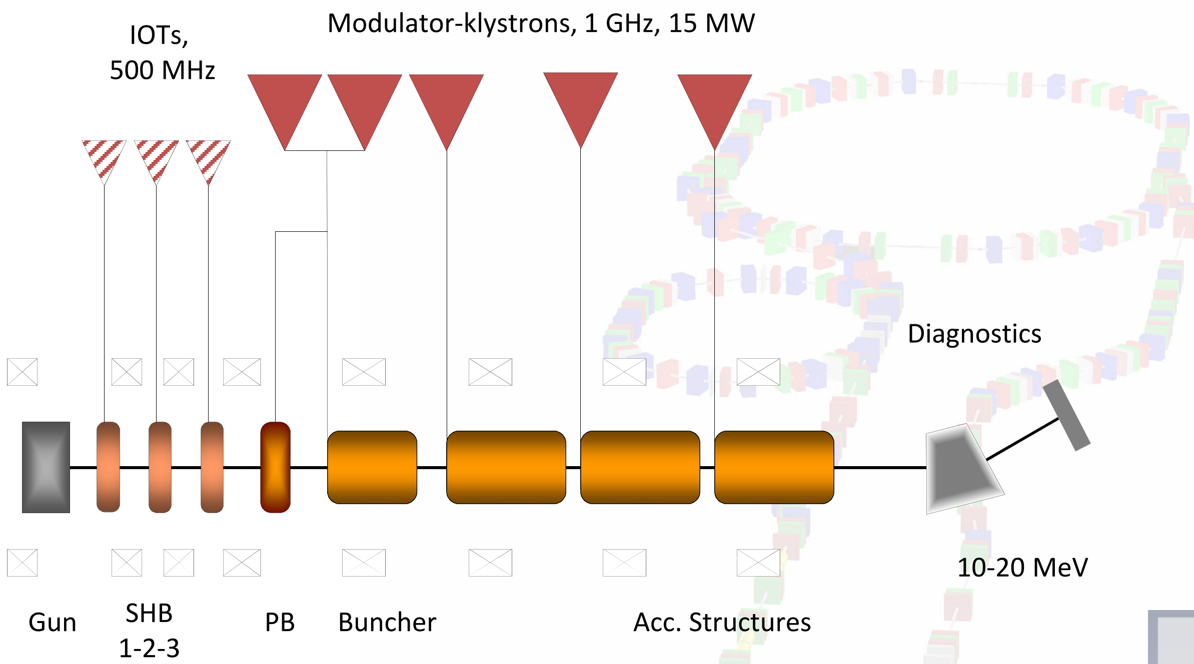
Module string installation late 2014

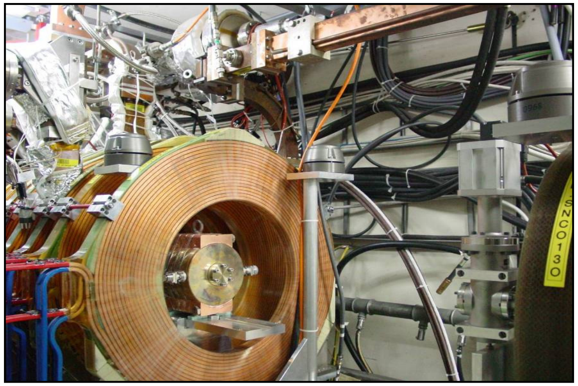
G. Riddone

CTF3 program in 2012-2017

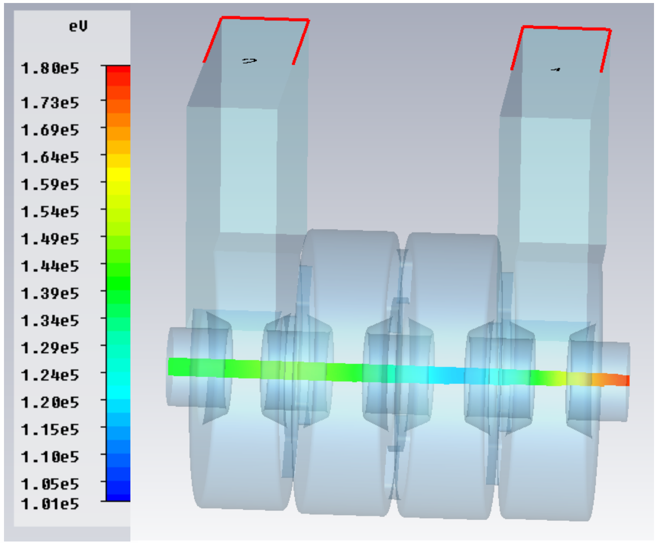


New facility – Drive Beam Front-End (2012-2016)




CTF3 Injector

Sub-Harmonic Buncher RF design



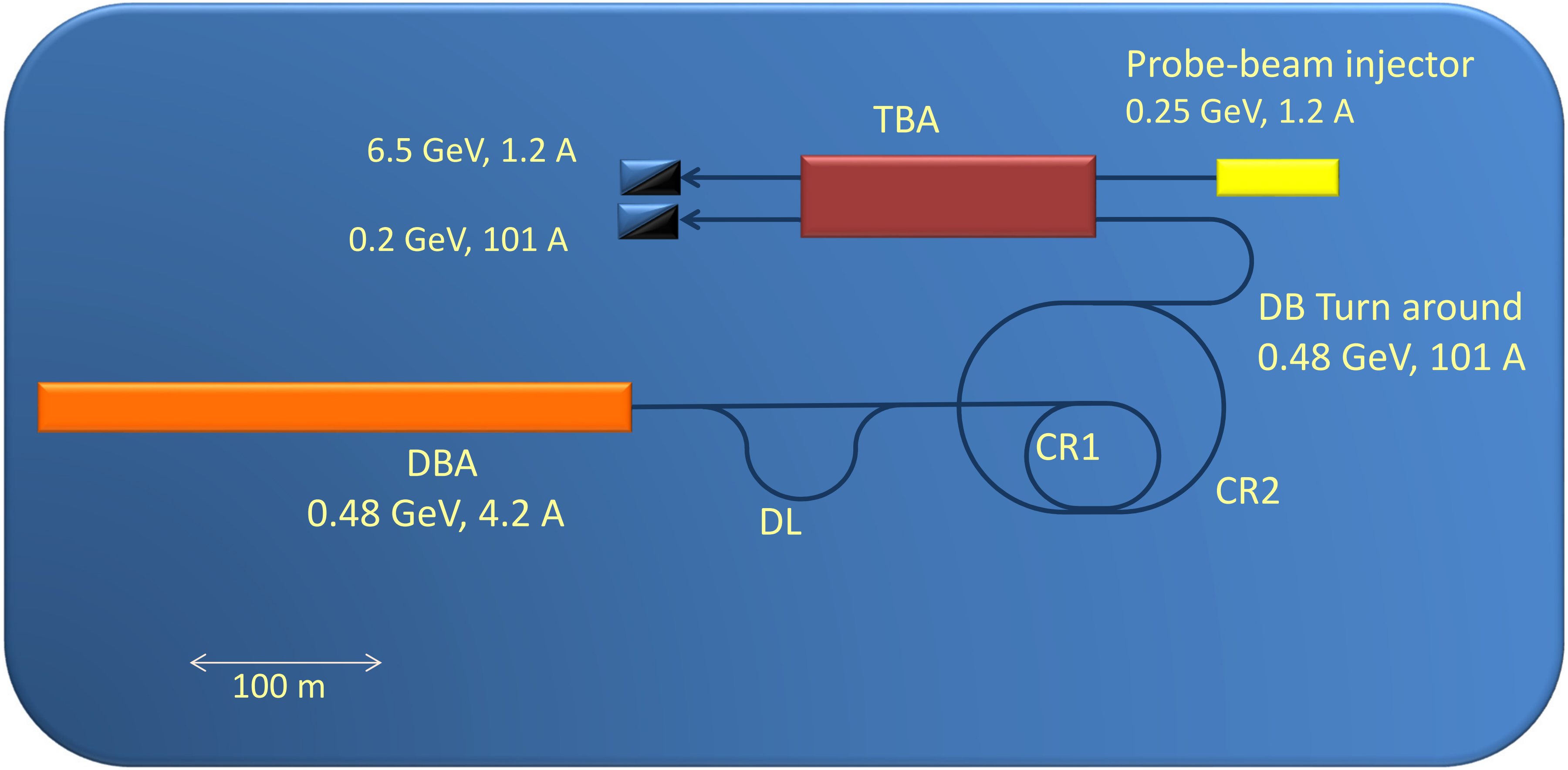
H. Shaker

Build and commission Drive Beam front-end with nominal CLIC parameters

- Essential R&D to assess drive beam injector (critical for performance)
- Develop RF unit for the drive beam linac (critical for cost/efficiency)
- Preparation for full CLIC Zero facility

CLIC Zero

CLIC Zero (almost) full-scale DB Generation Complex	• Beam driven processing/qualifying facility for X-band structures/modules • Significant size series production of cost and performance critical hardware – drives industrialization needed for CLIC • Demonstrate nominal drive beam generation (full combination, full pulse length) & two-beam acceleration/deceleration over a significant distance • Most hardware re-usable for CLIC • Other possible uses (outside the CLIC scope) presently being investigated S. Stapnes -WEYA01



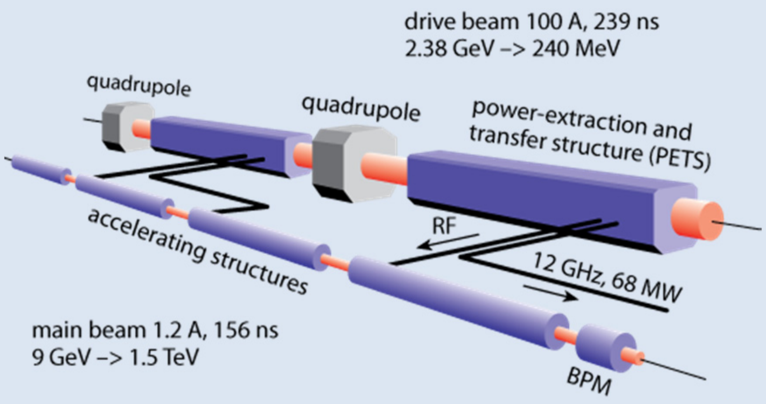
CONCLUSIONS

Feasibility of the CLIC Two-Beam scheme has been established in the CLIC Test Facility CTF3

- Original experimental program basically completed
- Drive Beam generation demonstrated – emittance and stability to be further improved this year
- Nominal parameters for RF production & two-beam acceleration reached and exceeded – 150 MV/m gradient measured with beam
- Deceleration by 26% of a 21 A beam of the drive beam with no losses, expect > 40% this year

CTF3 experimental program for the next five years established and under way

- Drive beam phase feed-forward experiment
- Beam loading / breakdown experiment
- High-power testing of structures in TBL
- Full fledged two-beam modules tested with beam in CLEX



First steps towards the next stage in the study

- Drive beam front-end facility (2012-2016)
- Preparation of CLIC Zero

CLIC multi-lateral collaboration - 44 Institutes from 22 countries

ACAS (Australia)
Aarhus University (Denmark)
Ankara University (Turkey)
Argonne National Laboratory (USA)
Athens University (Greece)
BINP (Russia)
CERN
CIEMAT (Spain)
Cockcroft Institute (UK)
ETH Zurich (Switzerland)
FNAL (USA)

Gazi Universities (Turkey)
Helsinki Institute of Physics (Finland)
IAP (Russia)
IAP NASU (Ukraine)
IHEP (China)
INFN / LNF (Italy)
Instituto de Fisica Corpuscular (Spain)
IRFU / Saclay (France)
Jefferson Lab (USA)
John Adams Institute/Oxford (UK)
Joint Institute for Power and Nuclear Research SOSNY /Minsk (Belarus)

John Adams Institute/RHUL (UK)
JINR (Russia)
Karlsruhe University (Germany)
KEK (Japan)
LAL / Orsay (France)
LAPP / ESIA (France)
NIKHEF/Amsterdam (Netherland)
NCP (Pakistan)
North-West. Univ. Illinois (USA)
Patras University (Greece)
Polytech. Univ. of Catalonia (Spain)

PSI (Switzerland)
RAL (UK)
RRCAT / Indore (India)
SLAC (USA)
Sincrotrone Trieste/ELETTRA (Italy)
Thrace University (Greece)
Tsinghua University (China)
University of Oslo (Norway)
University of Vigo (Spain)
Uppsala University (Sweden)
UCSC SCIPP (USA)