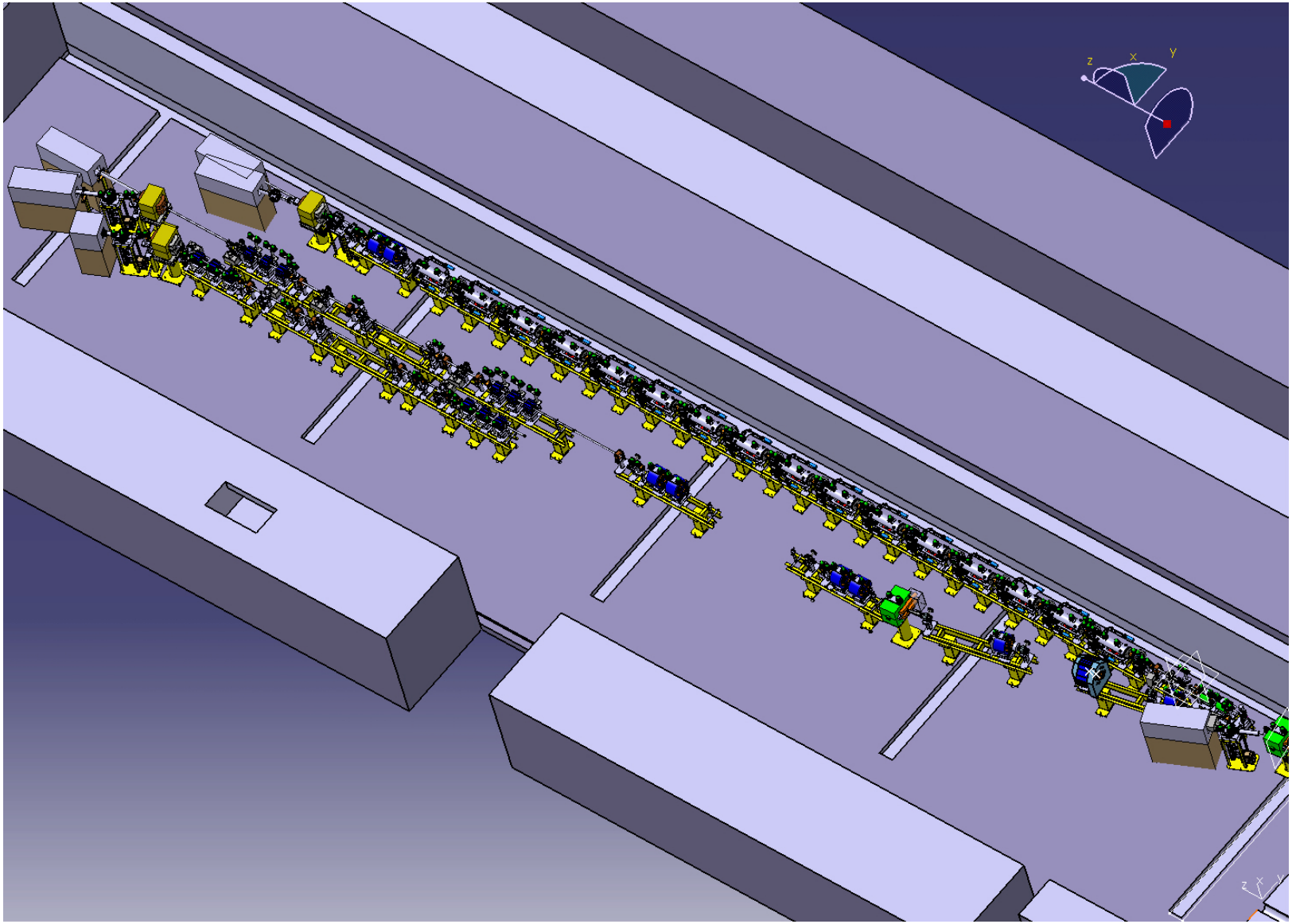
TBL experimental program Status and Results

- Introduction
- Status
- Experimental program for 2010 and beyond
- Outlook

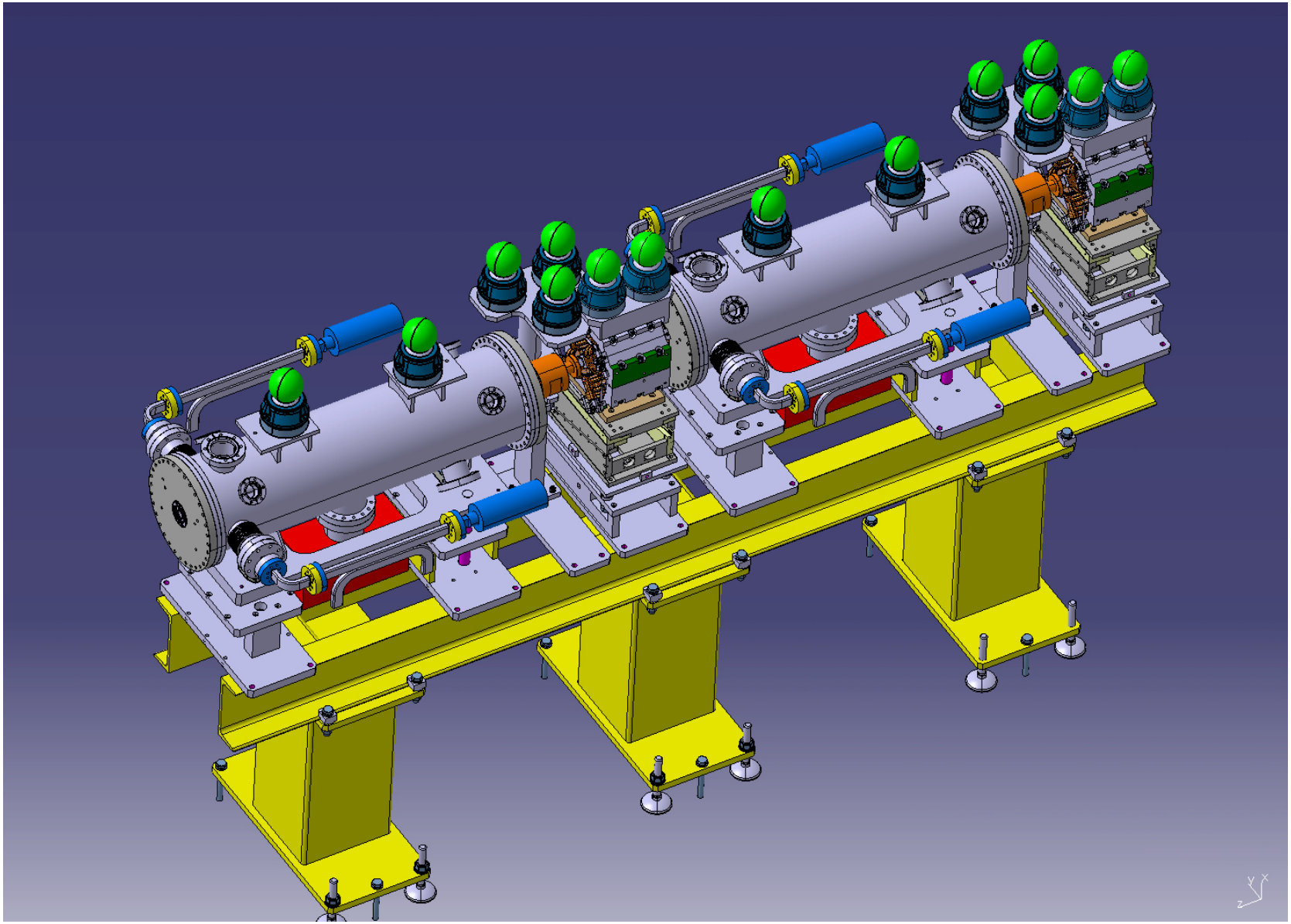
Goals and Requirements

- o High energy spread beam transport, low losses
  (Bench mark simulations)
- o RF Power Production, Stability
  (End Energy <50%, 2.6 GW of RF power)
- o Alignment
  Active Quad alignment with movers
  (Test procedures for BBA, DFS)
  100 microns pre-alignment for PETS
- o Drive Beam Stability, Wake fields
  (no direct measurement of the wake fields)
- o 'Realistic' show case of a CLIC decelerator
- o Industrialization of complicated RF components

TBL integration into CLEX



TBL cell



Status

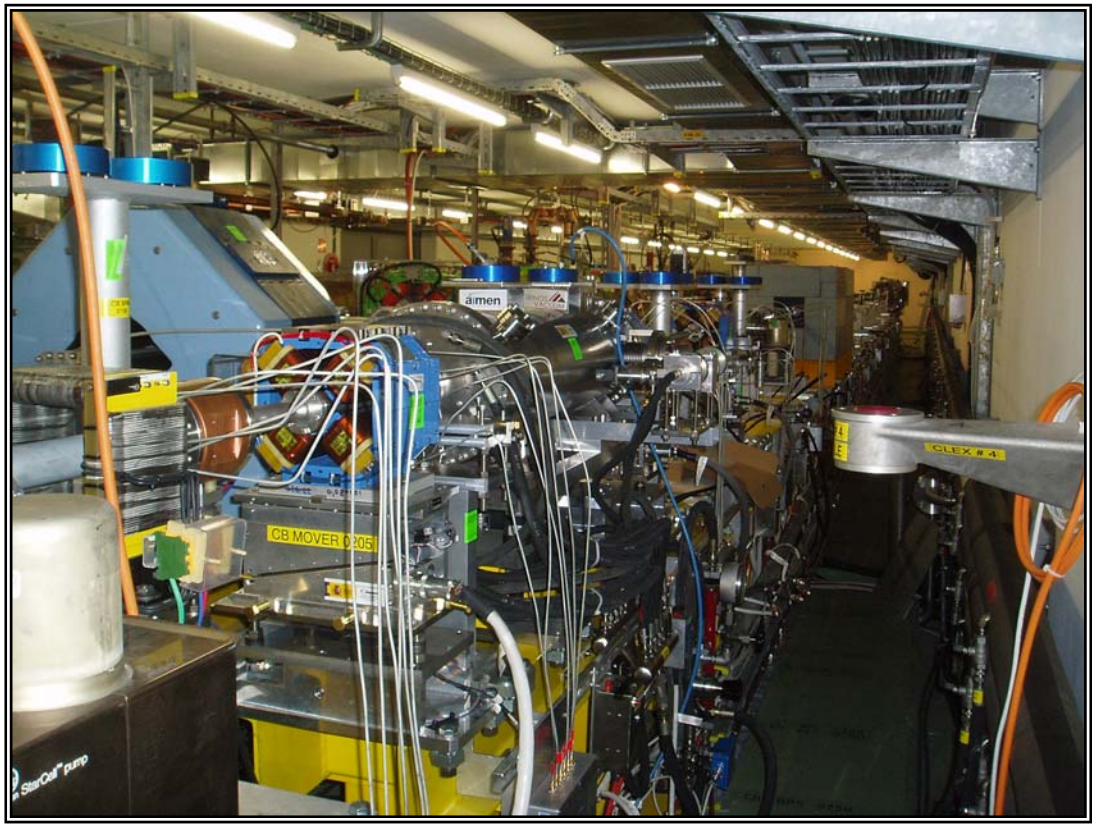
- Installation of prototype beam line completed, waiting for beam
  (3 Quads on movers, 3 BPM's and 1 PETS tank with undamped PETS)
- Beam line without PETS tanks will be finished this fall

Prototyping:

- PETS tank: engineered and manufactured by CIEMAT
  (low level measurements performed and accepted)
- BPM's: smaller version of CTF3 type BPM, made by IFC Valencia
  Electronics from UPC Barcelona and LAPP Annecy
  (basic tests with beam done)
- Quads: Designed at CERN and manufactured by BINP Russia
- Quad-Movers: engineered and manufactured by CIEMAT
  (tests demonstrated the micron level accuracy)

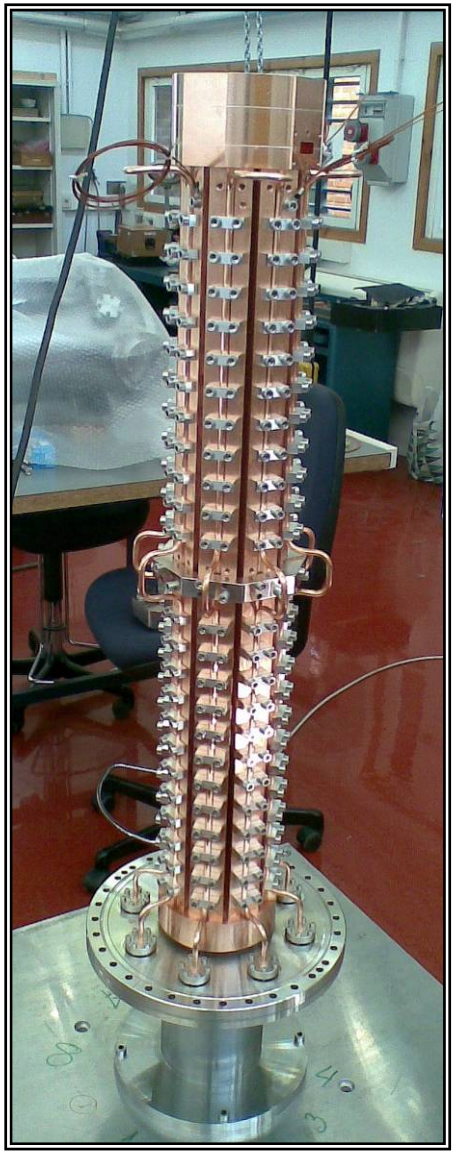
TBL prototype beam line spring 2009

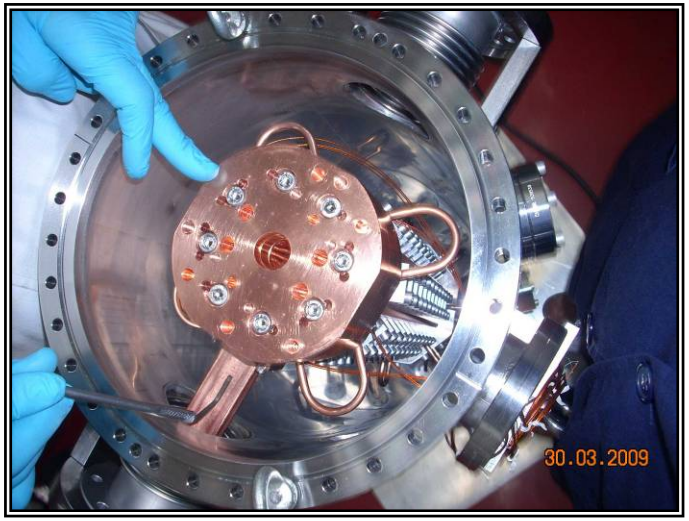
Beam line girders



First part, prototype module

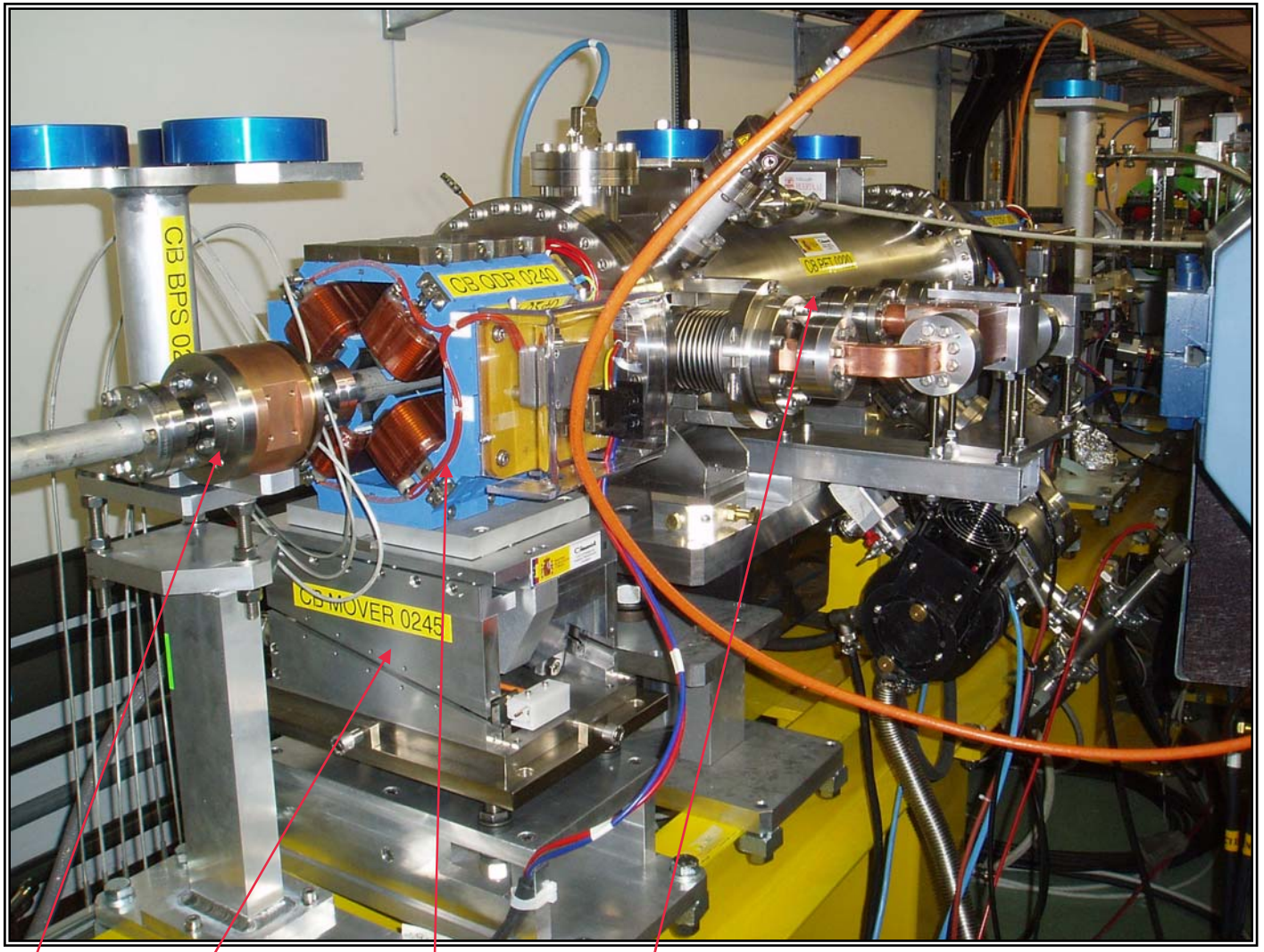
PETS tank assembly at CIEMAT





Happy Team after finishing the first tank

TBL prototype beam line spring 2009



BPM, Quad Mover, Quad, PETS-tank

The current plan for TBL

- Due to the long lead time to produce the PETS structures TBL can't be completed before 2011

- Organize and launch production of at least 7 more PETS with our collaborations to be commissioned with beam in 2010.
  Approach: parallel fabrication at CIEMAT and CERN
  using multiples vendors
- CDR demonstration measurement milestones at the end of 2010
- Assuming continuous production with two vendors in parallel
  TBL could be completed in 2011 profiting from first series experience
  Second batch has to be launched early 2010
- Full demonstration of drive beam decelerator end of 2011

Status of series production (batch of 8)

- Market survey for PETS bars launched MS-3642/BE/CLIC
- Specification meeting 29.5.2009
- Call for Tender 5.6.2009
- Closing of Tender 15.7.2009
- Pre series, October 2009
- 8 PETS installed in CLEX, August 2010

! We still have not identified the damping material to be used in the PETS

What can we expect in 2010 for the CDR

- Unlikely to install more than 8 PETS until mid 2010
- Can we declare feasibility with only 8 PETS ?

8 PETS only

E_0 = 130 MeV

I=28 A

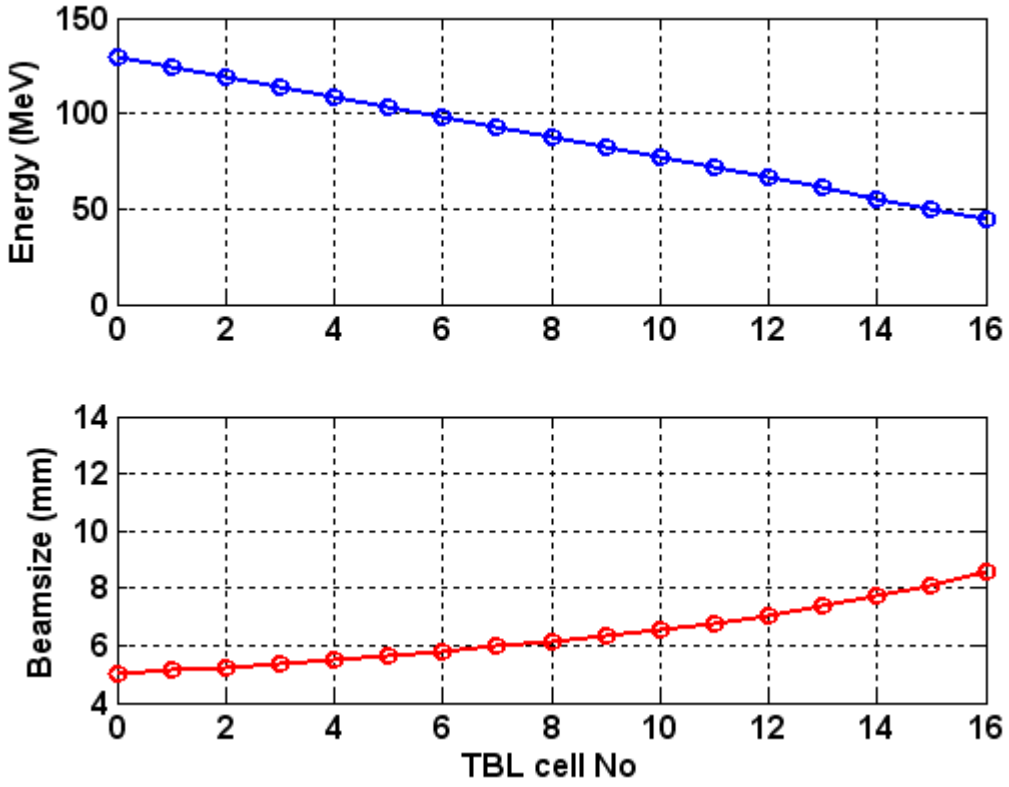
Eff = 33 %
(was 65% for 16)

1.2 GW of rf power

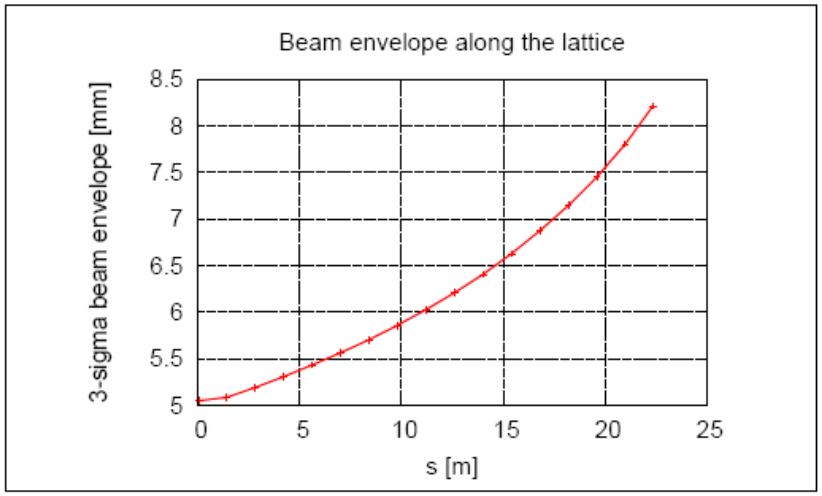
E_0 = 100 MeV

I=28 A

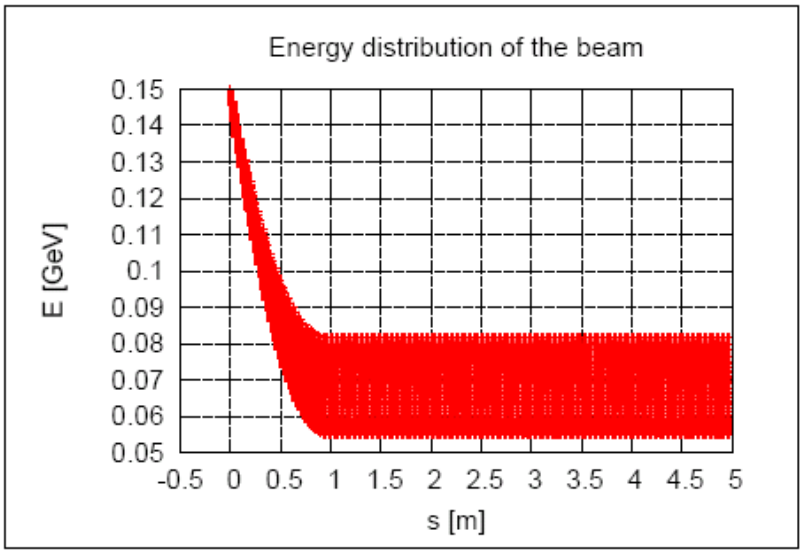
Eff = 42 %



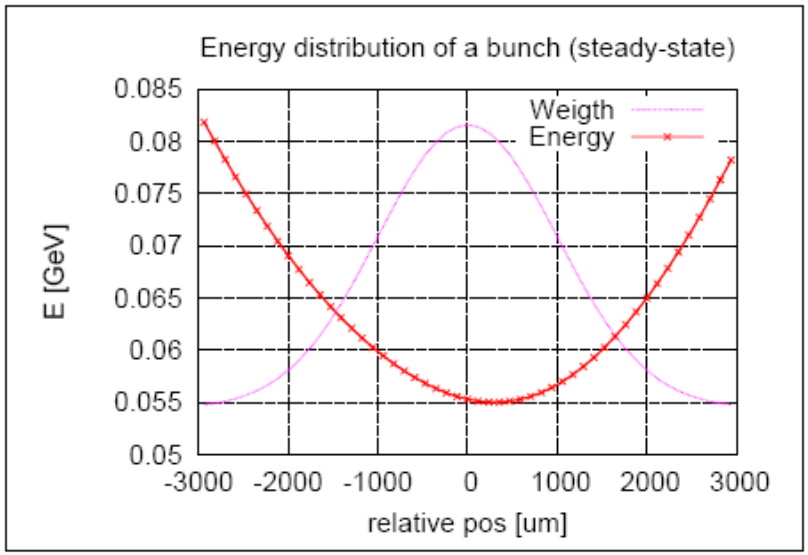
TBL beam dynamics



3-σ beam envelope along lattice (adiabatic effects alone)



Beam energy after lattice



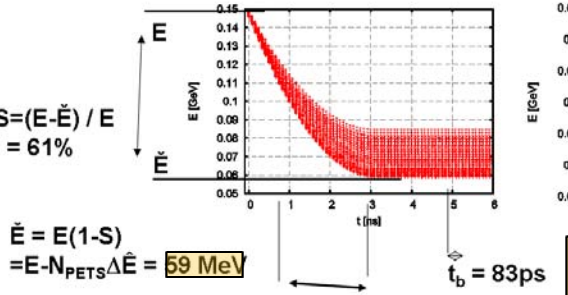
Steady state bunch energy profile

1m ~ 3 ns

TBL versus CLIC

Parameters	Symbol	TBL value	CLIC value	Unit
Number of FODO cells	N_{cell}	8	500	-
Bunch separation	z_{bb}	25	25	mm
Bunch rms length	σ_z	1	1	mm
Pulse length	t_{pulse}	140	240	ns
Transient length	$t_{transient}$	3	1	ns
Initial average current	I_0	30	100	A
Power production	P	159	135	MW
Initial energy	E_0	150	2400	MeV
Final min. energy	E_{min}	59	240	MeV
Final max. energy spread	S	61	90	-
Initial norm. emit.	$\epsilon_{n\,x,y}$	150	150	μm rad

TBL

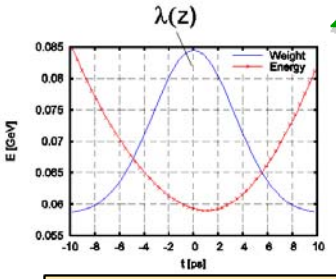


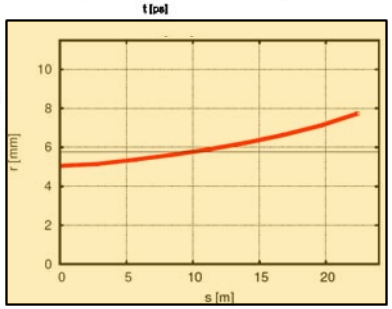
S=(E-Ě) / E = 61%

Ě = E(1-S) =E-N_{PETS}ΔÊ = 59 MeV

t_b = 83ps

t_{fill} = (L_{PETS}/v_g)(1-β_g) $_g$ = 3ns





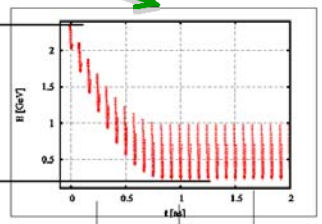
Power extracted from beam (ss) :

P ≈ (1/4) I^2 L_{pets}^2 $F(\sigma)^2$ (R'/Q) ω_b / v_g = 159 MW

Power extraction efficiency (ss) :

$\eta = E_{in}/E_{ext}$ = 59%

CLIC

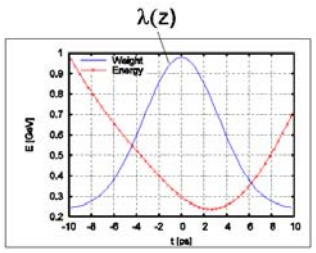


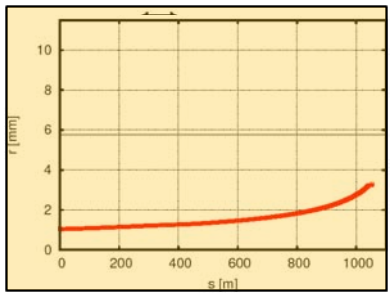
S=(E-Ě) / E = 90%

Ě = E(1-S) =E-N_{PETS}ΔÊ = 240 MeV

t_b = 83ps

t_{fill} = (L_{PETS}/v_g)(1-β_g) $_g$ = 1ns





Power extracted from beam (ss) :

P ≈ (1/4) I^2 L_{pets}^2 FF^2 (R'/Q) ω_b / v_g = 136 MW

Power extraction efficiency (ss) :

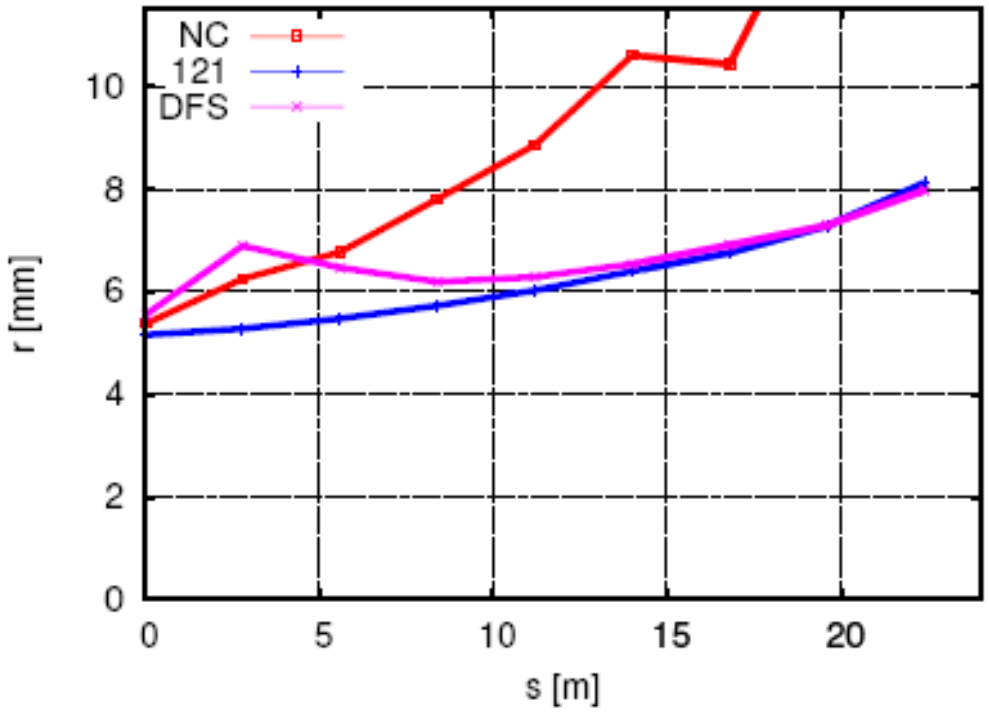
$\eta = E_{in}/E_{ext}$ = S FF η_{dist} = 84%

TBL versus CLIC – quad kicks

Effect of σ_{quads} = 20 μm
- **CLIC: r_c = 16 mm**
- **TBL: r_c = 2.1 mm**

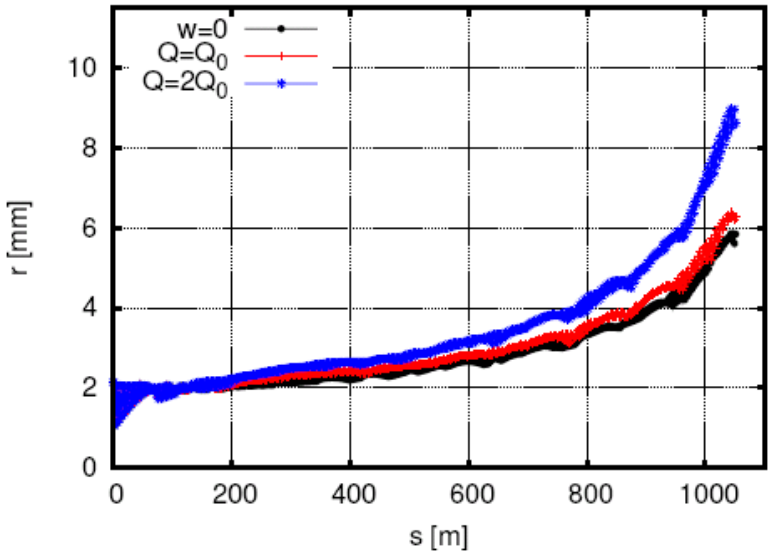
$\Rightarrow$ **Precise quadrupole alignment is also required for the TBL. σ_{quads} = 20 μm leads to small increase in beam envelope while σ_{quads} = 100 μm implies that BBA might be required**

TBL with σ_{quads} = 100 μm

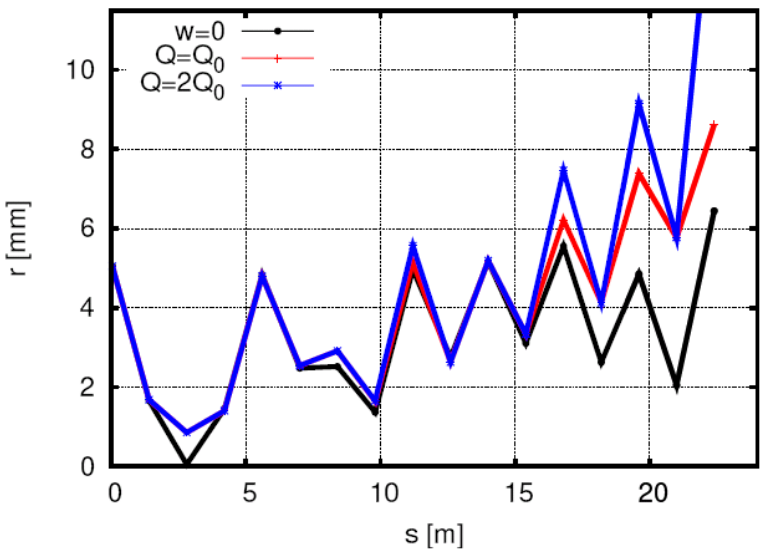


TBL versus CLIC – transverse wakes

Transverse wake amplification CLIC



Transverse wake amplification TBL



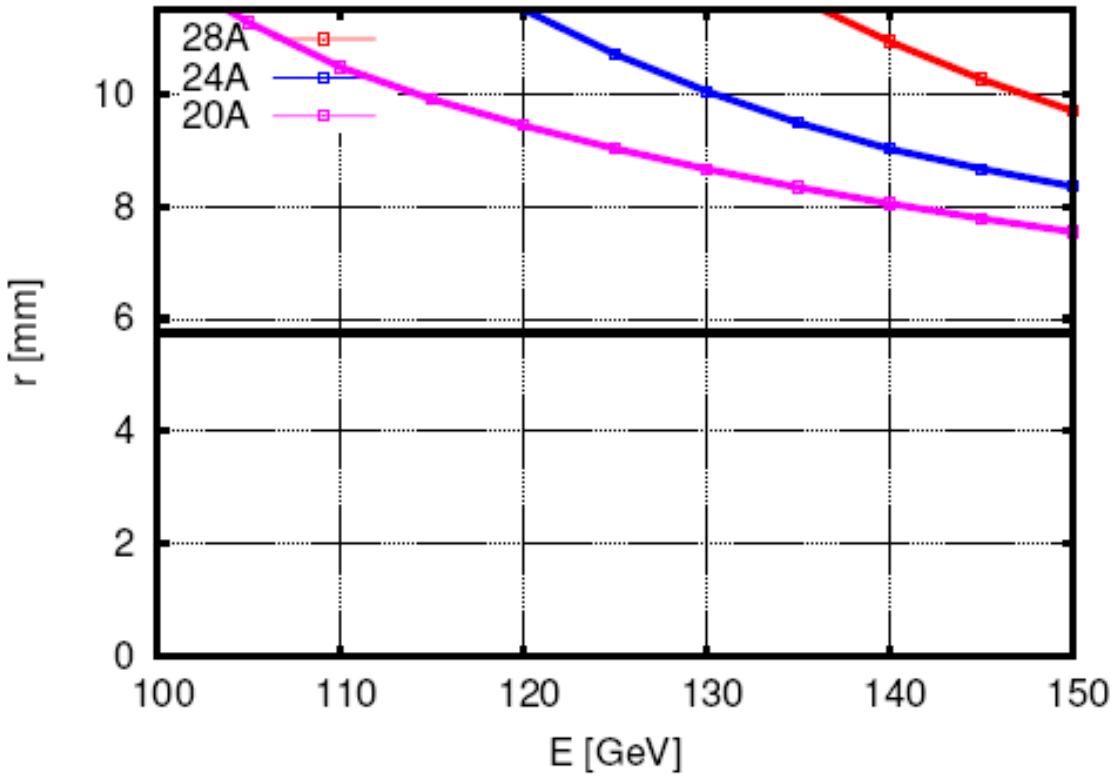
Effect of σ_{PETS} = 100 μm
- **CLIC: r_c = 0.6 mm**
- **TBL: r_c = 0.5 mm**

$\Rightarrow$

Precise PETS alignment (100 μm) is also required for the TBL

Energy, Current issues

Maximum beam size after 16 PETS for different energies and currents



A 3-sigma transport through TBL looks like a difficult task, but if we come close to it, it will be a great step towards proving feasibility of the CLIC decelerator

TBL diagnostics

What can we measure in TBL:

Power production: Energy balance % level, rf-pulse stability
(amplitude % level, phase ~1 deg
order of magnitude worse than needed in CLIC)

Efficiency: Low loss beam transport % level

Transverse Phase Space: Beam size, Emittance; 10 % level

Energy spread compared to simulation: %-level

Time resolved energy spread: 10 ns

Longitudinal profile: streak camera; ps-level

Is this sufficient ?

Experiments with TBL in 2009

- Evaluation of PETS tank prototype with beam and high power (Ideal: produce > 100 MW = 24A)
- Produce > 20 A drive beam (~ 80 MW)
- Resolution measurement of BPS (5 microns specified)
- Beam based quad alignment with mover (5 micron level)
- Commission beam line and diagnostics
- Transport beam with 2 or 3 PETS installed
- Measure beam properties, transverse and longitudinal

Experiments with TBL in 2010 for CDR

- Produce nominal 28 A beam and nominal CLIC power (135 MW) with at least 8 PETS and 100% transmission (120 MeV from CTF3) This corresponds to 35 % power extraction
- Beam based quad alignment with movers to optimize transmission and transverse beam parameters
- Detailed energy and energy spread measurements to verify deceleration.
- Streak camera measurements before and after TBL
- Monitor rf power production stability, amplitude and phase (% level in amplitude, 1 degree in phase)
- Measure beam properties and compare with simulations
- Controlled misalignment of quads, measure effect ?
- Controlled beam offset in PETS, measure effect ?

Conclusions and Outlook

- TBL with 8 PETS for 2010 possible but on a tight schedule
- Basic set of measurements possible for CDR with a reduced scope
- Impressive set of hardware for power production
- Important exercise towards a CLIC decelerator
- Some more reflection and simulations needed for the experiments
- Very nice effort of the CTF3 collaboration

- Finish up TBL with 16 PETS and demonstrate stable operation, complete measurements (end of 2011)
- Emerging plans to use TBL for power production in TDR phase