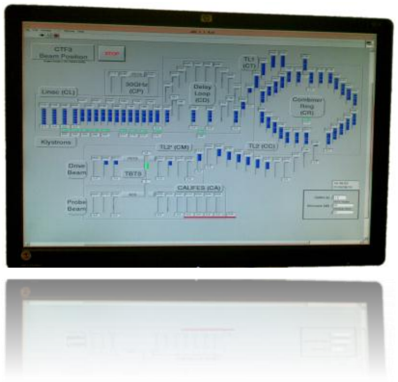


CTF3 Results

R. Corsini for the CTF3 Team & the CLIC Collaboration

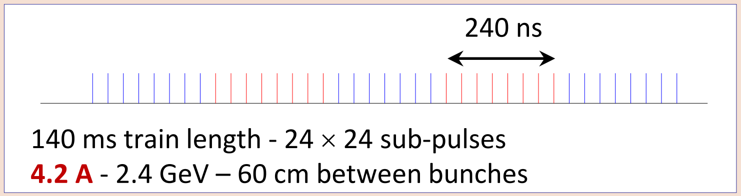
OUTLINE:

- Short introduction to CTF3
- Feasibility studies
  - Drive beam generation
  - Deceleration and RF power production
  - Two-Beam acceleration

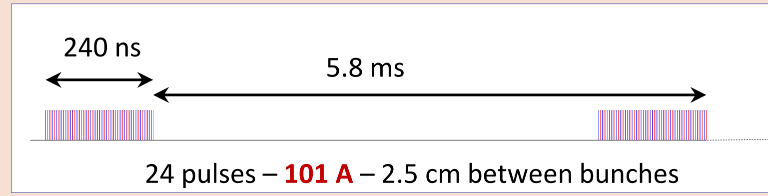
    ➔ (Conceptual Design Report)
- Timelines and program for the coming years
- Conclusions

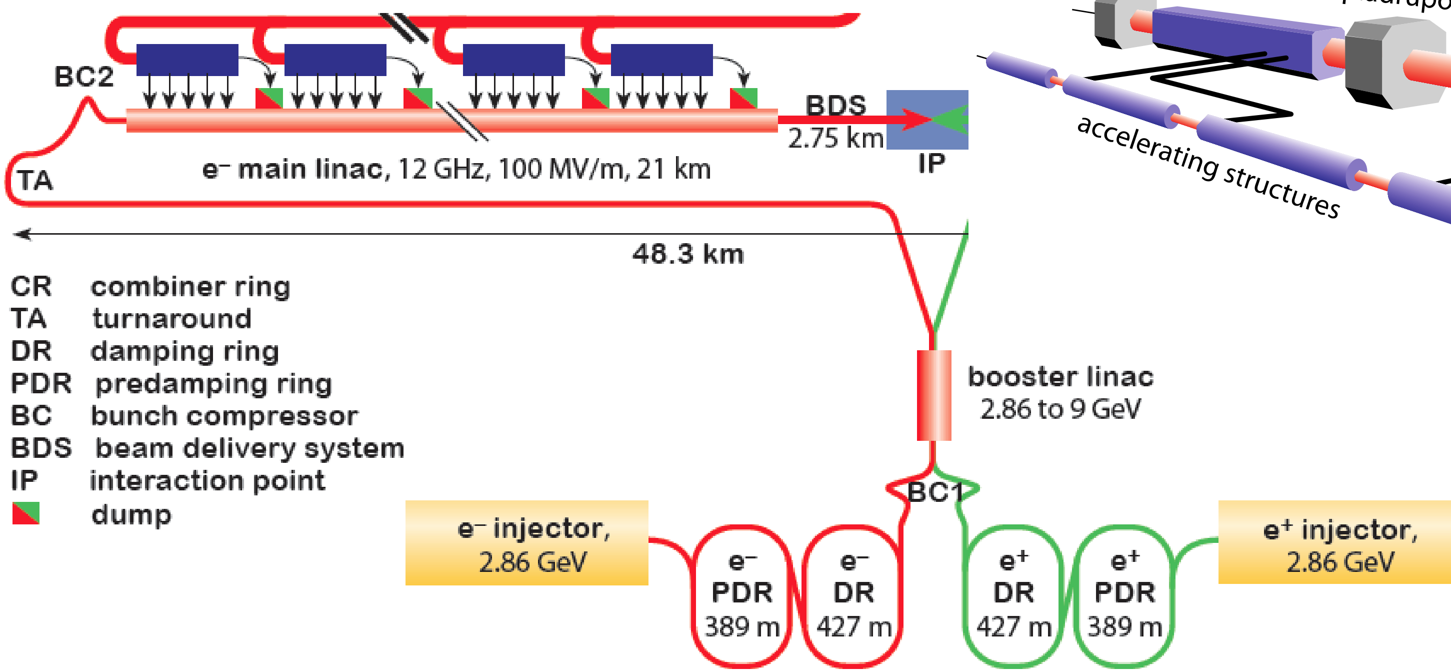
CLIC Layout at 3 TeV

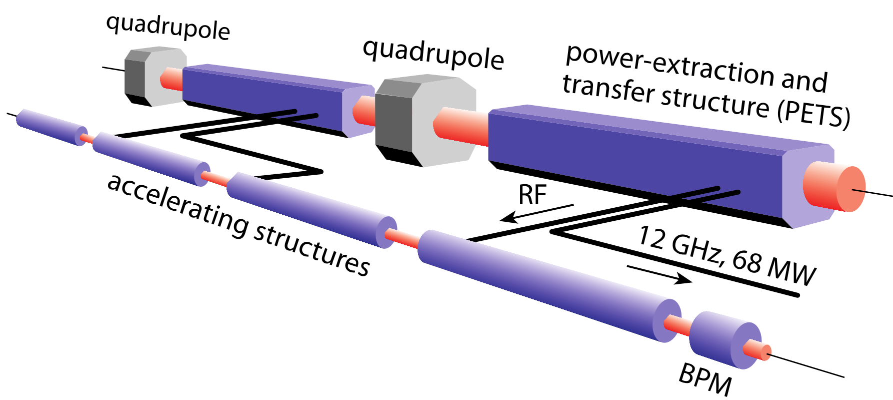
Drive beam time structure - initial



Drive beam time structure - final



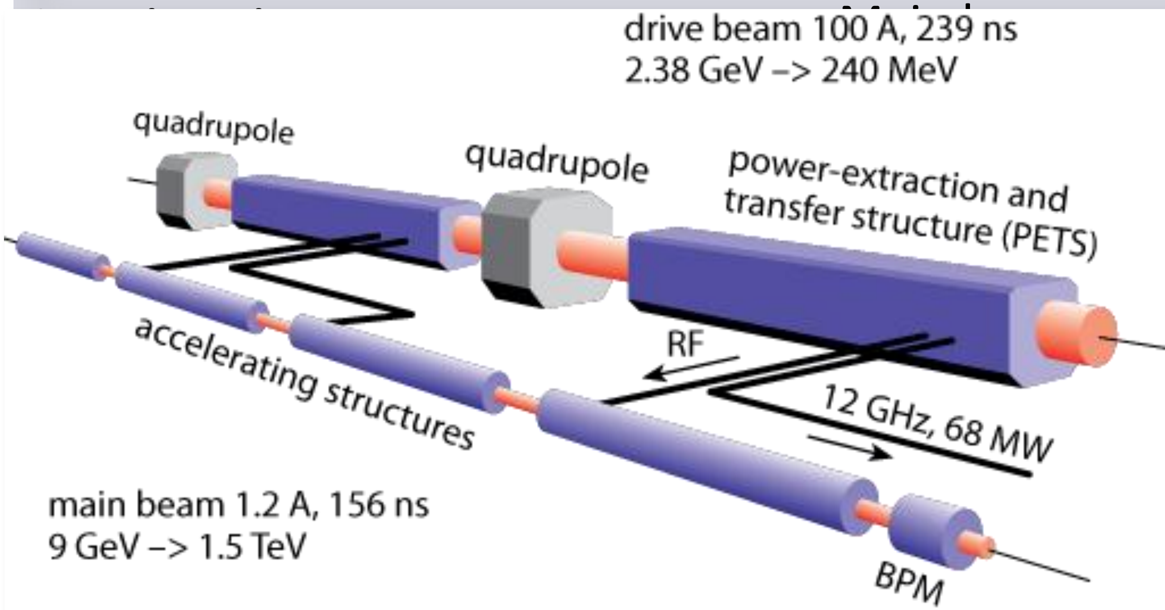




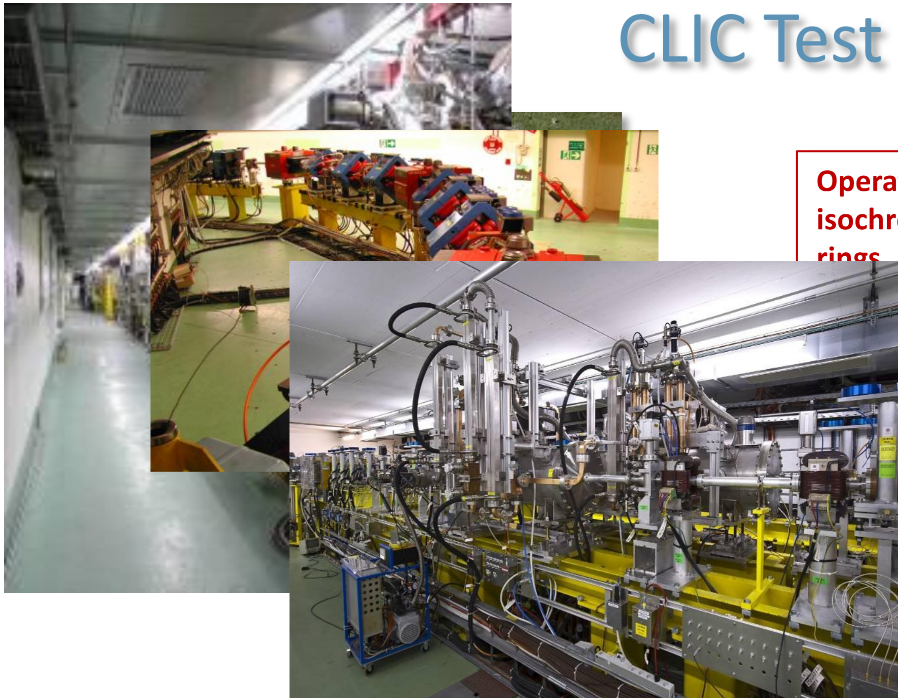
Main Beam Generation Complex

CLIC Feasibility Benchmarks

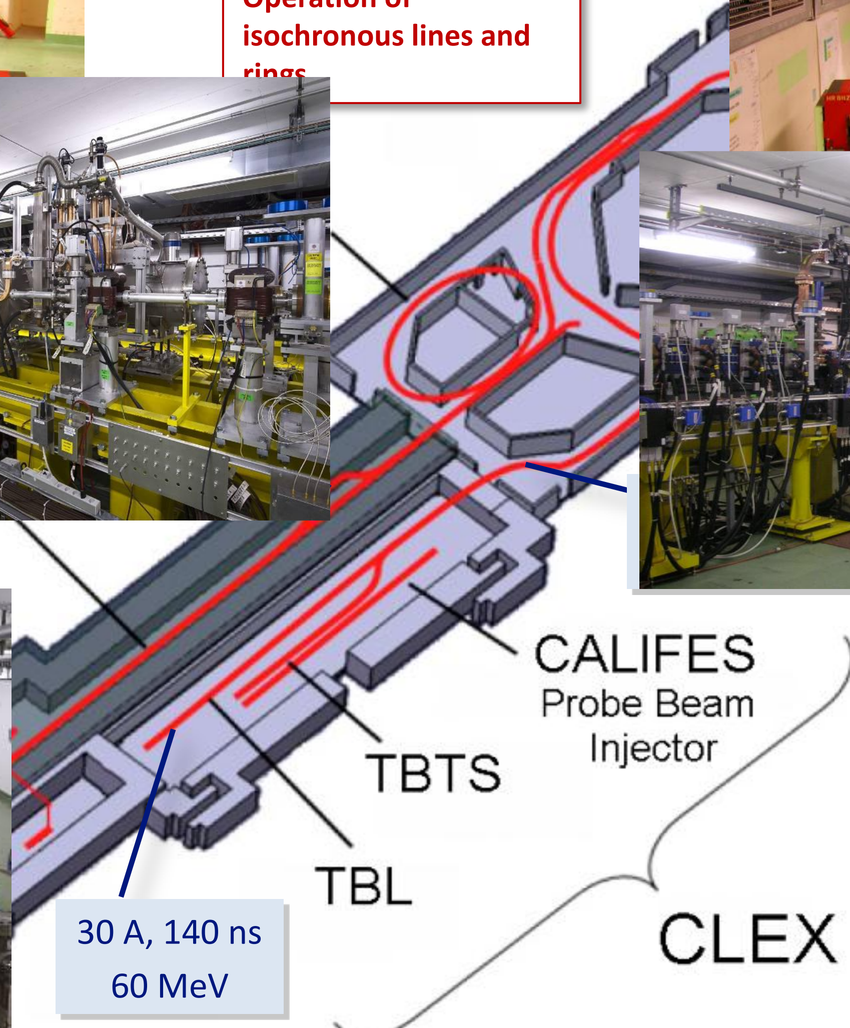
Main linac gradient	–	Accelerating structure	(CTF3)
Drive beam scheme CTF3	–	Drive beam generation	
	–	PETS (power extraction and transfer structures)	
	–	Two beam acceleration	
	–	Drive beam deceleration	
		ittance generation, d focusing stabilisation	(CTF3)
		robustness)	(CTF3)



CLIC Test Facility (CTF3)



Operation of isochronous lines and rings



High current, full

and current multiplication by RF deflectors

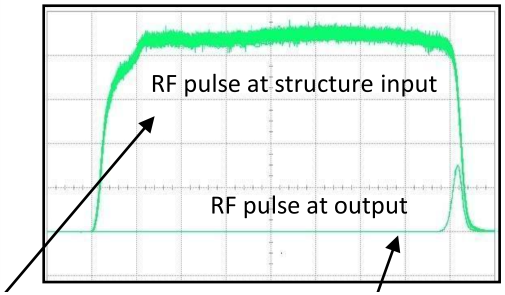
30 A, 140 ns
60 MeV

12 GHz power generation by drive beam deceleration

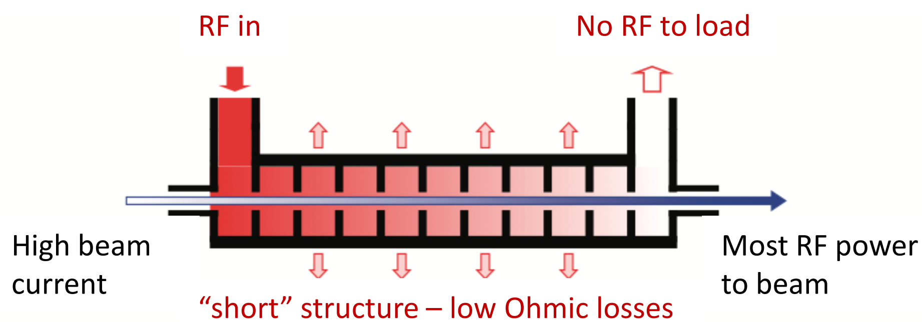
High-gradient two-beam acceleration

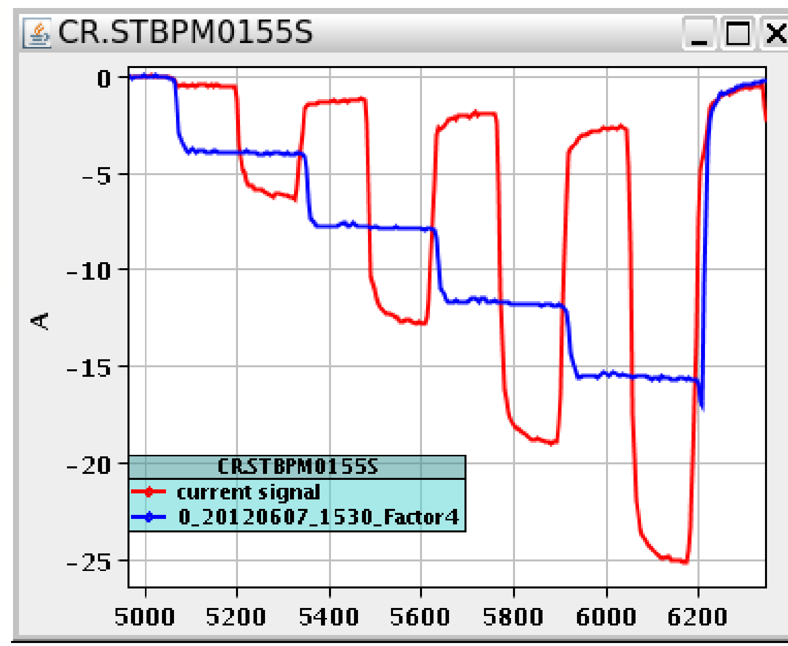
Drive Beam Generation

Full beam loading acceleration

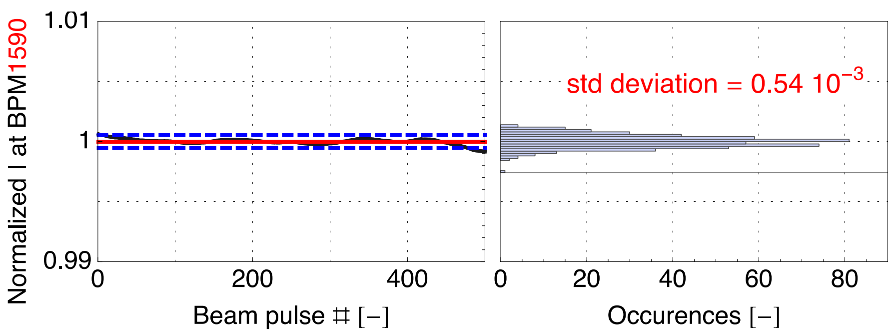


- 95.3% RF to beam efficiency
- Stable high current acceleration
- Current stability
- Isochronicity, phase coding
- Factor 8 current & frequency multiplication





Pulse charge measurement

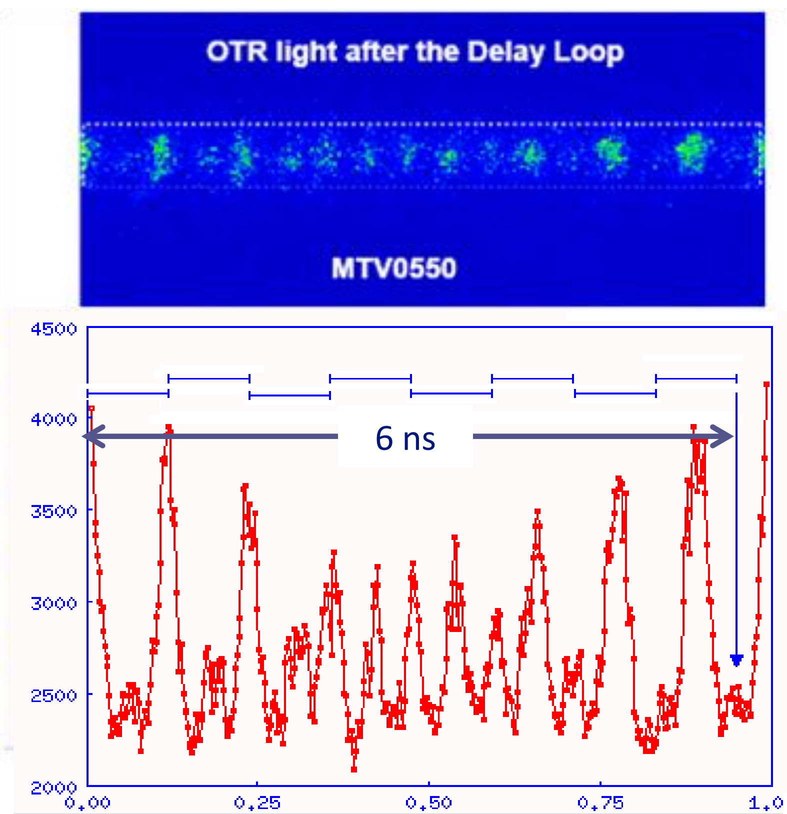


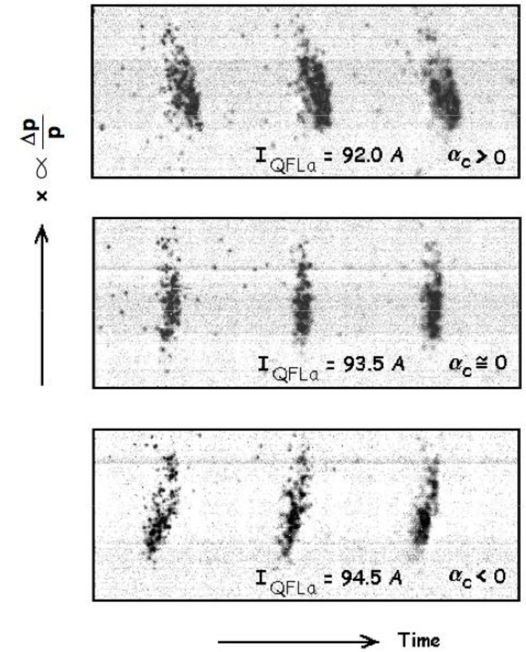
Factor 8 combination

Drive Beam Generation

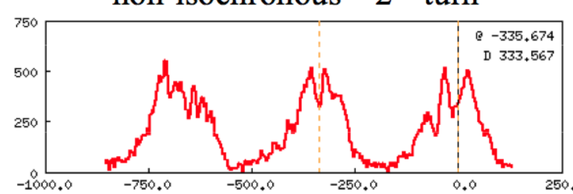
Beam recombination

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

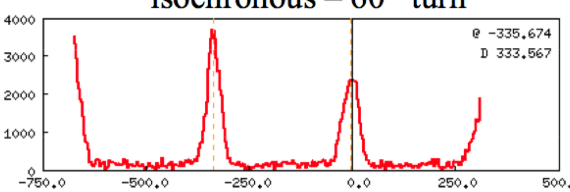




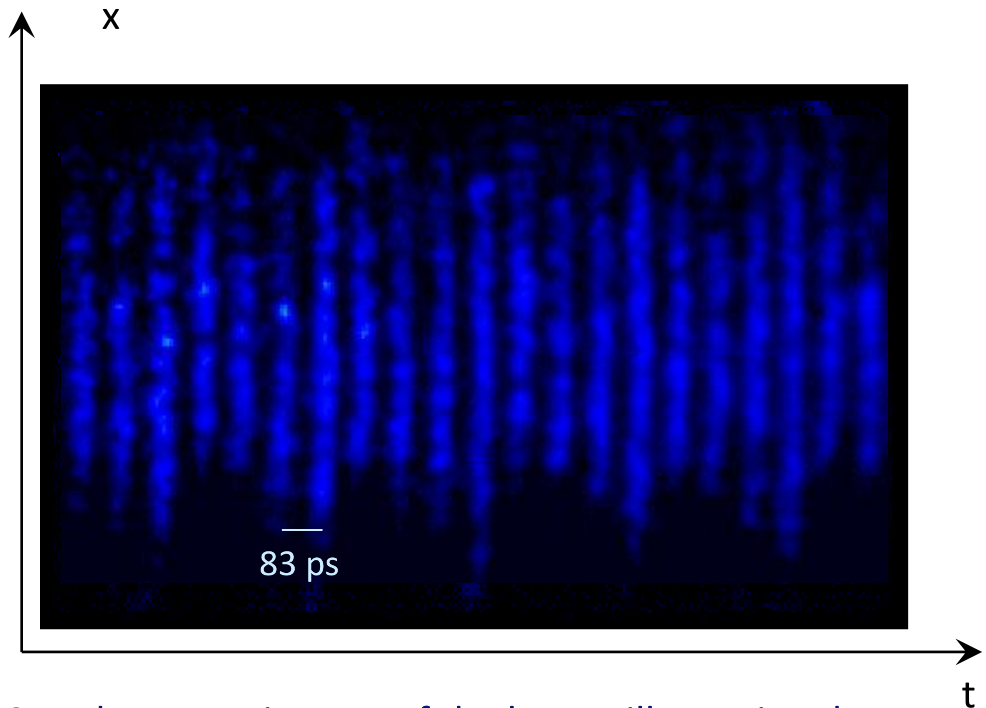
non-isochronous – 2nd turn



isochronous – 60th turn



Drive Beam Generation

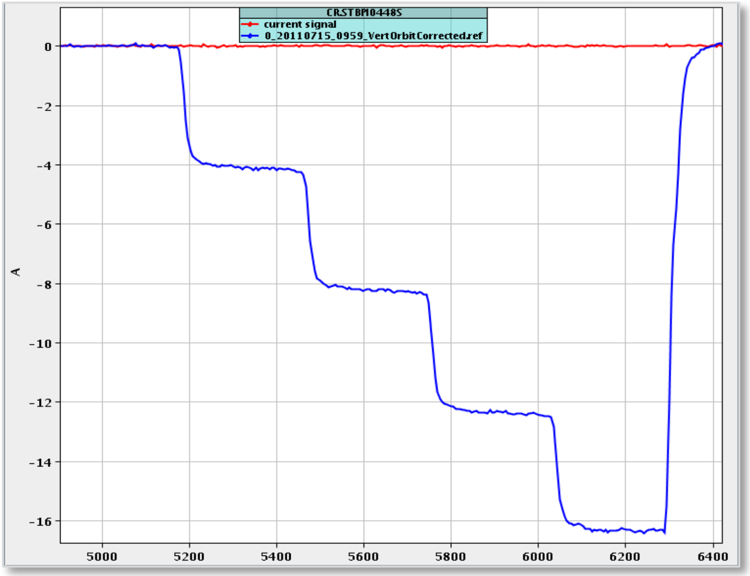


Streak camera images of the beam, illustrating the bunch combination process in the ring

Drive Beam Generation

Beam recombination

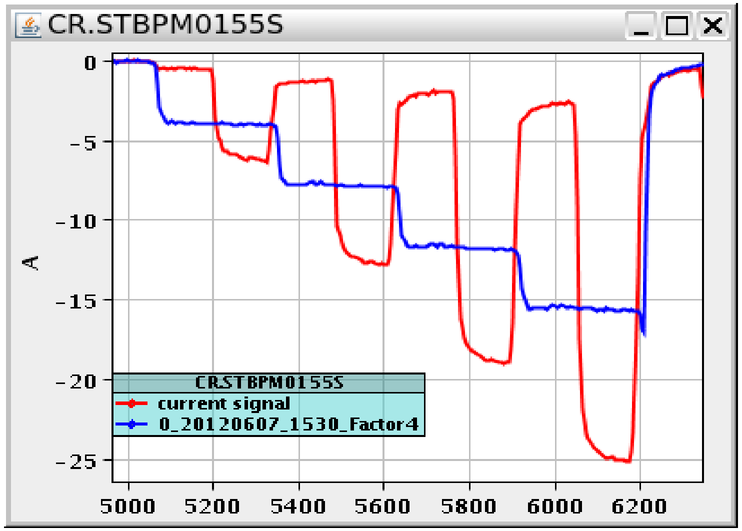
- Factor 4 - OK
- Factor 8
  - basic principle demonstrated
  - Still need some improvement (stability, emittance)



Beam recombination - Emittance

Best results in CLEX
for factor 4: ε_H= 250 um ε_V= 140 um
for factor 8: ε_H= 550 um ε_V= 170 um

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

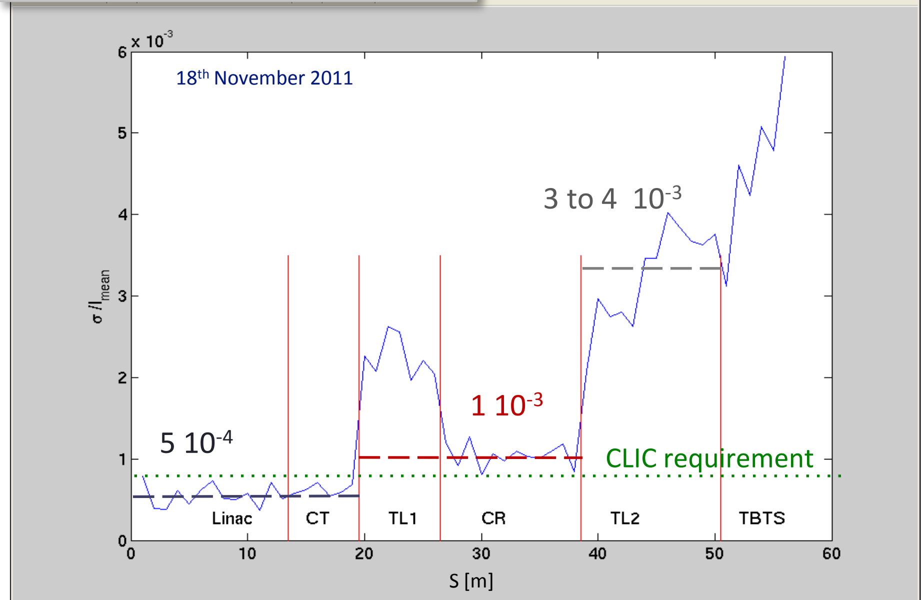


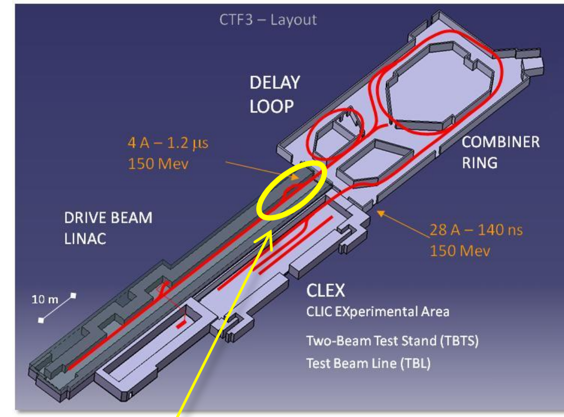
Drive Beam Stability

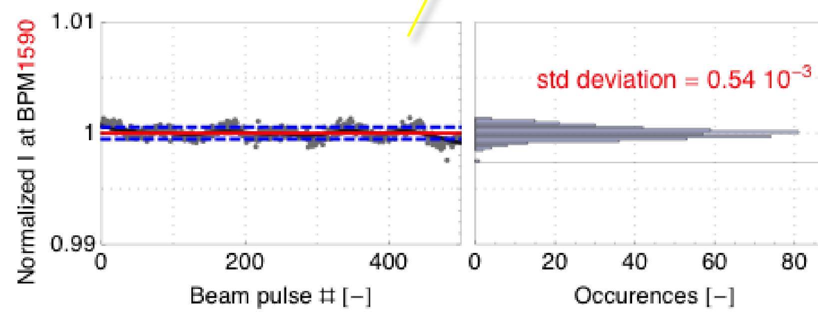
Repeatability and long term current stability improved

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

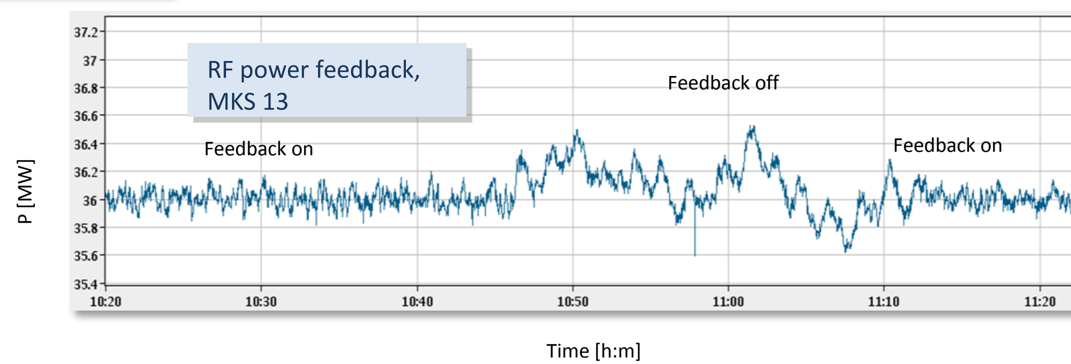
Charge stability – Factor 4



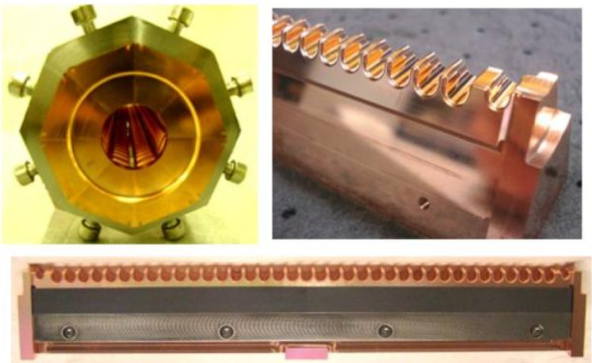




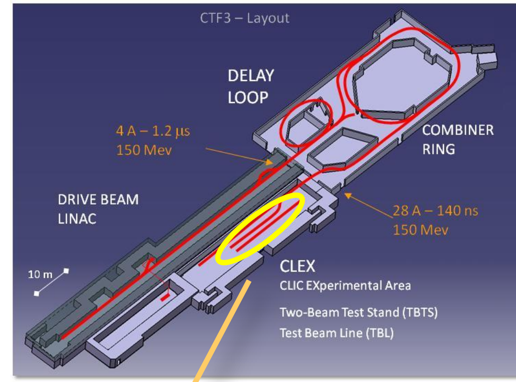
Several feed-back loops operational, for temperature, RF phase and power and gun current.



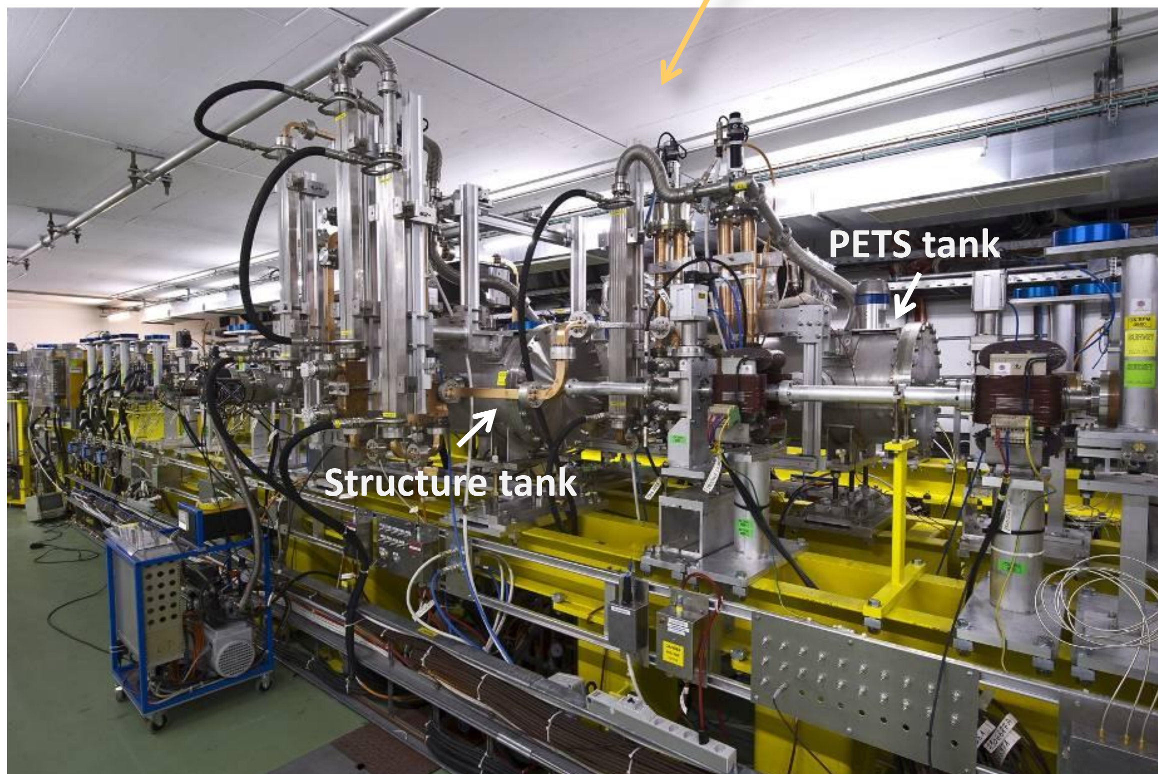
The Two-Beam Test Stand (TBTS)

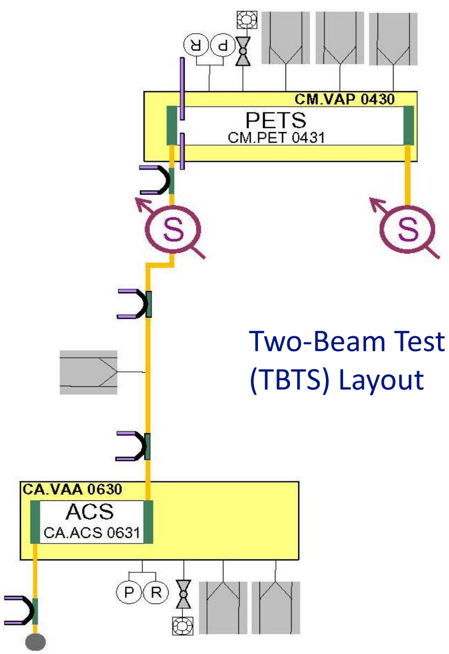


PETS – Power Extraction & Transfer Structure



Two-Beam Test Stand in CLEX





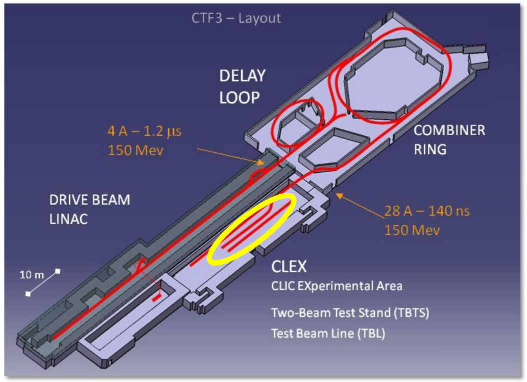
Two-Beam Test Stand (TBTS) Layout

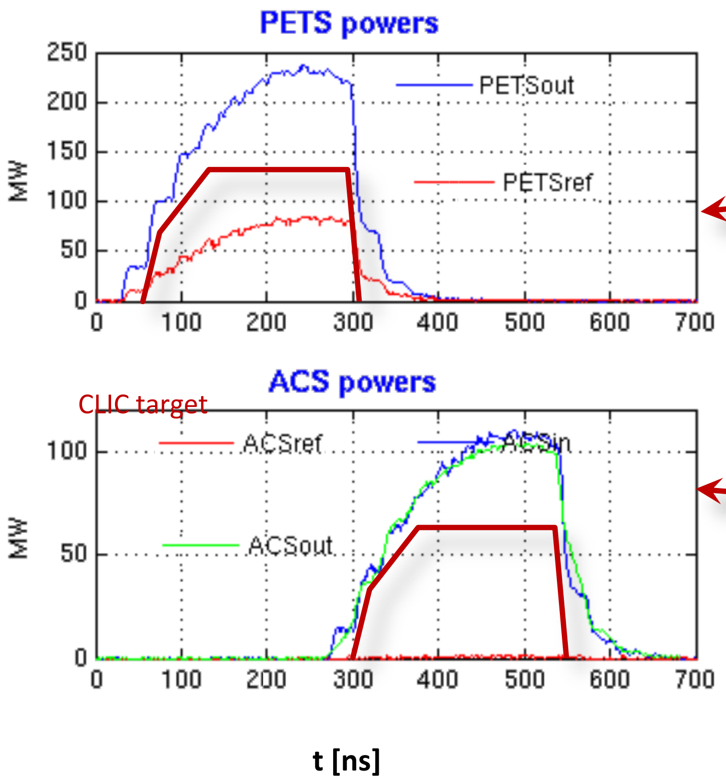
Power production in TBTS

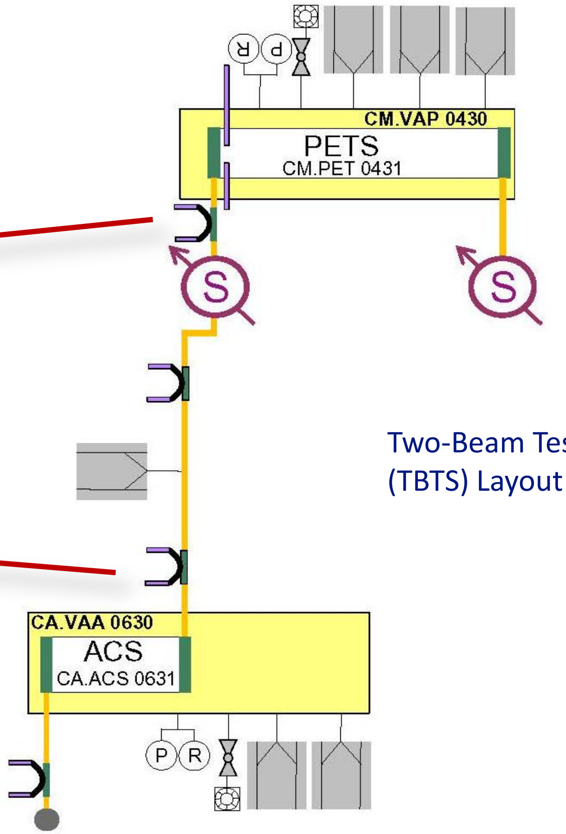
PETS operated routinely above **200 MW** peak RF power

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.

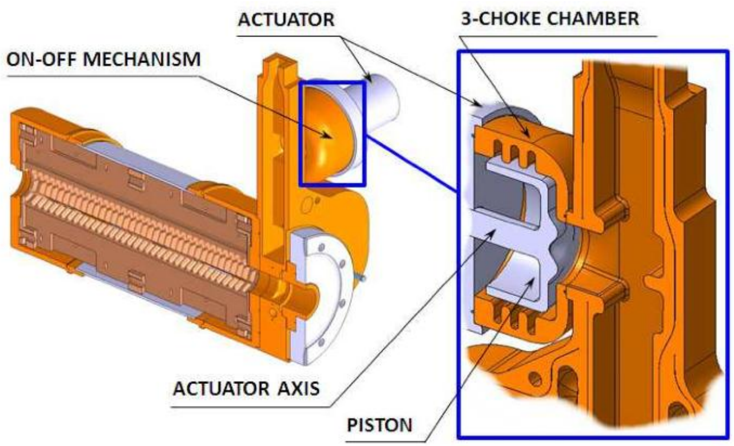


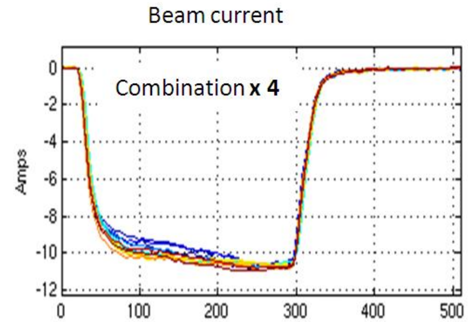


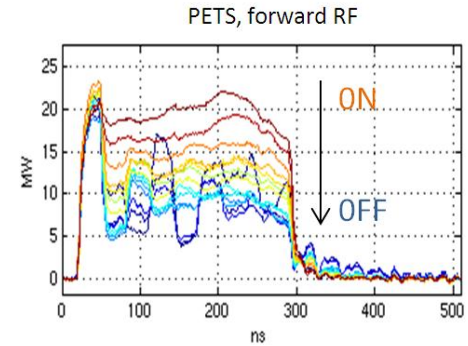


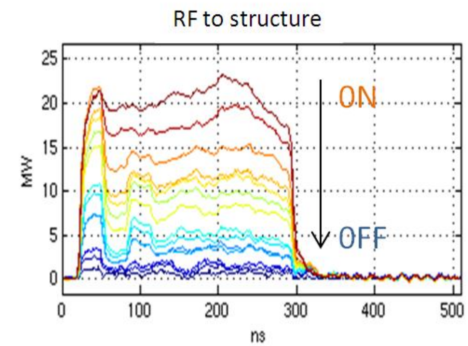
Two-Beam Test Stand (TBTS) Layout

TBTS – PETS On-off mechanism

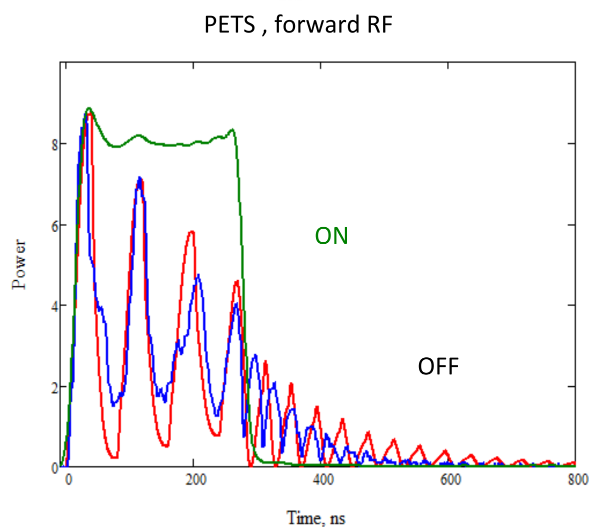


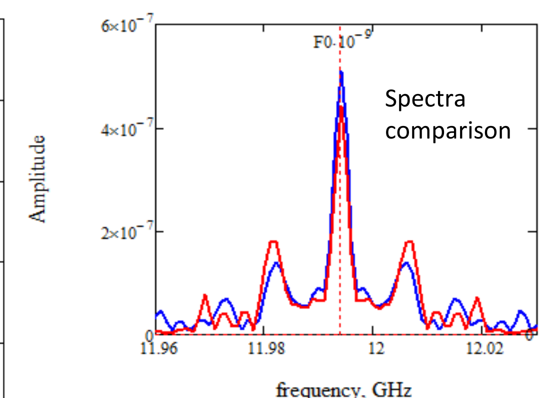






Simulation vs. experiment





Demonstration of PETS of-off mechanism

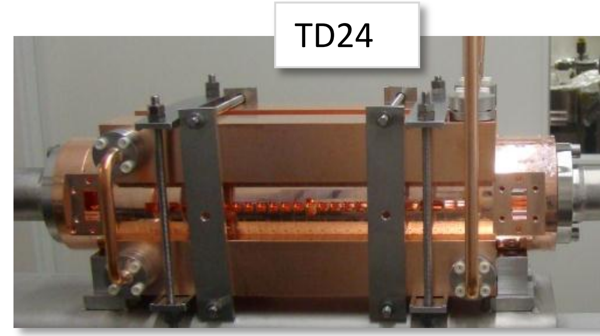
- Considered a feasibility issue
- Ability to:
  - Switch off power from individual PETS to accelerating structure in case of breakdown
  - Reduce substantially power in PETS, to cope with PETS breakdowns
- PETS on-off principle fully tested
- Conditioned at high power (135 MW - nominal) by recirculation

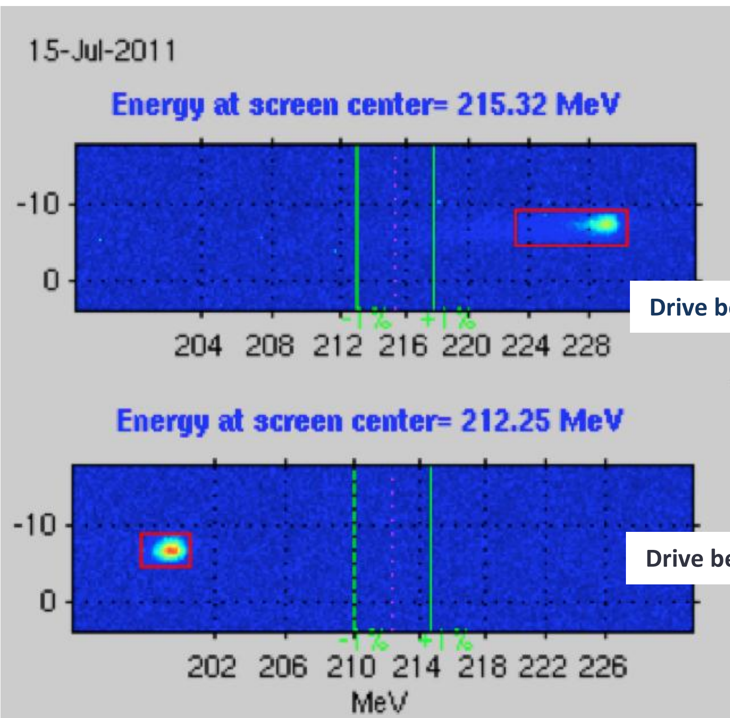
Two-Beam Acceleration

Two-Beam Acceleration demonstration in TBTS

Up to 145 MV/m measured gradient

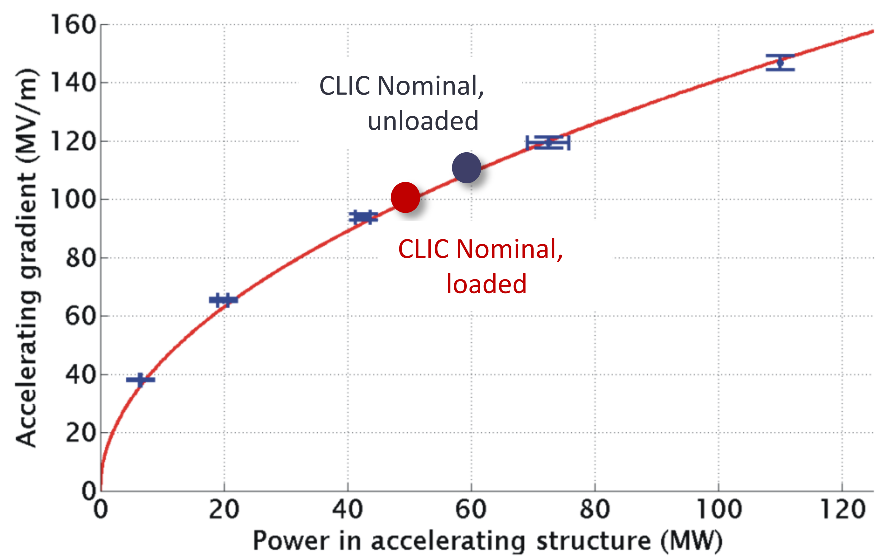
Good agreement with expectations (power vs. gradient)



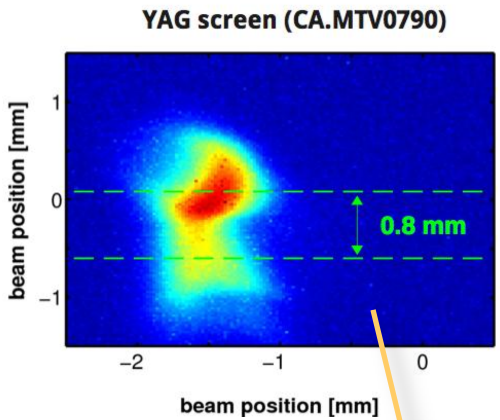


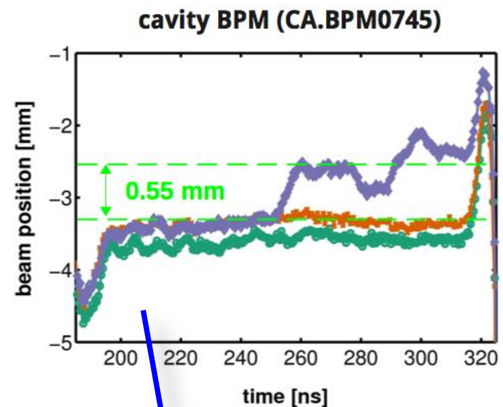
Maximum stable probe beam acceleration measured: 31 MeV

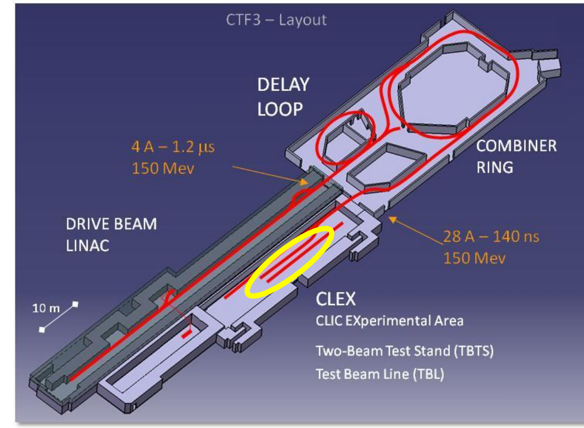
⇒ Corresponding to a gradient of **145 MV/m**

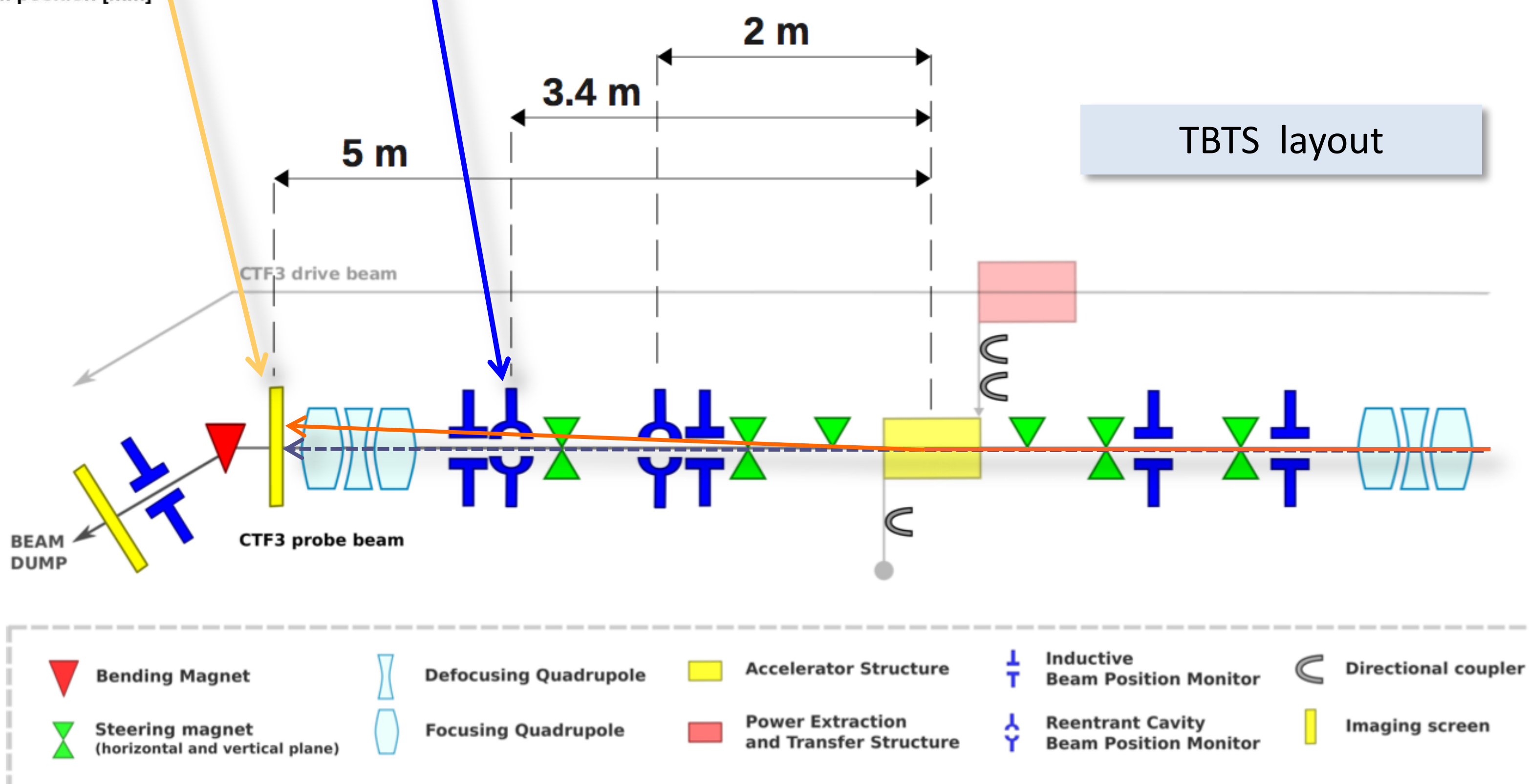


Breakdown kick studies









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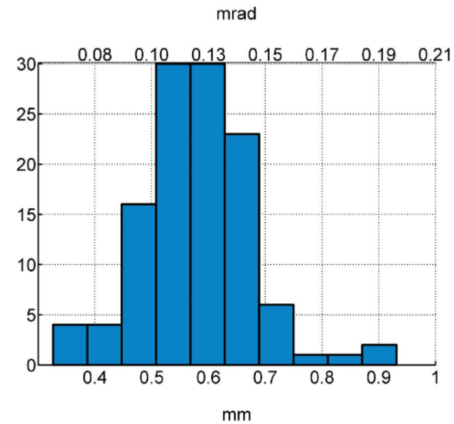
Breakdown kick studies

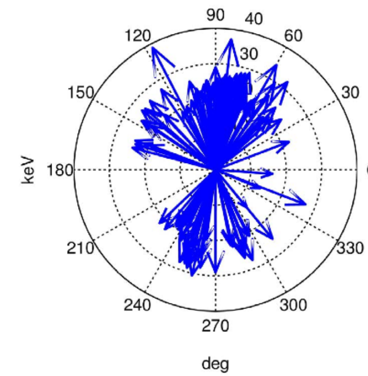
2011 run

- Limited amount of events
- Using only screen

kick magnitude
(typically 0.13 mrad)

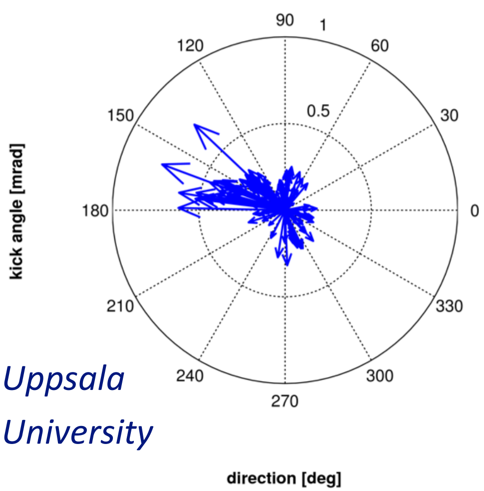


transverse electric field
(typically 25 keV)



- 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);

kick magnitude and direction



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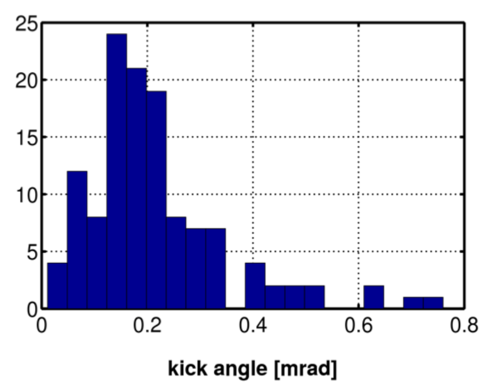
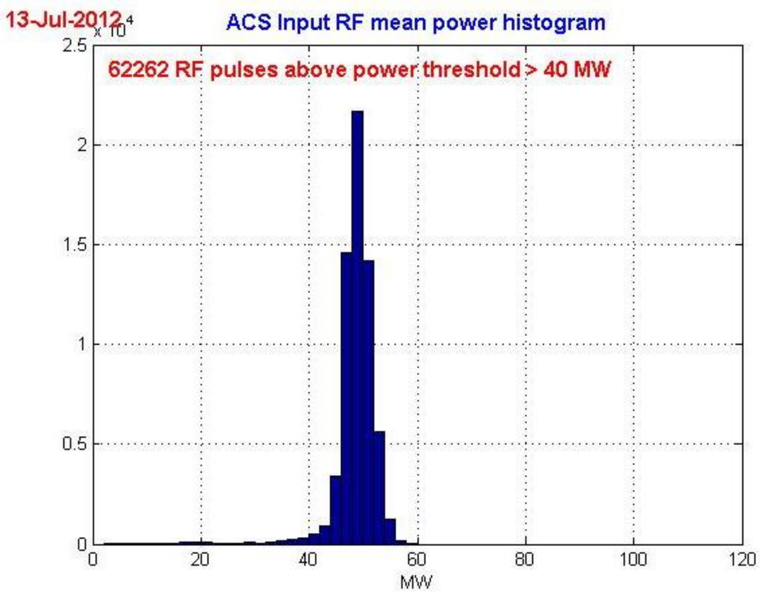
kick magnitude

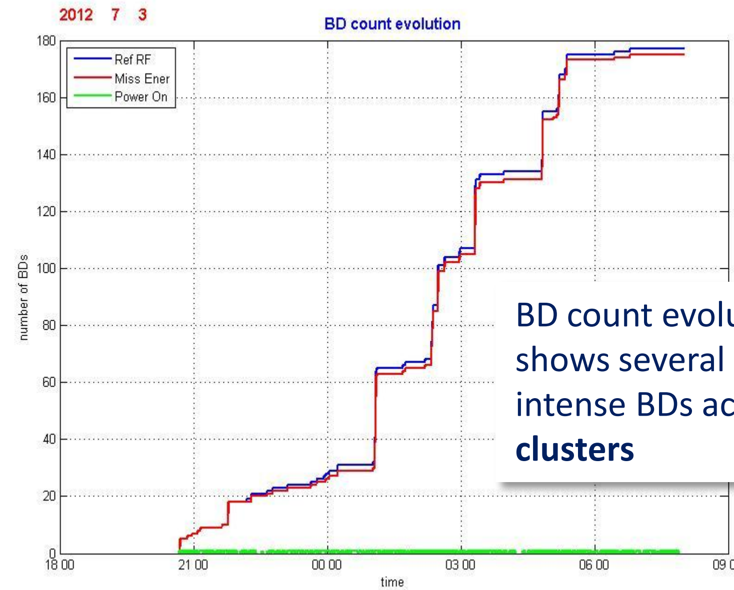


2012 run

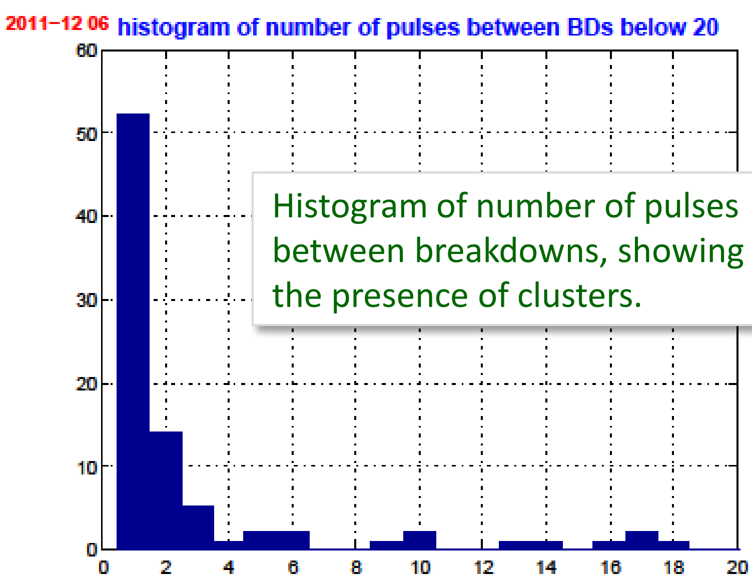
- Many events, larger statistics
- Using BPMs and screen
- Time resolution
- Subtraction of systematic effects
- Analysis ongoing, but basically confirming 2011 results

Breakdown physics & statistics



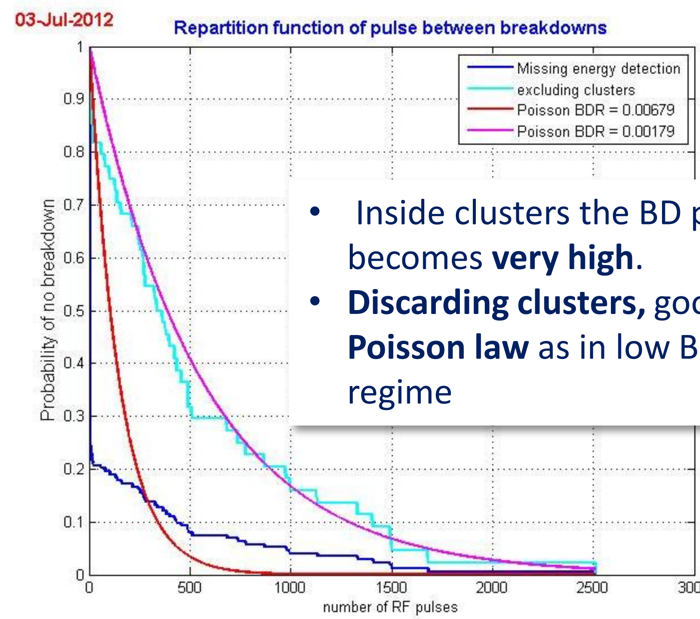


BD count evolution shows several period of intense BDs activity: **clusters**



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

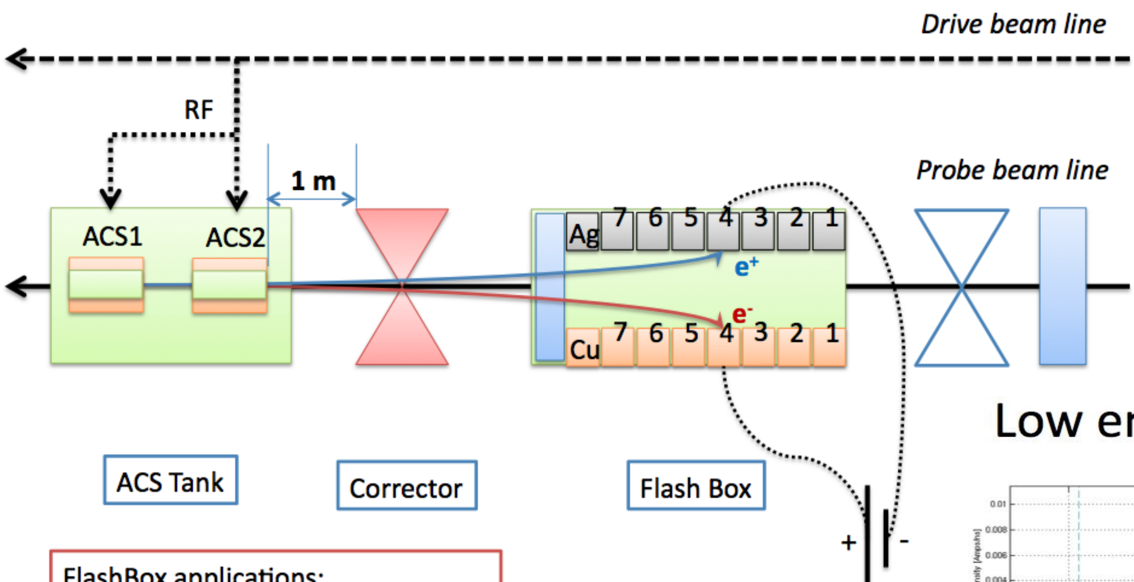
CEA-Dapnia & Uppsala University



- Inside clusters the BD probability becomes **very high**.
- **Discarding clusters,** good fit by a **Poisson law** as in low BD rate regime

Breakdown physics & statistics

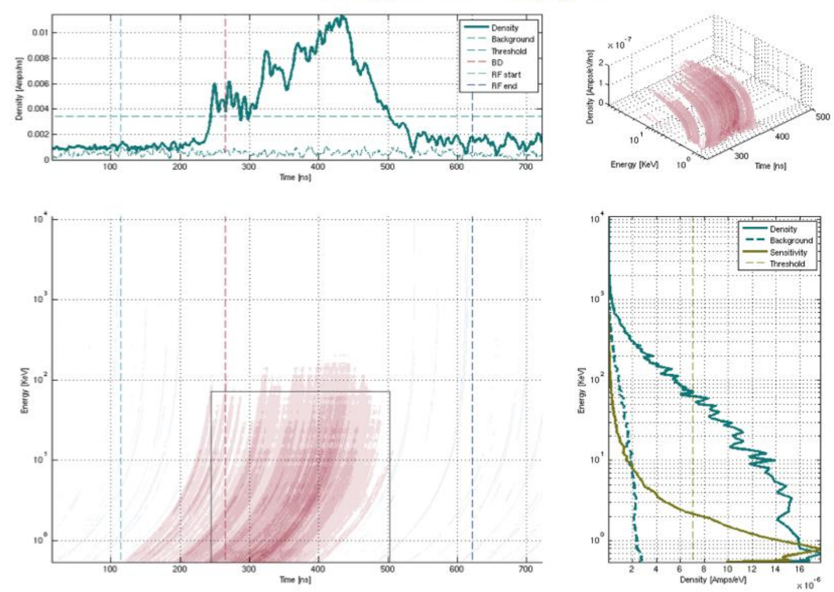
Layout of FlashBox experiment



FlashBox applications:
- Fundamental BD study;
- Compact beam spectra analyzer.

Low energy electrons: distributions

Without channels Cu8, Ag1-8



Measurement of intensity and energy distribution of electrons/ions produced during a break-down event

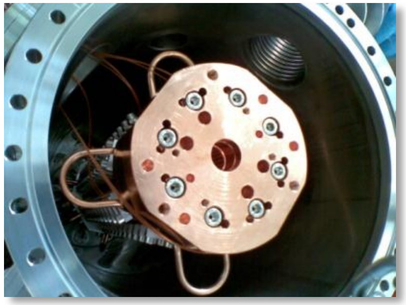
Uppsala University

Test Beam Line

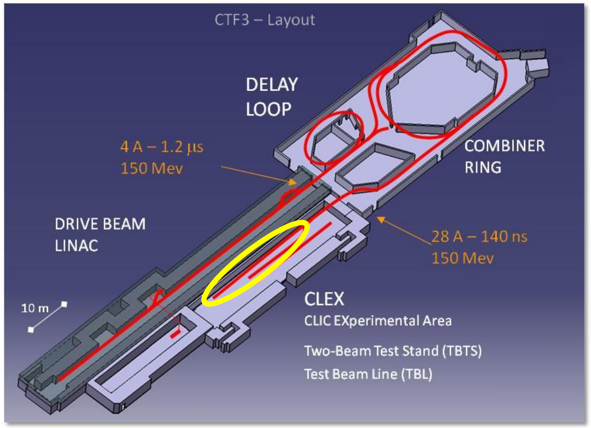
13 Power Extraction & Transfer Structures (PETS) installed and running in 2012 (9 PETS in 2011)

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.



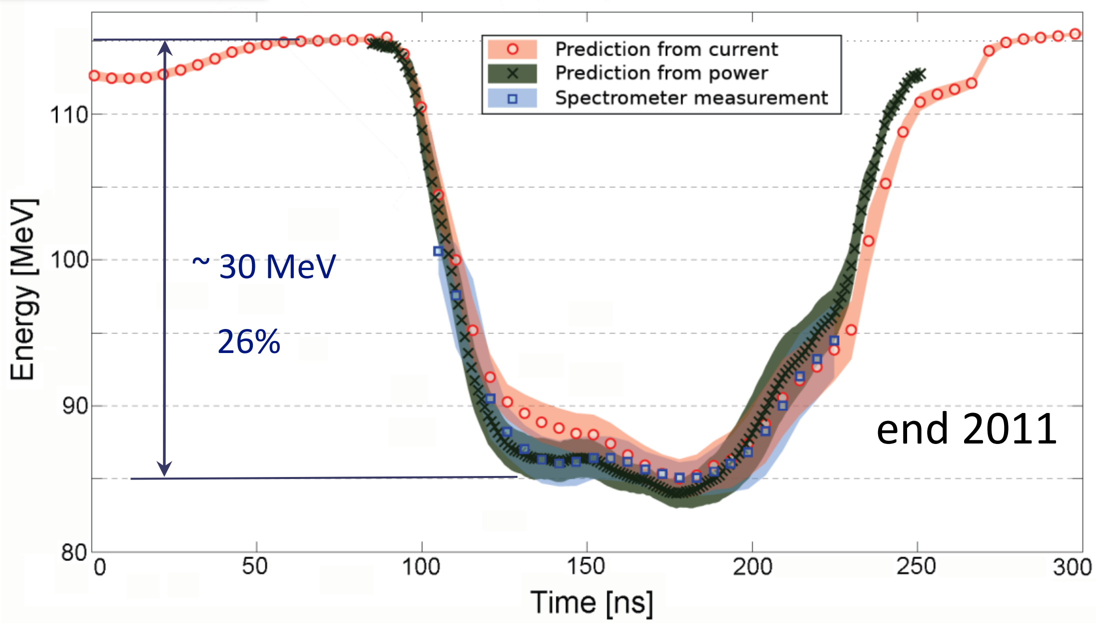
PETS tank during installation



More than half a GW of 12 GHz power!

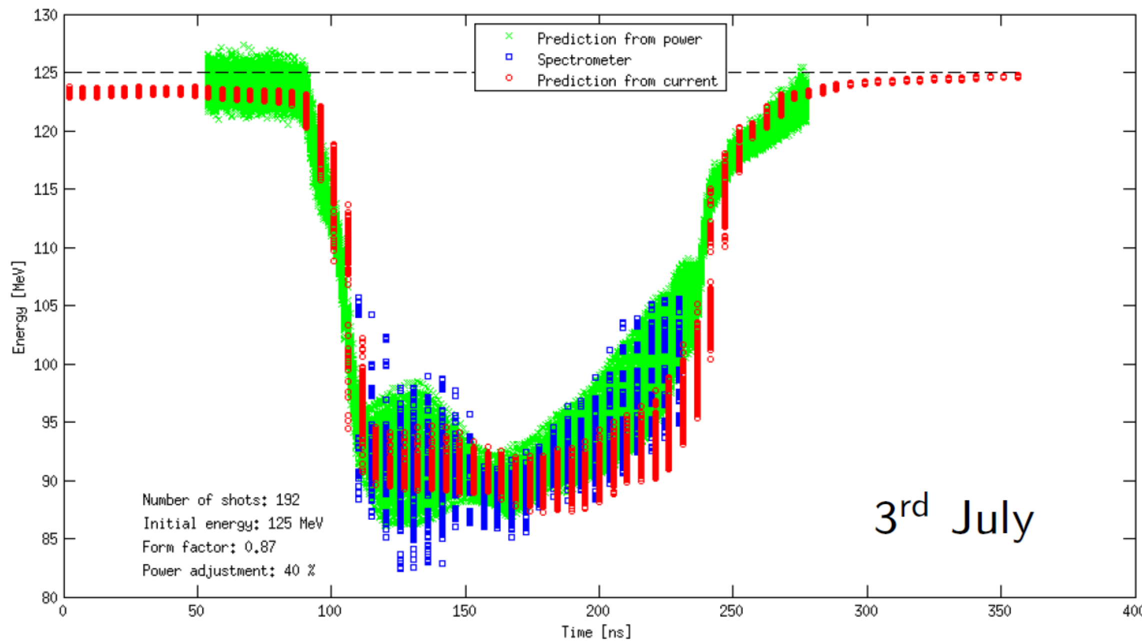
TBL line in CLEX

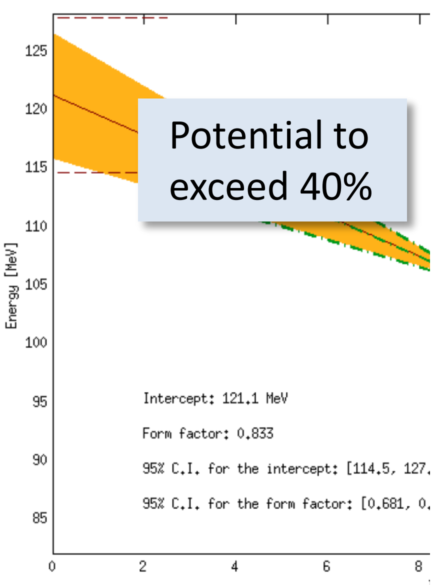
Beam deceleration, measured in spectrometer and compared with expectations



Test Beam Line

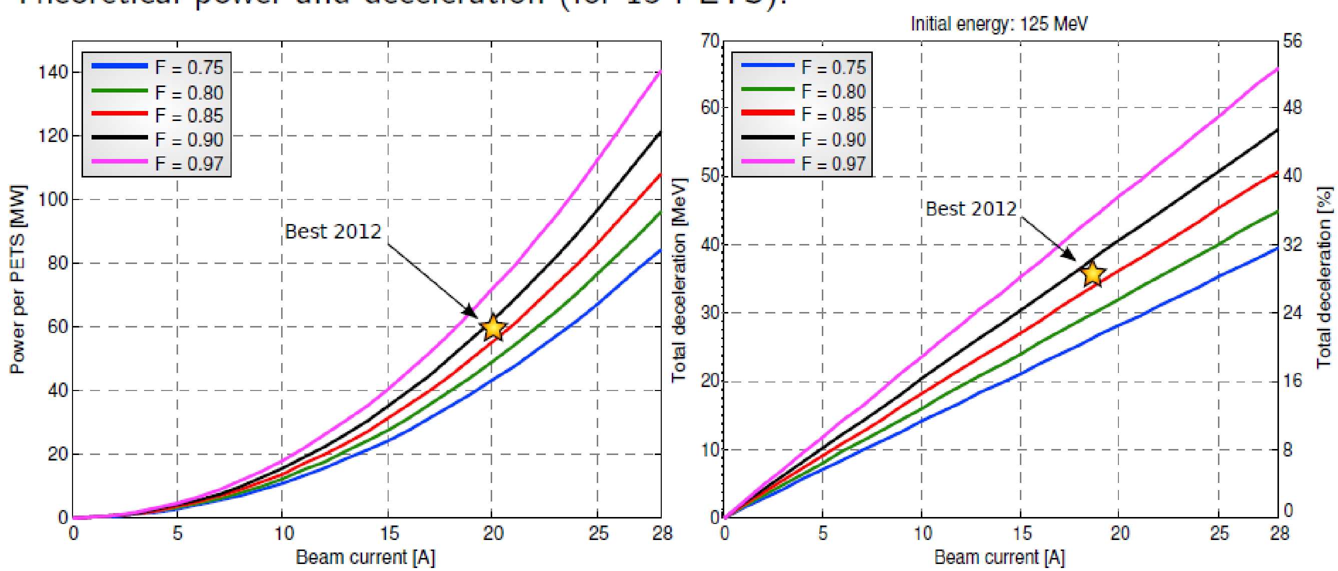
2012: Reached 30% deceleration





Potential to exceed 40%

Theoretical power and deceleration (for 13 PETS):



Conclusion of our CDR studies

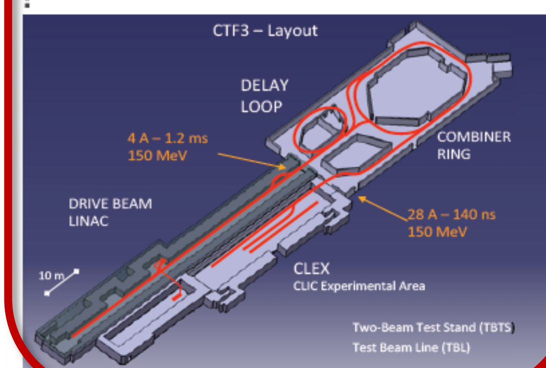
Two-beam scheme	– Drive Beam generation fully tested – Nominal parameters for RF production reached and exceeded – Deceleration as expected – Used to accelerate test beam - 150 MV/m gradient measured with beam – Improvements on operation, reliability, losses – More deceleration and improvements on drive beam quality expected this year

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

CLIC project time-line

2012-16 Development Phase

Develop a Project Plan for a staged implementation in agreement with LHC findings; further technical developments with industry, performance studies for accelerator parts and systems, as well as for detectors.



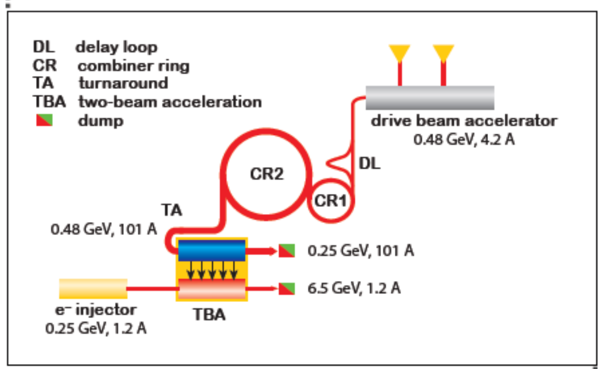
2016-17 Decisions

On the basis of LHC data and Project Plans (for CLIC and other potential projects), take decisions about next project(s) at the Energy Frontier.

2017-22 Preparation Phase

Finalise implementation parameters, Drive Beam Facility and other system verifications, site authorisation and preparation for industrial procurement.

Prepare detailed Technical Proposals for the detector-systems.



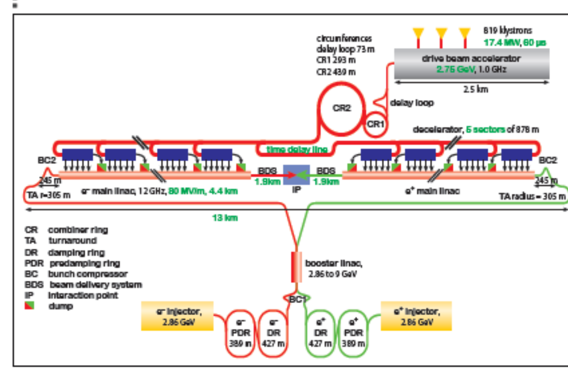
2022-23 Construction Start

Ready for full construction and main tunnel excavation.

2023-2030 Construction Phase

Stage 1 construction of a 500 GeV CLIC, in parallel with detector construction.

Preparation for implementation of further stages.

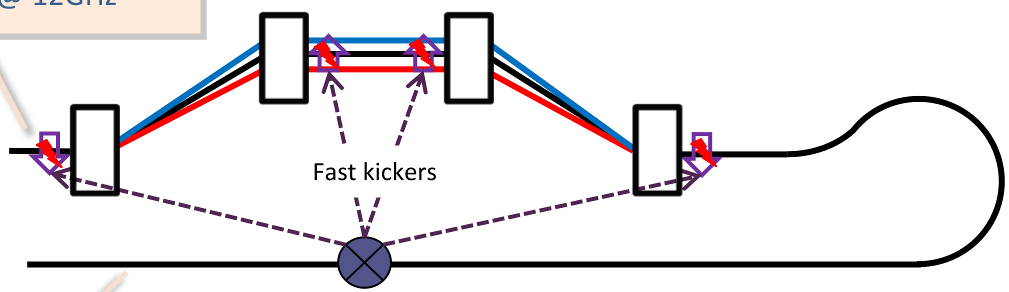


2030 Commissioning

From 2030, becoming ready for data-taking as the LHC programme reaches completion.

Drive Beam phase feed-forward tests

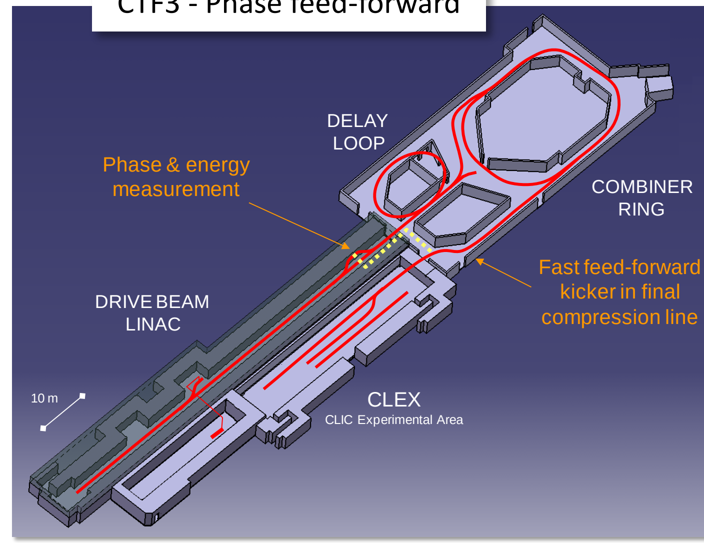
Phase stability
0.2° @ 12GHz



CLIC drive beam phase feed-forward concept

Phase stability 2.5° @ 12GHz
0.2° @ 1GHz

CTF3 - Phase feed-forward



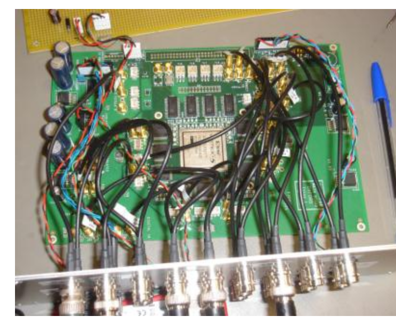
Not just a single experiment – series of related studies:

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

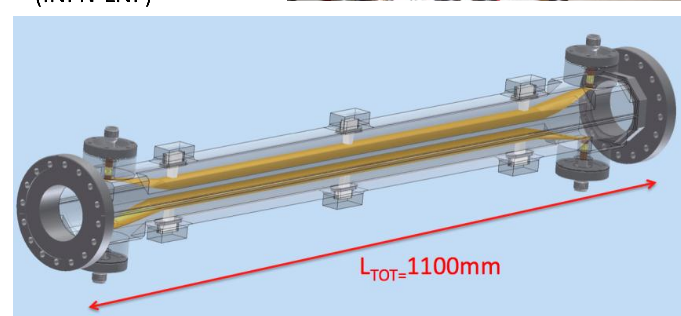
Close link to collaborating partners:

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

FONT5 board (Oxford)



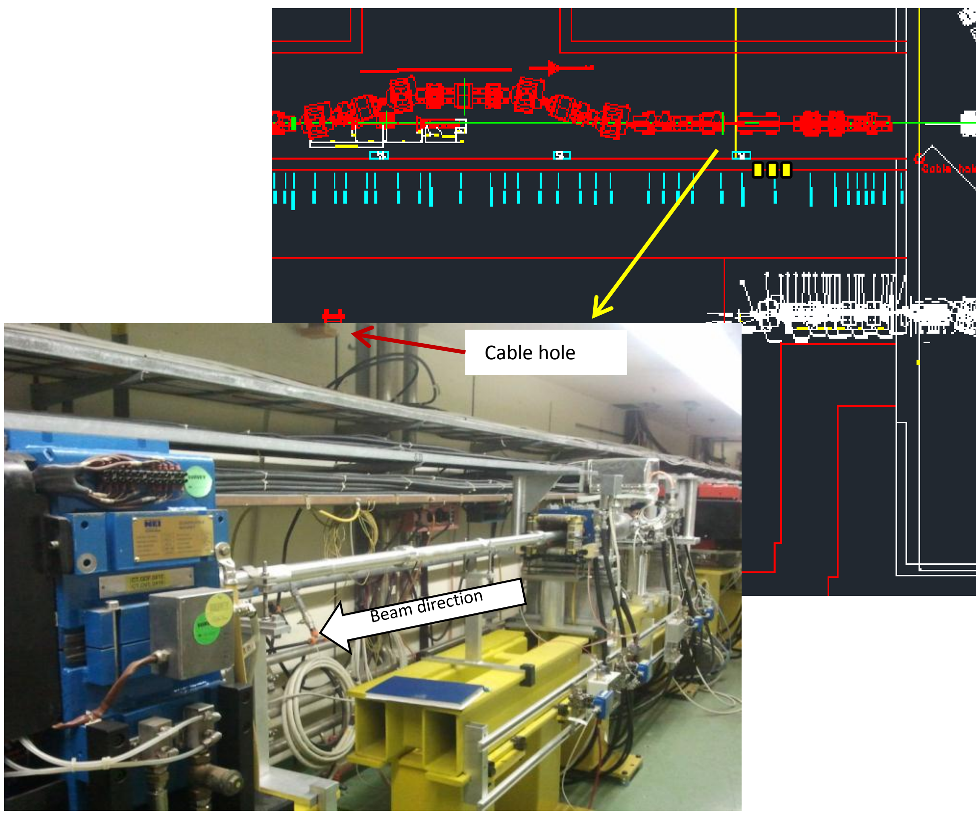
Stripline kicker (INFN-LNF)



Feed-forward tests in CTF3

- Phase monitor tests – 2 monitors installed in summer 2012
- First system tests planned in summer 2013

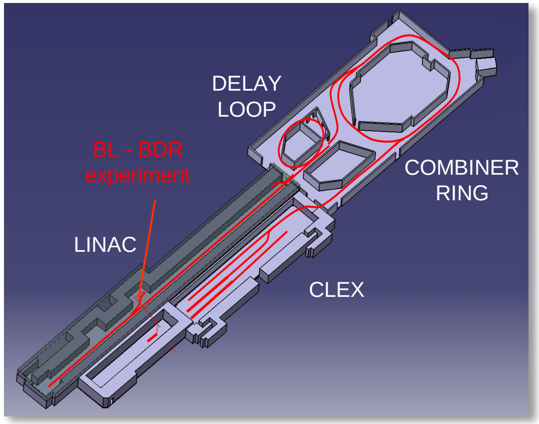
Test starting in 1-2 weeks



Phase monitor (INF-LNF, EuCARD)

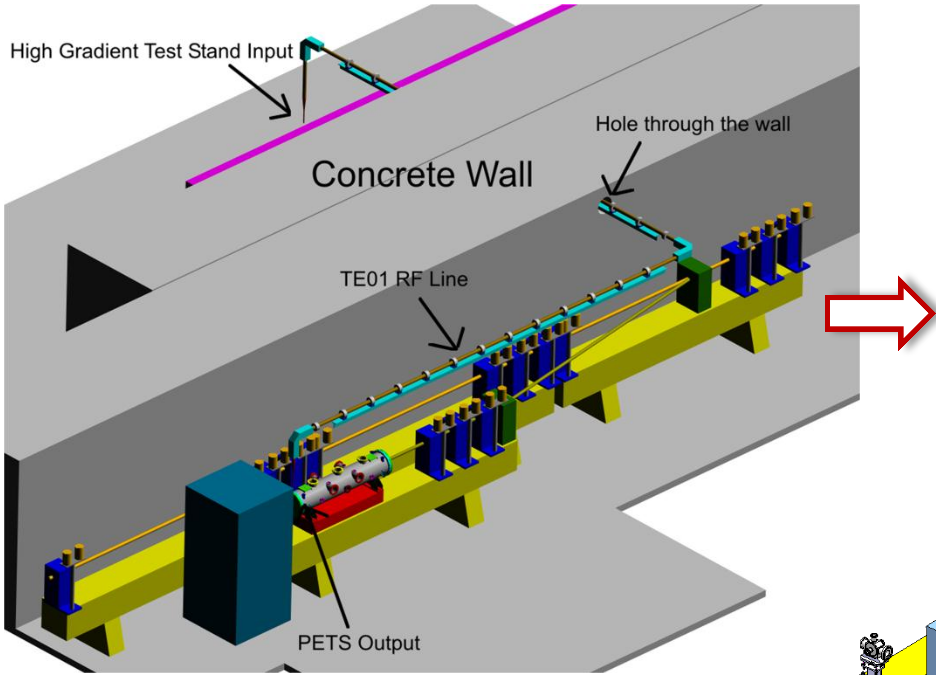
Experiment on the effect of Beam-Loading on BD rate

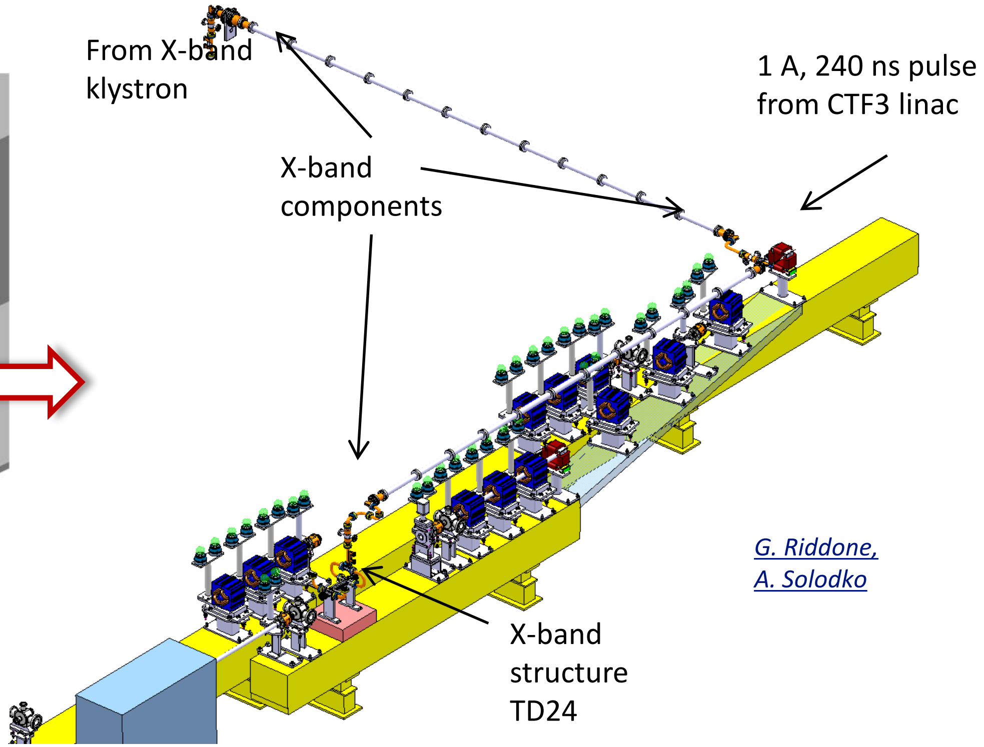
Beam loading reduces field locally in the structure
⇨ is it the break-down rate lower (or higher)?



- 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, 1 A 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

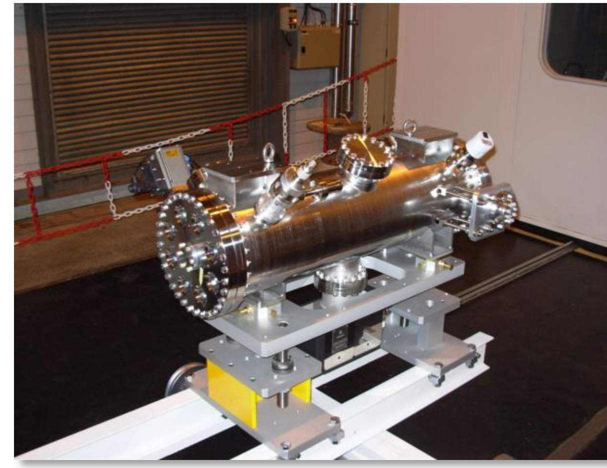
Evolution of TBL

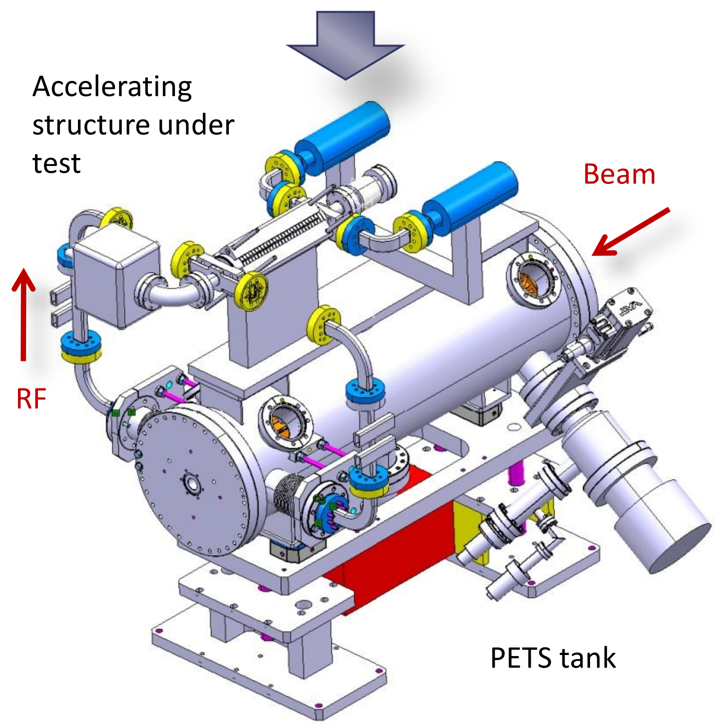
Upgrade TBL to a test facility relevant for future CLIC program

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

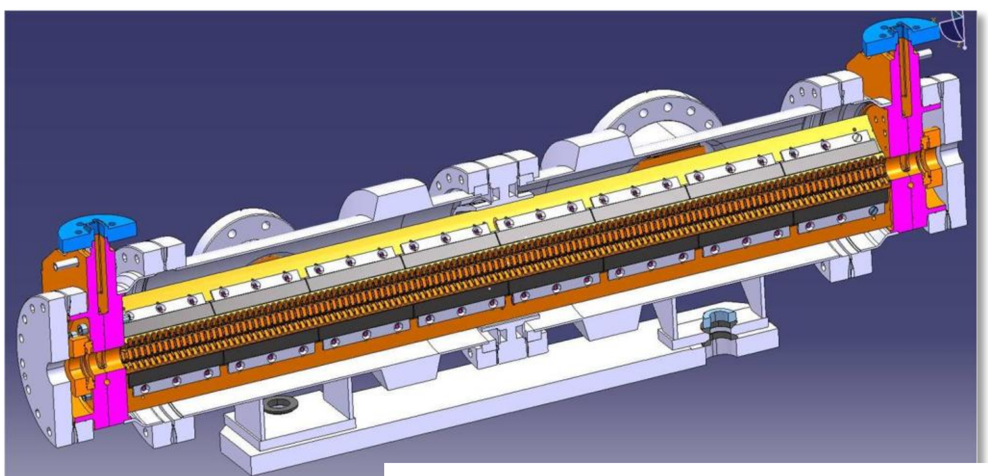
Timeline:

- 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





S. Doebert



Improved PETS design, mini-tank + input coupler

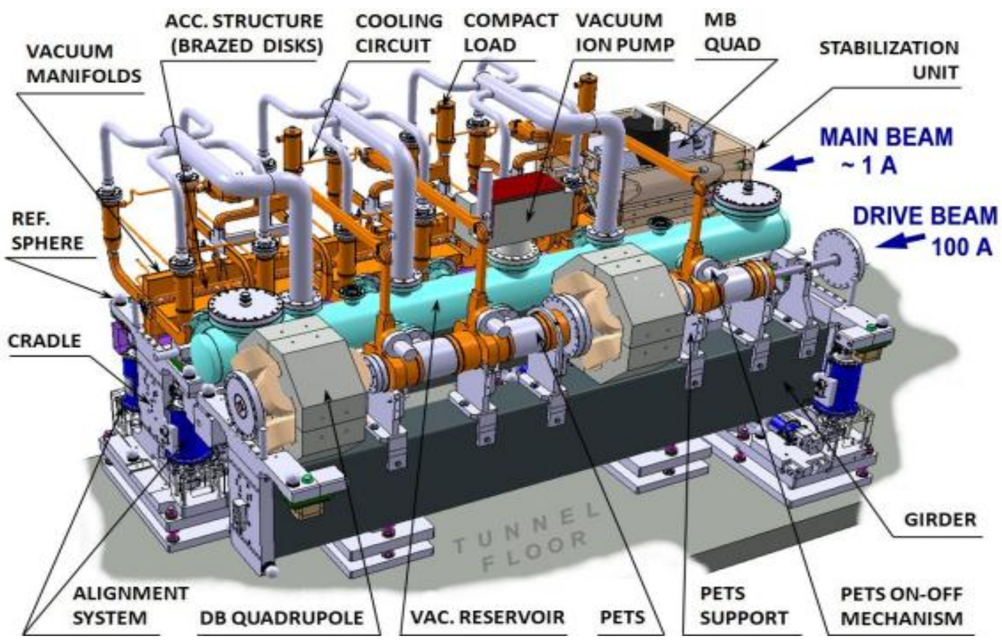
Two-Beam Modules

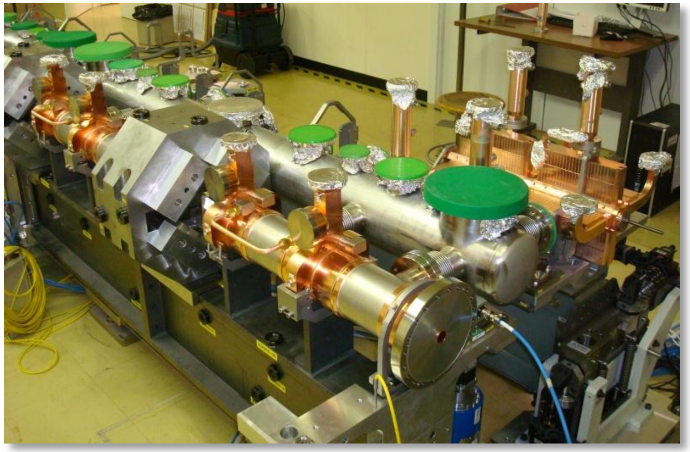
Ongoing: Fabrication of 4 modules to be mechanically tested in laboratory

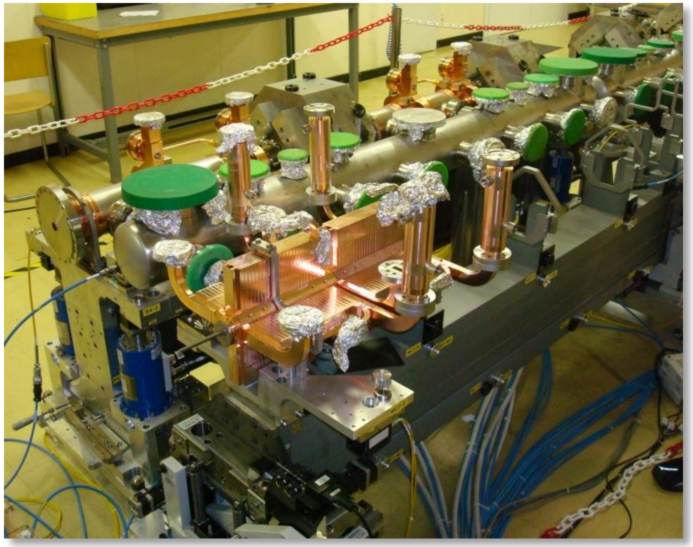
Next Step: Installation and test of full-fledged Two-Beam Modules in CLEX

First module in development, installation end 2013

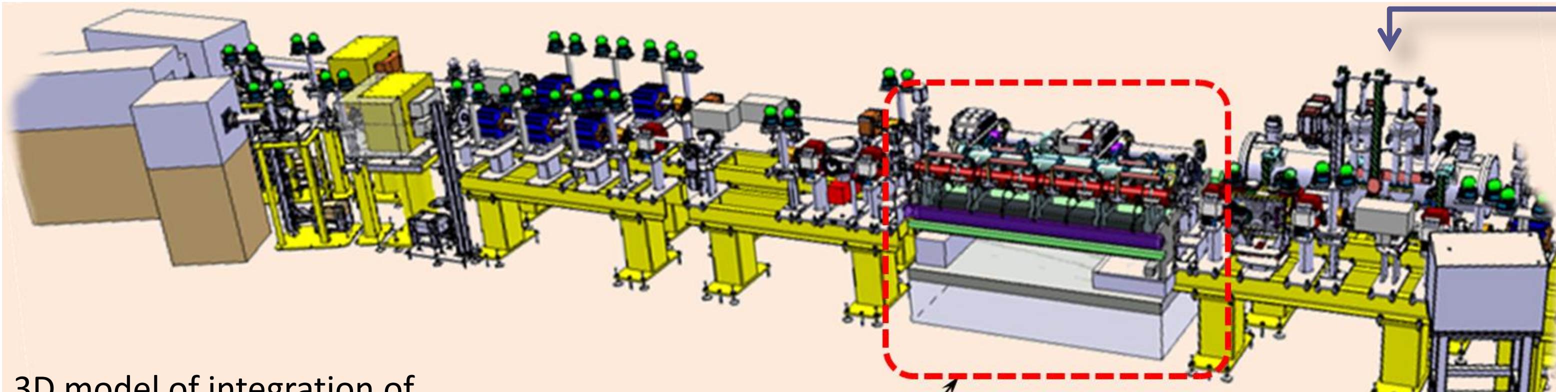
Three modules in 2014-2016





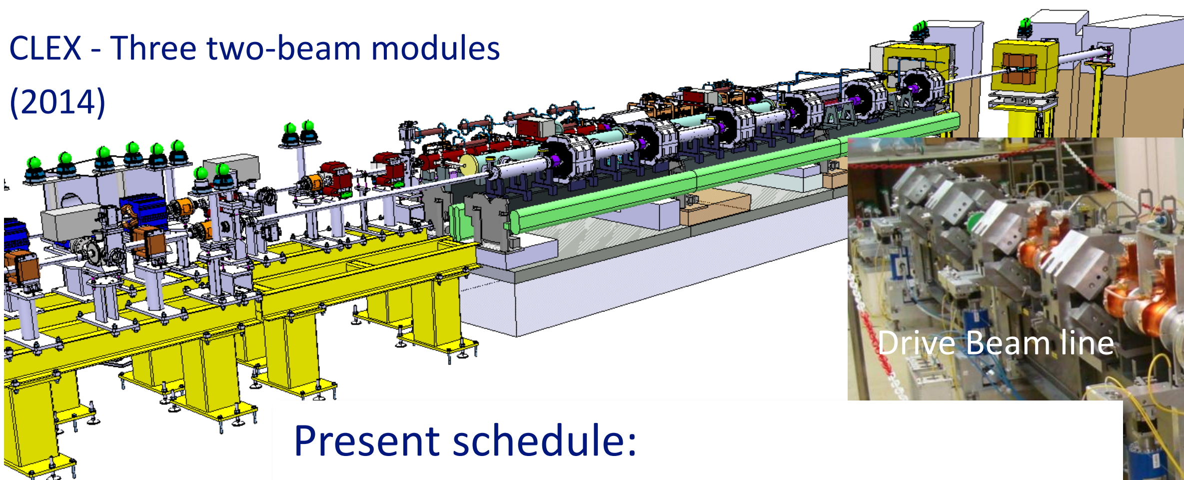


Two-Beam Modules

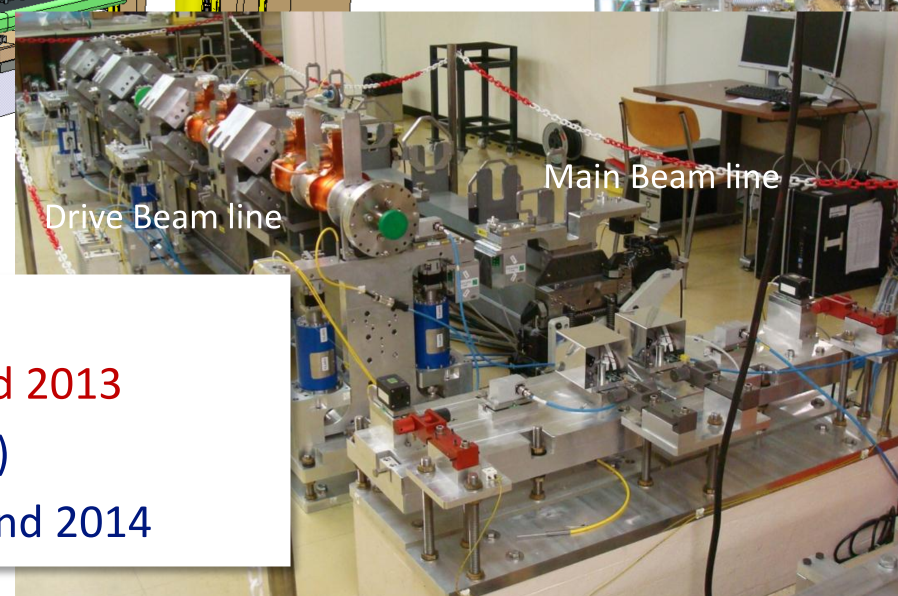


3D model of integration of
the first CLIC Module in CLEX (2013)

CLEX - Three two-beam modules
(2014)



TBTS PETS tank



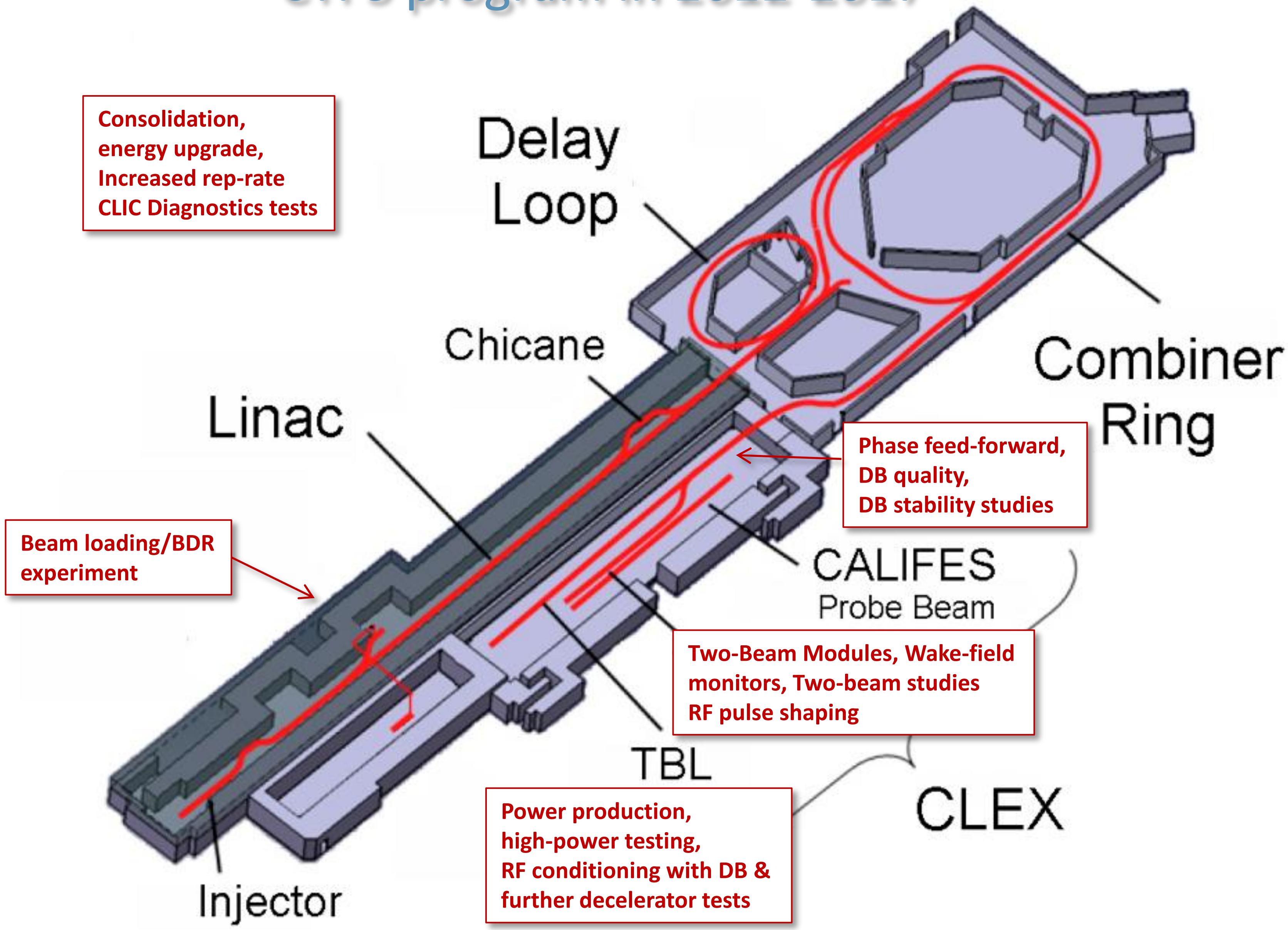
Present schedule:

First module installation end 2013

(At least one year of testing)

Module string installation end 2014

CTF3 program in 2012-2017



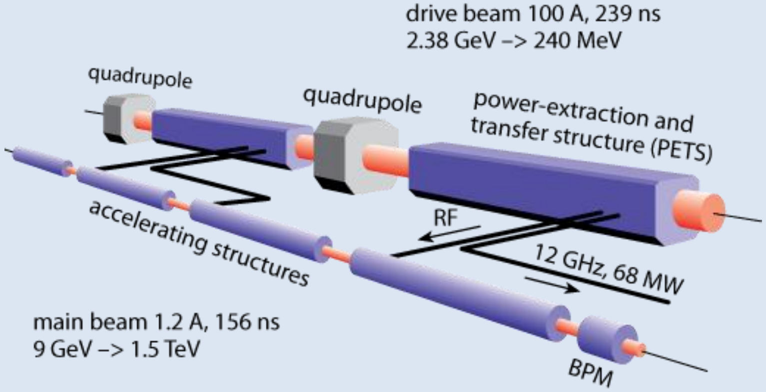
CONCLUSIONS

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 shall 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 30% of a 20 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



Current CLIC & CTF3 Collaboration

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)