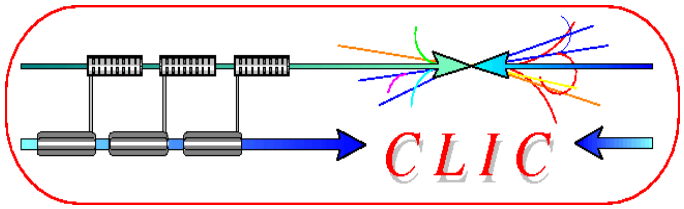


CTF3 program completion and upgrade to CTF3+

Frank Tecker – CERN
for the CTF3 team

- Introduction
- CTF3 program completion
- CTF3+
- Conclusion

CTF3 2010 main goals (feasibility demonstration)

Drive Beam Generation

- Bunch train recombination 2 x 4 in DL and CR (from 3.5 to 28 A) — done in 2009 – to be reestablished
- Transverse rms emittance < 150 □ mm mrad (combined beam) — close in vertical – horizontal to be done
- Bunch length control to < 1 mm rms (combined beam) — ok in linac – to be done for combined beam
- Beam current stability ~ 0.1 % for combined beam — ok in linac – to be done for combined beam

RF Power Production

- 20.8 A beam-powered test of a single PETS (without re-circulation) in the TBTS — up to >17A, no BDR measurements
  - **135 MW** (with 28 A potentially available in CLEX, the peak power can reach 240 MW)
  - 140 ns total pulse length
  - A measured breakdown rate in the range of 10^{-4} or lower
  - Operation of a few hundred hours at 1 Hz
- 7.4(10) A beam-powered test of a single PETS with external recirculation in TBTS — up to >12A, no BDR measurements, operation at 1 Hz – 5 Hz tests
  - **135 (81) MW** circulating power or **65 (65) MW** available for accelerating testing
  - 250 ns total pulse length, 100 (170) ns flattish-top
  - A measured breakdown rate in the range of 10^{-4} or lower
  - Operation of a few hundred hours at 5 Hz
  - On/off/adjust will be demonstrated using the external reflection/recirculation system mounted on one of the PETS in TBL.

Two Beam Acceleration issues

- TBTS — first measurements done – power meas. to be improved; >100 MV/m measured
  - Improved measurements of power and energy loss.
  - Breakdown transverse kick measurements.
  - Probe Beam energy gain and beam loading tests.
- TBL
  - The current schedule is to have **8 PETS** installed as well as a spectrometer dump for energy spectrum studies, toward the summer 2010. This will allow to verify transport of a beam with up to **30%** of the energy extracted. — only 1 PETS

2011 CTF3 main goals

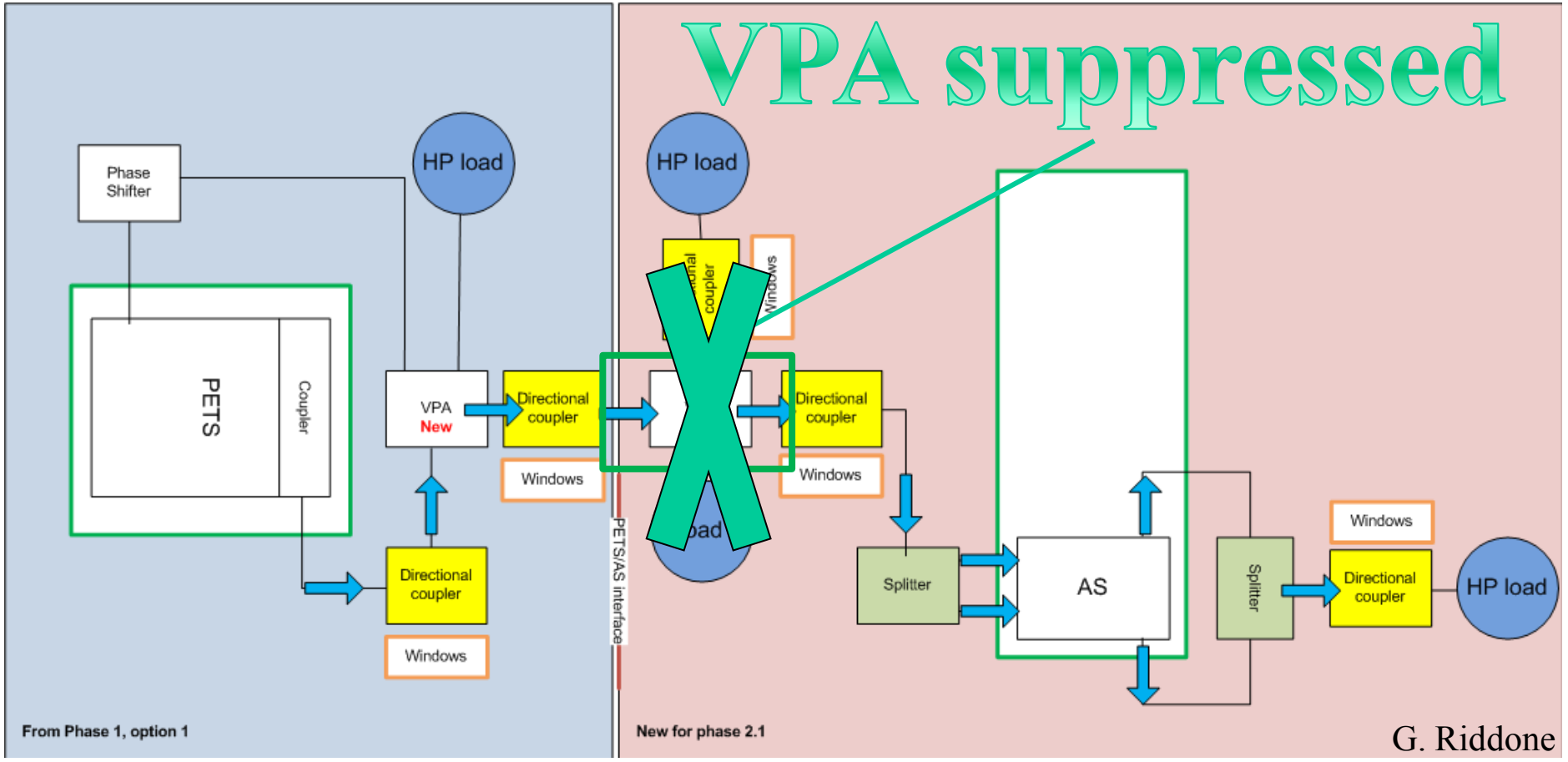
- Drive beam generation
  - DL+CR recombination with higher current (MKS13 back)
  - <150 π mm mrad emittance of combined beam
  - Bunch length control to < 1 mm rms (combined beam)
  - Beam current stability ~ 0.1 % for combined beam
  - The above at 28 A combined beam in CLEX
- Power production
  - 20.8 A beam-powered test of a single PETS (without re-circulation) in the TBTS
    - 135 MW (with 28 A potentially available in CLEX, the peak power can reach 240 MW)
      140 ns total pulse length
      A measured breakdown rate in the range of 10^{-4} or lower
      Operation of a few hundred hours at 1 Hz
  - 7.4 (10) A beam-powered test of a single PETS with external recirculation in TBTS
    - 135 (81) MW circulating power or 65 (65) MW available for accelerating testing
      250 ns total pulse length, 100 (170) ns flattish-top
      A measured breakdown rate in the range of 10^{-4} or lower
      Operation of a few hundred hours at 5 Hz
      On/off/adjust will be demonstrated using the external reflection/recirculation system mounted on the PETS in TBTS
- Two Beam Acceleration issues
  - TBTS
    - Consistent power and energy loss measurements
    - Probe Beam energy gain and beam loading tests
    - Breakdown transverse kick measurements
  - TBL
    - Current schedule: 4 PETS installed as well as a spectrometer dump for energy spectrum studies, 8 toward the summer 2011 This will allow to verify transport of a beam with up to 30% of the energy extracted

Drive Beam generation

- DL+CR recombination
  - set up the beam with MKS13 (rematch optics)
- <150 π mm mrad emittance of combined beam
  - optimize dispersion
  - verify DL/CR orbit closure
  - verify DL/CR optics
- Bunch length control to < 1 mm rms (combined beam)
  - R_{56} tuning in Frascati chicane and TL2 arc
  - streak camera measurements in CLEX
- Beam current stability ~ 0.1% for combined beam, improve slow variations
  - optimize combined emittance
  - systematically analyze jitter sources, find correlations
  - improve overall klystron stability (at least up to best performing klystrons)

TBTS 12 GHz RF installation

- Accelerating structure retuned (TD24) or exchanged (T24)
- 12 GHz network simplified



RF power

- Careful calibration of 12 GHz power measurements
- Breakdown rate measurements
  (at high BD rate - extrapolation to lower rates)
- Operation w/out recirculation – may have different breakdown rate…
- Test of new PETS on-off scheme (components and concept)

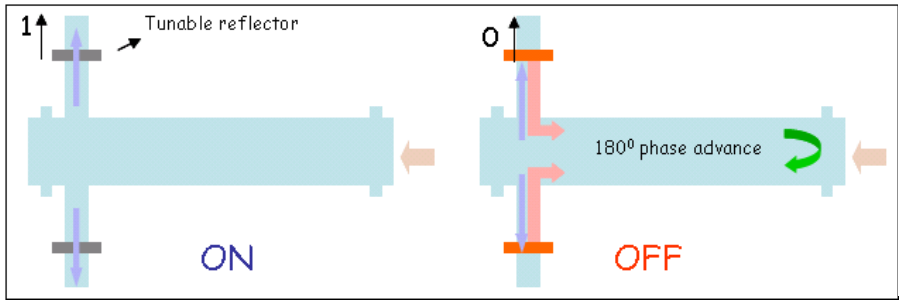
Two beam issues

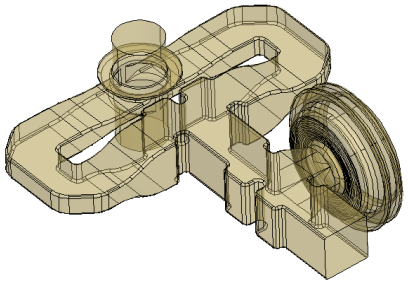
- TBTS
  - Two-Beam test – 100 MV/m, at nominal structure temperature
    consistency between power & beam energy gain
  - Drive beam, deceleration, power produced
  - Probe beam, power delivered to accelerating structure, energy gain
  - Beam Loading compensation experiment - by varying fast phase switches – check control of RF pulse shape with probe beam acceleration
  - Measurement of breakdown kicks
  - Measurement of effect of beam loading on breakdown rate
- TBL
  - Measurement of deceleration / produced power
  - Goal: deceleration by 30% (need 8 PETS installed)
    Measurement of energy spectrum
  - Optics, steering algorithm studies

Other issues

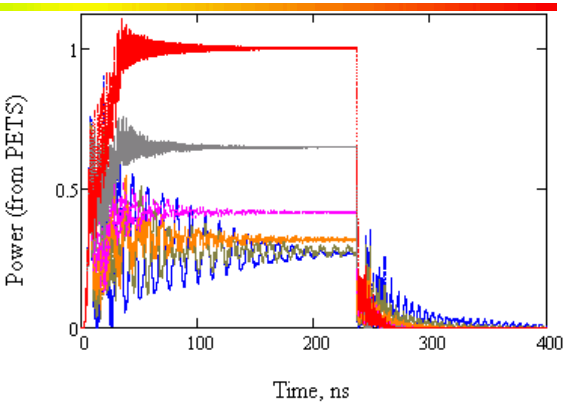
- CALIFES
  - Fully reach nominal parameters (total charge)
  - Bunch length measurements (RF defl. & screen)
- PHIN
  - 2011: test of phase coding with beam
- Other
  - First measurements of phase stability (PETS output, RF pickups…)
  - Operation at 5 Hz (or more)
  - Control of beam losses
  - Coherent Diffraction Radiation (RHUL collaboration)
  - …

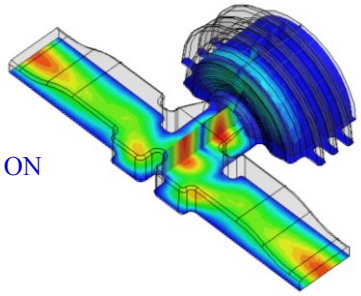
PETS on/off

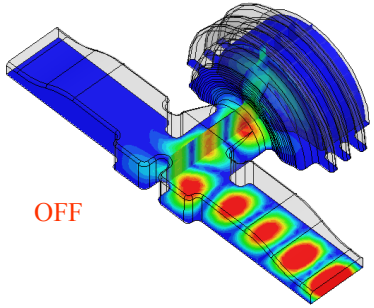




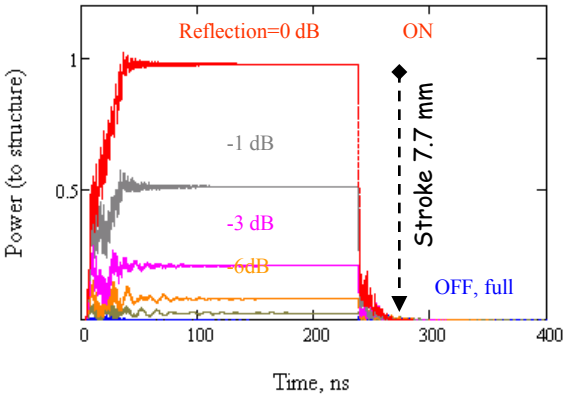
PETS coupler design with integrated RF reflector

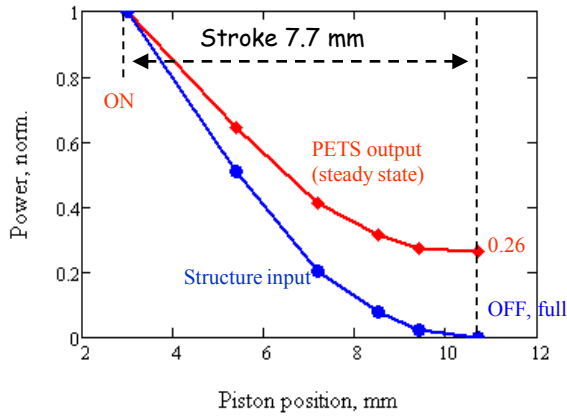






Power attenuation vs. piston position (full reflection in OFF position)





- Components under construction
- High power tests of components and concept validation (slow movement, external reflector at input coupler) can be done from summer 2011 in the TBTS PETS
- replaces recirculation loop (lower losses, faster recirculation)

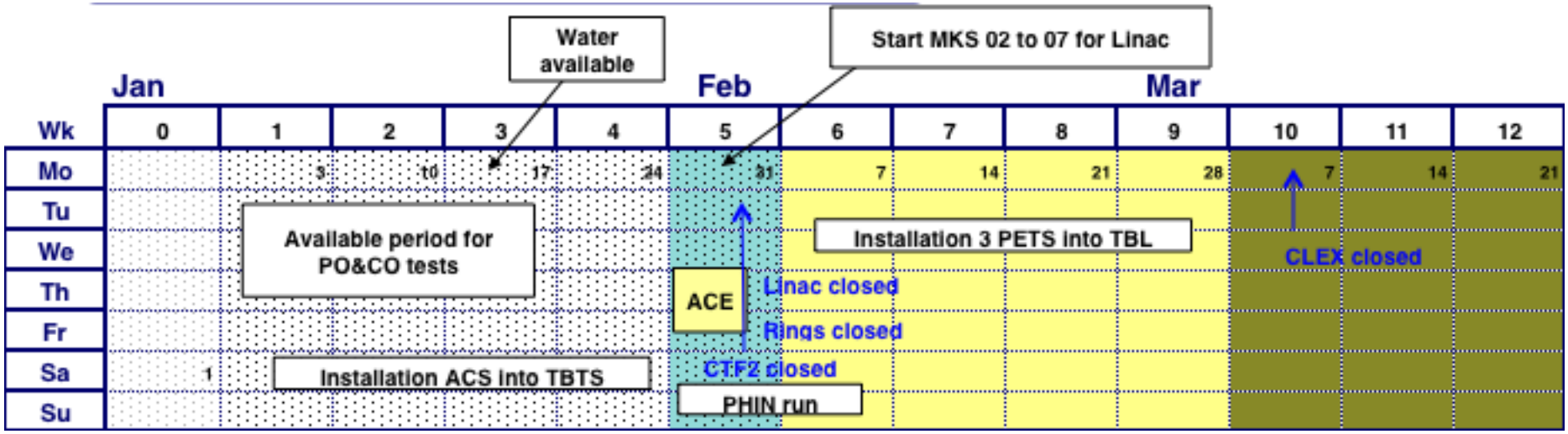
TBL completion

- 4 tanks installed by March 2011
- 4 more installed in summer 2011
  => Demonstration with 8 PETS
  >30% deceleration
- Another 4 PETS in shutdown 2011-2012
- 4 more with input coupler for priming

- Perform full experimental program afterwards
  >50% deceleration
- Detailed program in talk by Steffen Döbert

Schedule 2011

- Early start of Linac + CR/DL (combination setup + studies)
- Initial PHIN run for phase coding demonstration
- CLEX stop in summer for installation of
  - 4 more PETS
  - PETS ON/OFF mechanism
  - different accelerating structure ?



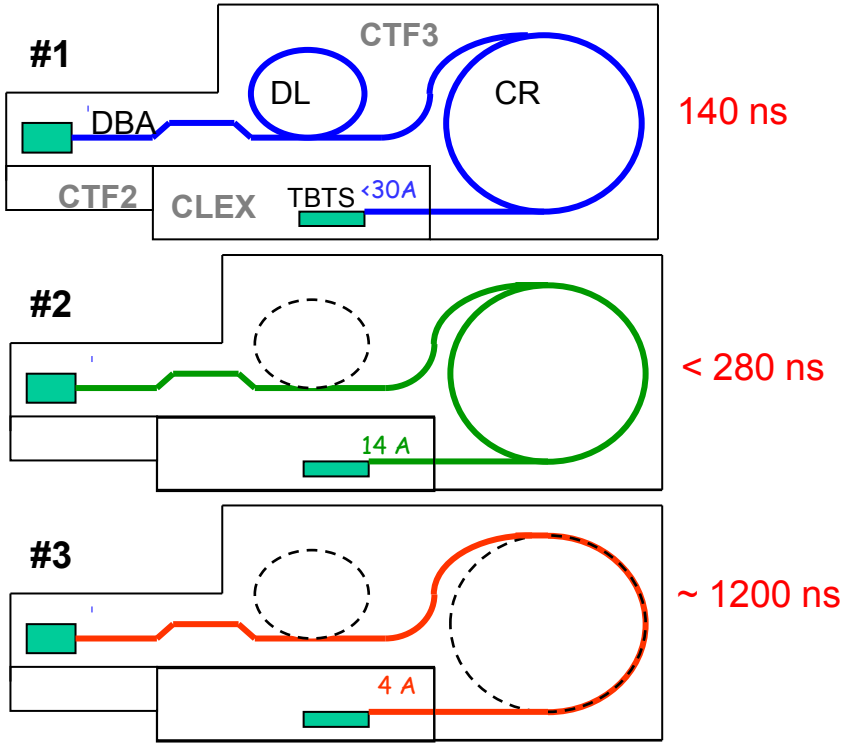
Increased run-time

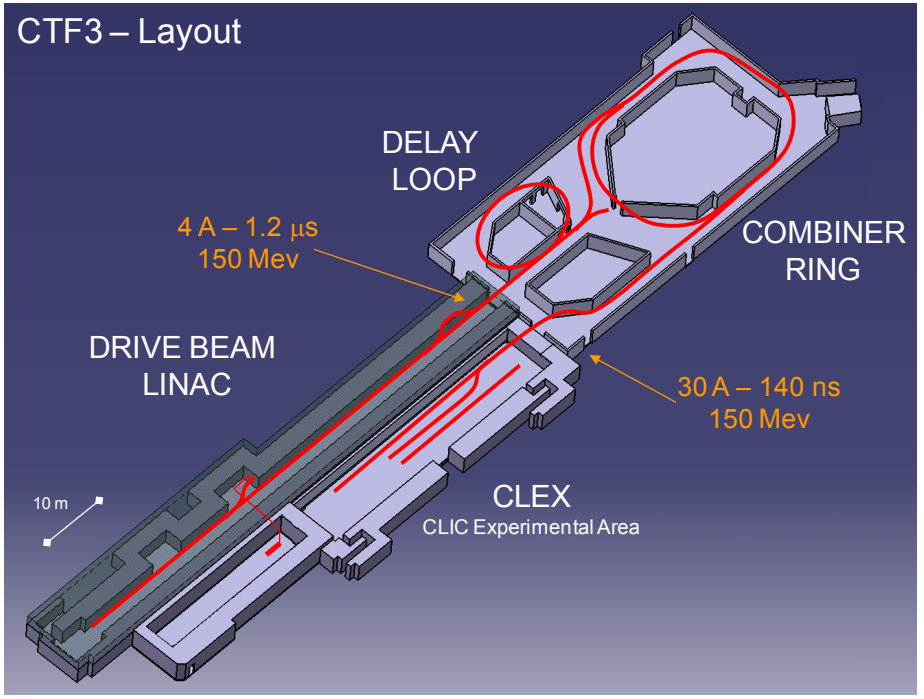
- need higher statistics for BDR measurements
- => increase repetition rate
  - test of 5 Hz running with 4x beam to CLEX TL2 spectrometer successful
    - klystrons OK at 5 Hz
    - radiation well within limits (to be verified when machine drifts)
  - shielding in CLEX towards CTF2 added
  - BPM readout at 5 Hz not operational, CO work in progress
- => running over nights and week-ends
  - RF compression feedback reduced slow machine drifts drastically
  - interlocks (losses, radiation) are in place
  - CCC supervision for beam started
  - could develop repetition rate feedback

Validation of DB scheme

Parameter	Unit	CLIC nominal	Present state	Objective 2011	Objective 2012
I initial	A	7	5	5	5
I final	A	100	28	30	30
Q_b	nC	8.4	4	2.5	2.5
Emittance, norm rms	π mm mrad	≤ 150	100 (end of linac) ~ 150 (y, comb. beam)	≤ 150 (comb. beam)	≤ 150 (comb. beam)
Bunch length	mm	≤ 1	≤ 1 (end of linac)	≤ 1 (comb. beam)	≤ 1 (comb. beam)
E	MeV	2400	120	120	150
T_{pulse} initial	∝s	140	1.4	1.4	1.4
T_{pulse} final	ns	240	140 (240)	140 (240)	140 (240)
Beam Load. Eff.	%	97	95	95	95
Deceleration	%	90	3	30	50
Phase stability @ 12 GHz	degrees	0.2	1	?	
Intensity stability		$7.5 10^{-4}$ to few 10^{-5}	$6\ 10^{-4}$ (linac) few 10^{-3} (DL) 10^{-2} (combined beam)	10^{-3} (combined beam)	

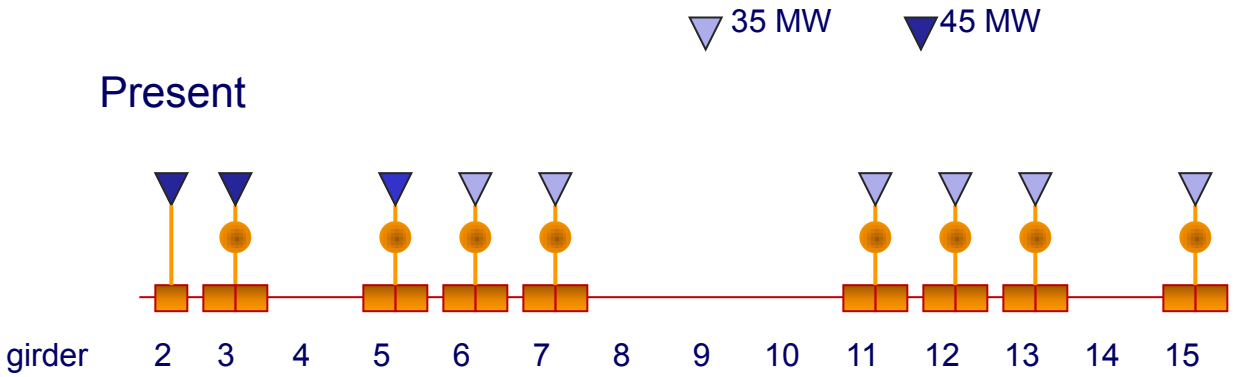
CTF3 limitations





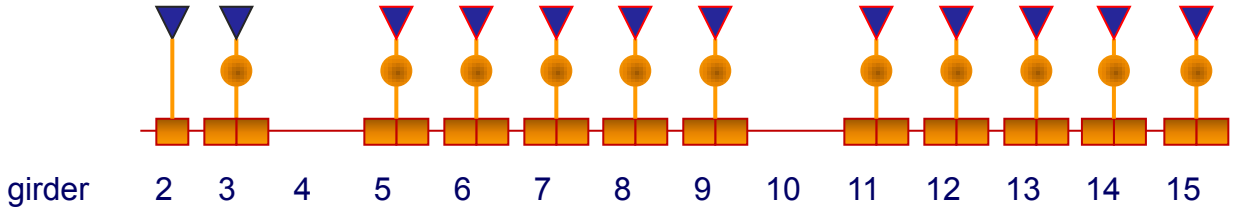
- Combined beam current, limited to ~ 30 A
  (possibly more for shorter pulses)
- Pulse length limited to 140 ns (instead of 240 ns) @ 30 A
  – alternative: 15 A, < 280 ns
- Total drive beam peak power (now ~ 3.5 GW – CLIC 240 GW)

CTF3 beam power upgrade



About 120 MeV
for final beam current of
about 28 A

Total beam power 3.3 GW
e.g., enough to feed
24 accel. structures
(final drive beam energy 50 MeV)



About 200 MeV
for final beam current of
about 28 A

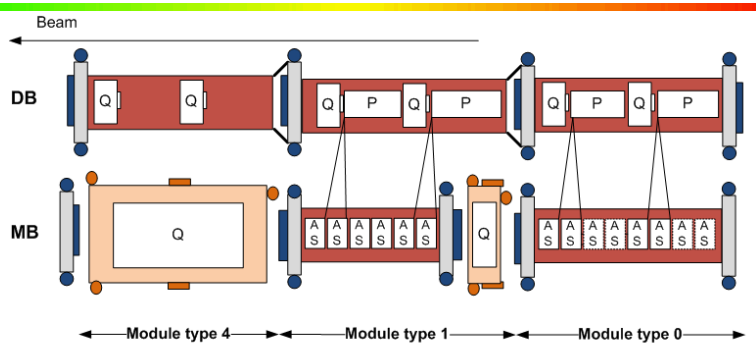
Total beam power 5.7 GW
e.g., enough to feed
50 accel. structures
(final beam energy 50 MeV)

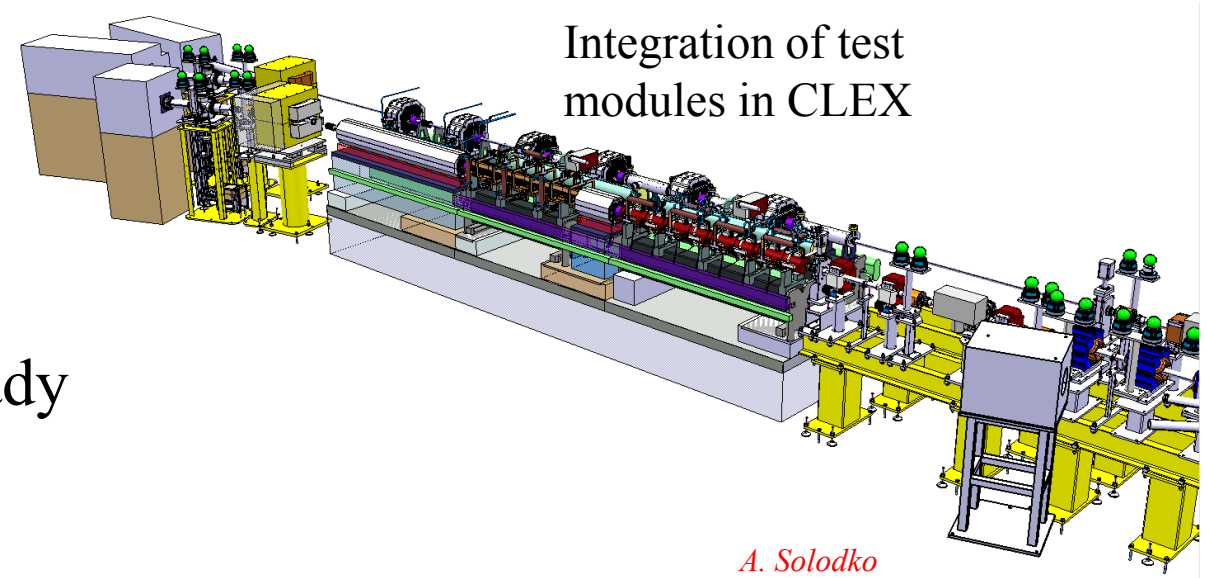
CTF3 beam power upgrade

- Assumptions
  - Need 3 additional power stations
  - All modulators/klystrons upgraded to 45 MW nominal power
  - RF pulse compression factor ~ 2 (about 38 MW/SICA input, including operational limits and losses)
  - 1.3 μs long RF pulse (needed for combination factor 8)
  - Keep girder 10 for diagnostics (emittance, momentum, energy spread)
  - Need new drive beam acc. structures
- Further possibilities ?
  - Add other power stations & structures (girder 10, CT line ?)
  - Further upgrade klystrons
  - Combine klystrons by two, double their number (space problem, maybe exceed structure limits…)

CLIC modules in CLEX

- 3 modules to be tested with beam and RF
- module layout compatible with CLEX requirements:
  - double length PETS feeding two accelerating structures
  - accelerating structures with all technical systems and damping features
- First module to be ready by end of 2011



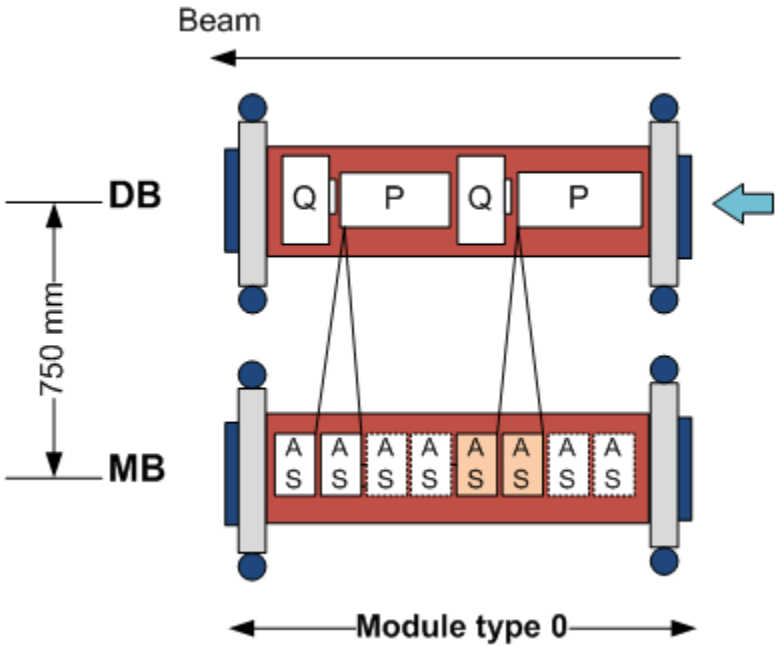


Integration of test modules in CLEX

A. Solodko

PROTOTYPE Module - CLEX: Phase 3

Phase 3 foresees the installation and testing of 1 module type 0: AS equipped with WFM (5 um accuracy / few WFM in the 1st powered AS)

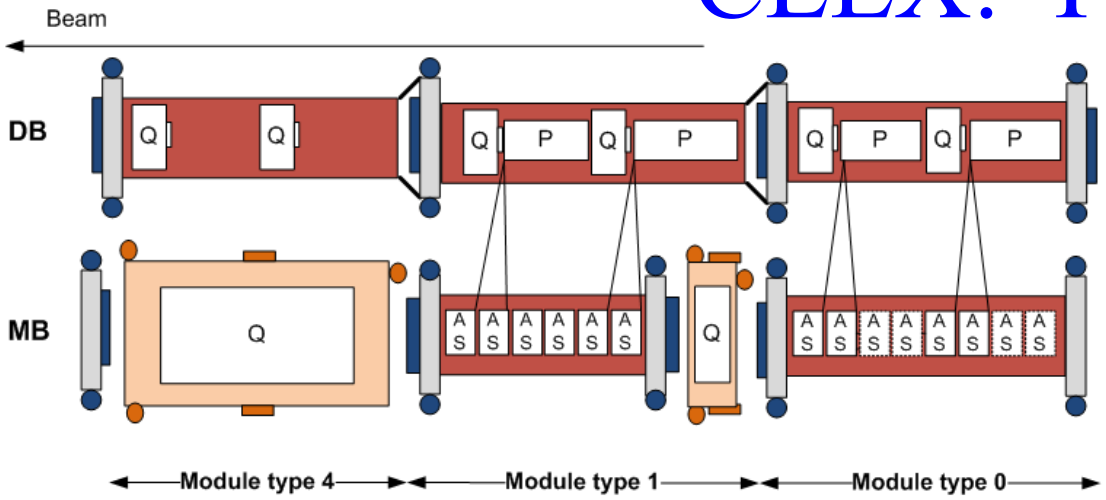


Existing PETS

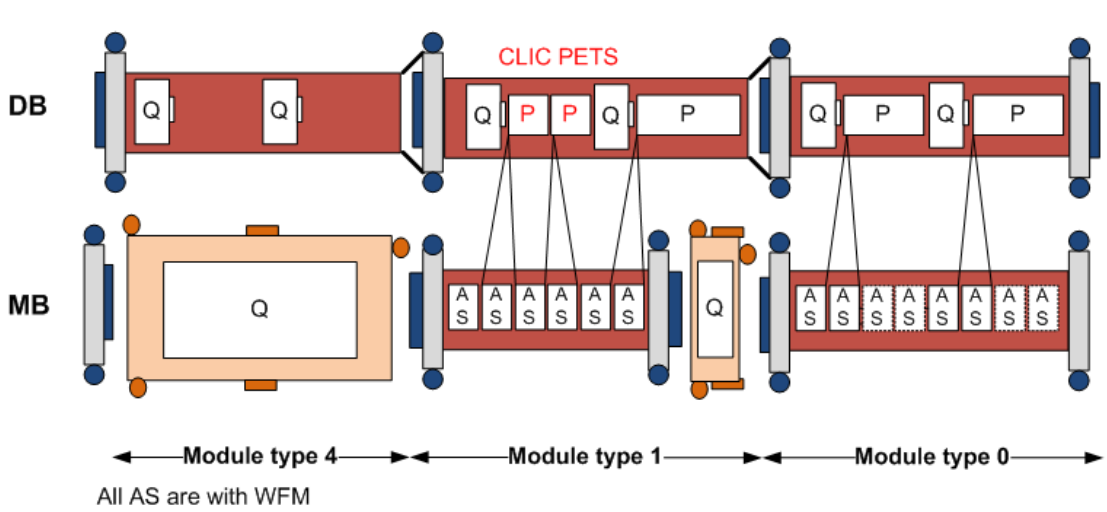
3.1 / Nominal power and pulse length for 1 PETS and 2 AS
Recirculation
12 A and 240 ns

3.2 / No modifications on the module type 0 HW
No Recirculation
Current increase from 12 A to 19.2 A
Pulse length reduced from 240 ns to 140 ns

PROTOTYPE Module - CLEX: Phase 4



No modifications on the module type 0
Addition of new modules - type 1 and 4
Increase of current from 19.2 A to 22 A

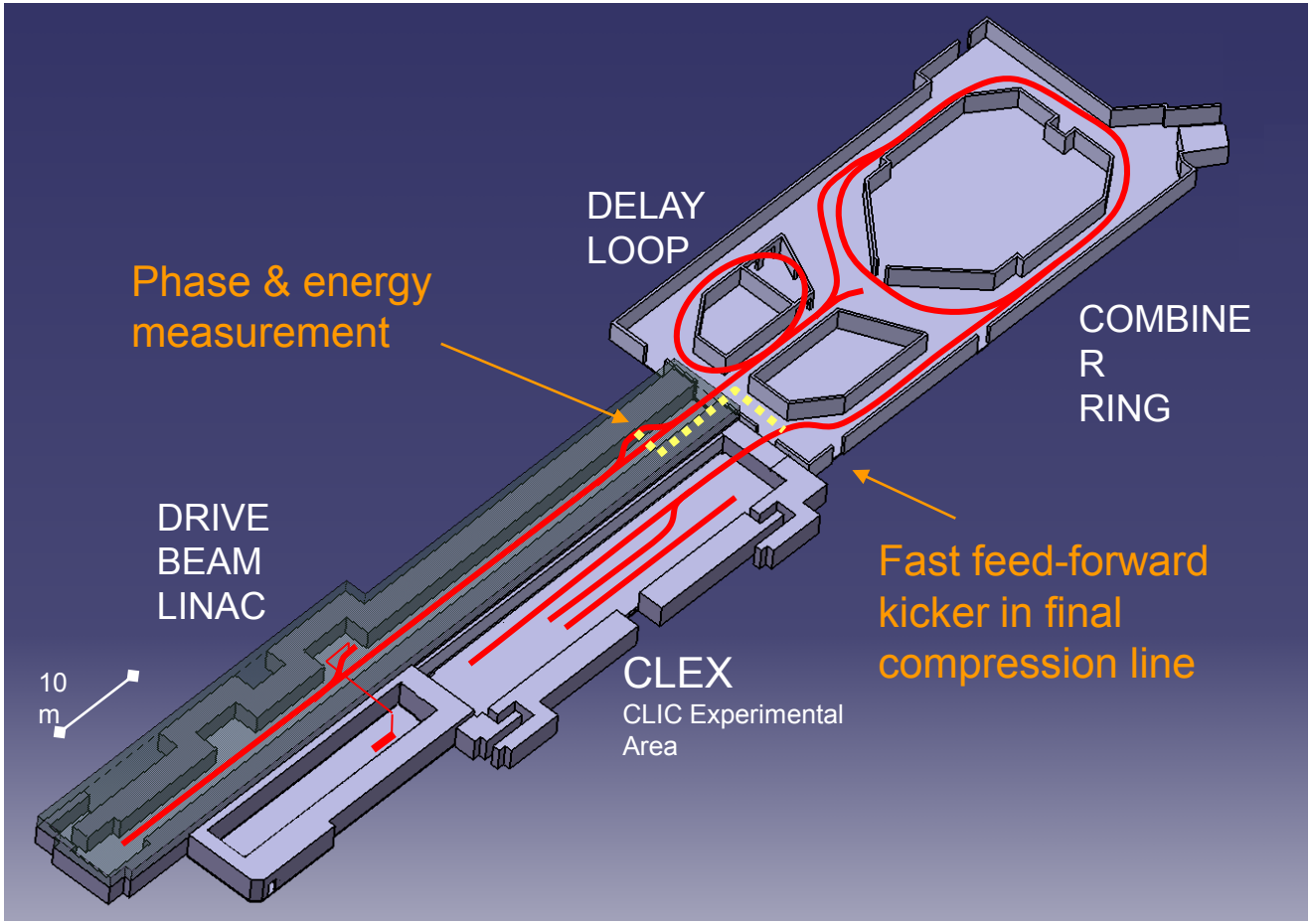


Modification on the module type 1 (2 CLIC PETS)
Needed klystrons and PC

Plans for TBL beyond 2012

- Upgrade to TBL+ as a test facility relevant for CLIC TDR work
- 12 GHz power production for structure conditioning
  - less pulses than klystron test stand but:
    - use of ON/OFF mechanism of PETS
    - precondition with klystron and then with beam
    - => develop conditioning scenario for CLIC conditioning with beam
    - conditioning of PETS
- Working experience with a real decelerator
  - Power production as a function of beam parameters, alignment, stability, pulse shape, phase stability, beam loses, failure modes
- Test bed for PETS development, ON/OFF, new designs, etc
- Beam dynamics studies, pulse shaping, feedbacks, etc
- => more in talk by Steffen Döbert

Phase measurements & feed-forward



- Phase monitor being developed (FP7) for 2012
- => more in following talk of Piotr Skowronski

TD phase - Preliminary schedule

	2010				2011				2012				2013				2014				2015				2016			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
CTF3 TBTS operation	inst.	1-2 structures, beam loading, breakdown kick																										
CTF3 TBL operation	inst.		Deceleration 8 PETS		final decelerator test (16 PETS, 50%)																							
Modules lab	initial tests, installation 2 modules				further tests, installation 4 modules				testing								pre-series production, industrialization											
Modules CTF3								1 module inst.	testing 1 module			3 modules inst.	testing 3 modules											> upgrades?				
CTF3 phase feedback	design, hardware tests							installation	testing																			
CTF3 TBL+								installation	commissio-ning								RF testing, potential upgrades											
CLIC DB injector & linac / CLIC 0-	design						component construction (injector)					installation (inj)	commissioning (inj)				staged upgrade & testing											
RF structures construction	precision metrology, fabr. procedures				up to 40 structures built, establish precision machining at CERN or elsewhere, 5 μm tolerances achieved												more than 200 structures built, final cost optimization, pre-series with industry											
RF test infrastructure	CERN test stand inst.		CERN test stand testing and upgrades (at least two slots)						continue testing with increased capabilities, CERN or elsewhere, up to 10 slots								testing, up to 200 accelerating structures plus PETS and RF components											
Prototypes of critical components	technical choices, design								construction, hardware tests								finalization, performance & cost optimization, industrialization for large scale components											
Other systems, Civil Engineering…	detailed program definition				first phase (CDR baseline)												second phase (new baseline ?, project implementation plan)											
Beam physics studies	CDR activities, feasibility studies						Performance and cost optimization										new baseline? Preparation for commissioning, operational scenarios…											

Beyond CTF3

- Plan to build one full-scale drive beam injector (up to ~ 30 MeV).
  - Thermionic + bunching system solution preferred w.r.t. photoinjector (possibly build both)
  - Time scale around 2013 => see Steffen Döbert's talk
- Need as well at least a few drive beam accelerator modules (klystron/modulator/structure)
  => see talks by Erk Jensen + ?
- Present plan – add modules to arrive gradually at about 200 MeV (first bunch compression stage / 10% of average CLIC beam power))
- Total cost: ~ 100 MCHF (including manpower)

Resources for CTF3+

Warning: Very rough estimates for time being

Project	Time- span	Estimated budget (MCHF)	
Energy upgrade	2011-2013	5	2 MKS +2 ACS
Rep. rate	2011-2013	3	10 Hz
Consolidation, stability, operation	2011-2016	8	feedbacks, spares, etc
Phase feedback + monitor	2011-2014	2	
TBL+	2011-2016	4	Modified tanks + testing infrastructure
Two-beam modules	2013-2016	14.5	17 modules
CLIC DB injector	2011- 2016	28	12 x1 GHz rf stations

Conclusion

- We have a plan to complete CTF3 and extend it for TDR type of studies
- Some choices have to be made
  - how much beam power is needed,
  - how many modules are reasonable
  - how many testing slots in TBL
  - do we want a production facility or dedicated experiments

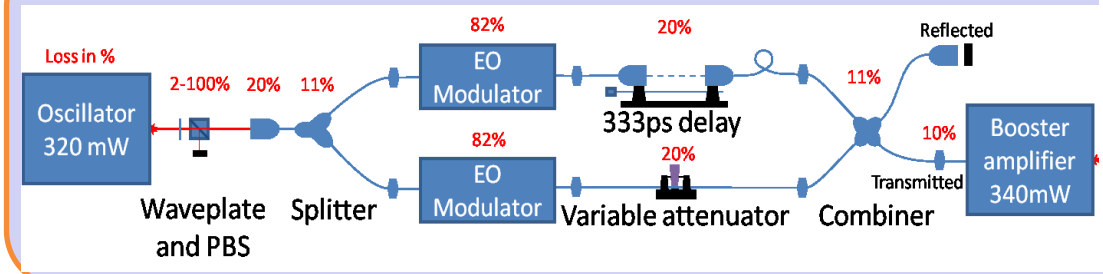
We would like your input for this !

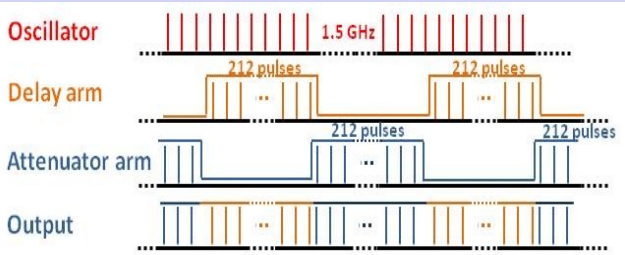
Spares

Phase coding for PHIN

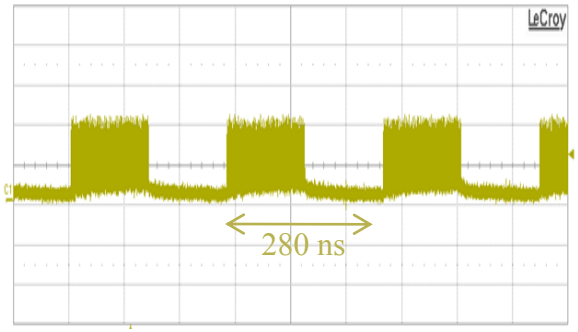
M. Csatari Divall

NEW scheme

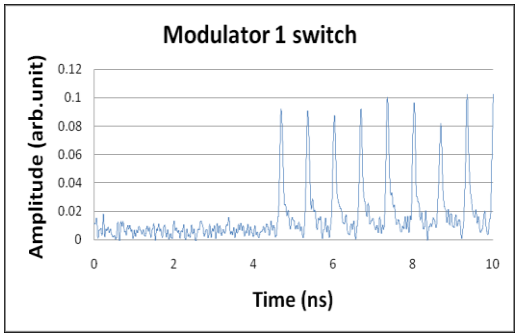




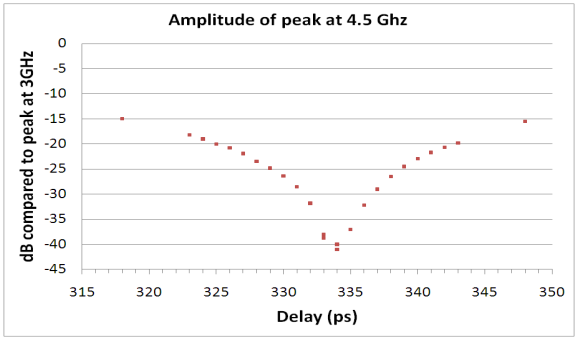
- 2 modulator scheme will be safer against power damage
- Better temperature stability with the 333ps delay
- Stable fiber booster amplifier to reach oscillator power
- Timing signal synched to 1.5 GHz with 300ps rise/fall time
- External photodiode for more stable bias control
- Driver amplifier with flat output response



Switching with one modulator



Clean cutting between pulses



Delay optimization with <1ps accuracy

- Optimization of 2 modulator scheme by end of January/2011
- Integration into laser system for test planned in PHIN February/2011
- Streak measurements on laser and electron beam February/ 2011

Feasibility demonstration

- R1: Feasibility
  - R1.2: Validation of drive beam generation scheme with fully loaded linac operation
  - R1.1: Test of damped accelerating structure at design gradient and pulse length
  - R1.3: Design and test of damped ON/OFF power extraction structure