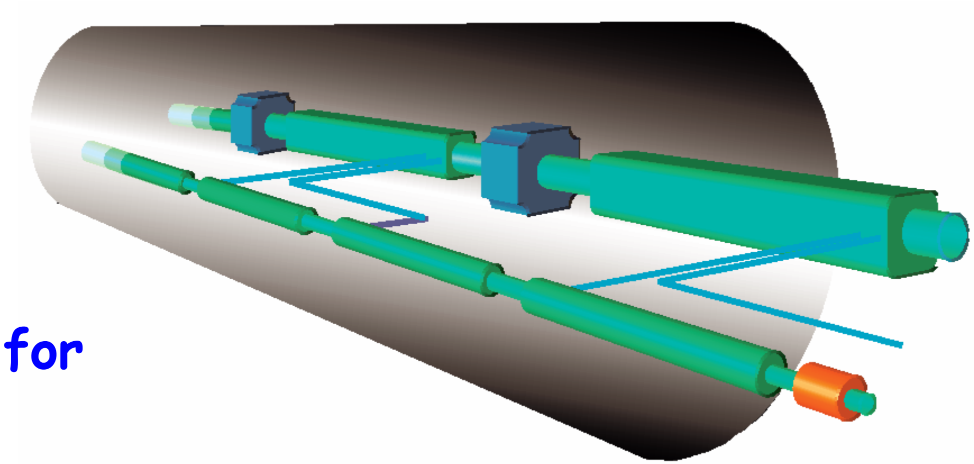
CLIC

STATUS and TRENDS of the COMPACT LINEAR COLLIDER (CLIC) STUDY



J.P.Delahaye for

The Compact LInear Collider Study Team

&

The CLIC/CTF3 Collaboration

http://clic-study.web.cern.ch/CLIC-Study/

OUTLINE

- **Linear Colliders in the HEP world-wide landscape**
- **The Compact Linear Collider (CLIC) concept**
  - **Design and new parameters recently adopted**
  - **Main challenges and key issues**
  - **The facilities to address the feasibility issues**
  - **Plans and schedule**
- **Fruitful contribution of Russian Institutes**
- **Conclusion**

High Energy Physics after LHC
a world-wide consensus

CLIC

In 1999 ICFA pointed out:
- compelling and unique scientific opportunities at a linear electron-positron collider in the TeV energy range.
- a necessary complement to the LHC hadron collider under construction at CERN.

Two options:

- **ILC based on SC technology in the TeV energy range (W.Bialowons)**
- **CLIC based on novel Two Beam scheme in the Multi-TeV energy range**
- **Close collaboration on common issues**

The European strategy *for particle physics*

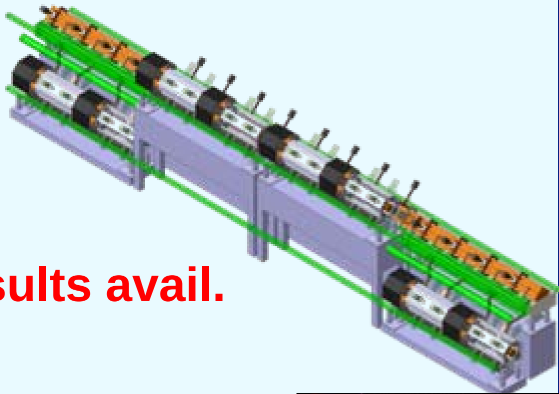
Unanimously approved by the CERN Council at the special Session held in Lisbon on 14 July 2006

4. In order to be in the position to push the energy and luminosity frontier even further it is vital to strengthen the advanced accelerator R&D programme; *a coordinated programme should be intensified, to develop the CLIC technology and high performance magnets for future accelerators, and to play a significant role in the study and development of a high-intensity neutrino facility.*

5. It is fundamental to complement the results of the LHC with measurements at a linear collider. In the energy range of 0.5 to 1 TeV, the ILC, based on superconducting technology, will provide a unique scientific opportunity at the precision frontier; *there should be a strong well-coordinated European activity, including CERN, through the Global Design Effort, for its design and technical preparation towards the construction decision, to be ready for a new assessment by Council around 2010.*

CERN/2685

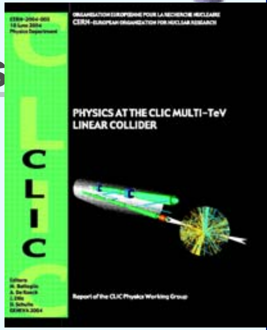
Site independent feasibility study aiming at the development of a realistic technology to extend e-/e+ linear colliders into the Multi-TeV energy range:



- ✓ E_{CM} energy range complementary to LHC
  =>E_{CM} = 0.5- 3 TeV
- ✓ L > few 10^{34} cm^{-2} with acceptable background
  ⇒ E_{CM} and L to be reviewed when LHC physics results avail.
- ✓ Affordable cost and power consumption

Physics motivation: http://clicphysics.web.cern.ch/CLICphysics

"Physics at the CLIC Multi-TeV Linear Collider:
by the CLIC Physics Working Group:CERN 2004-5



Present goal:

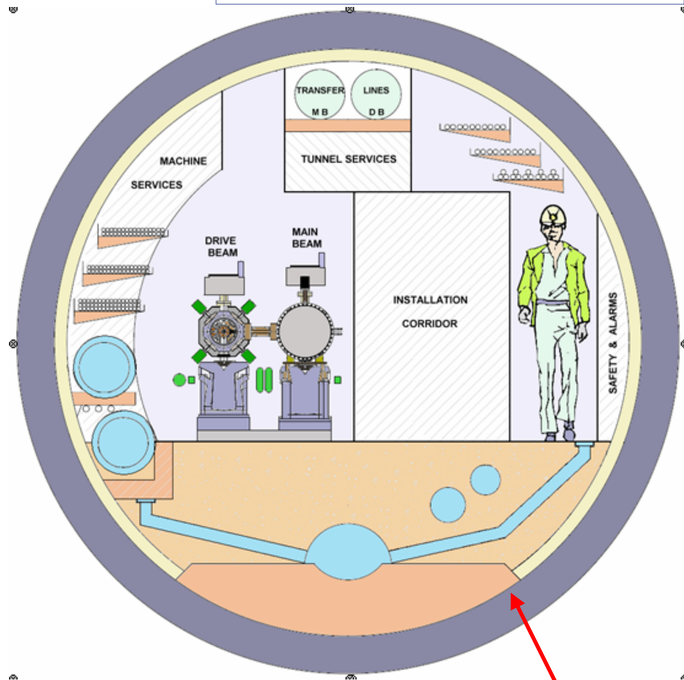
Design of a Linear Collider based on CLIC technology and address all key feasibility issues described in a Conceptual Design Report including Cost estimation by 2010

CLIC – basic features

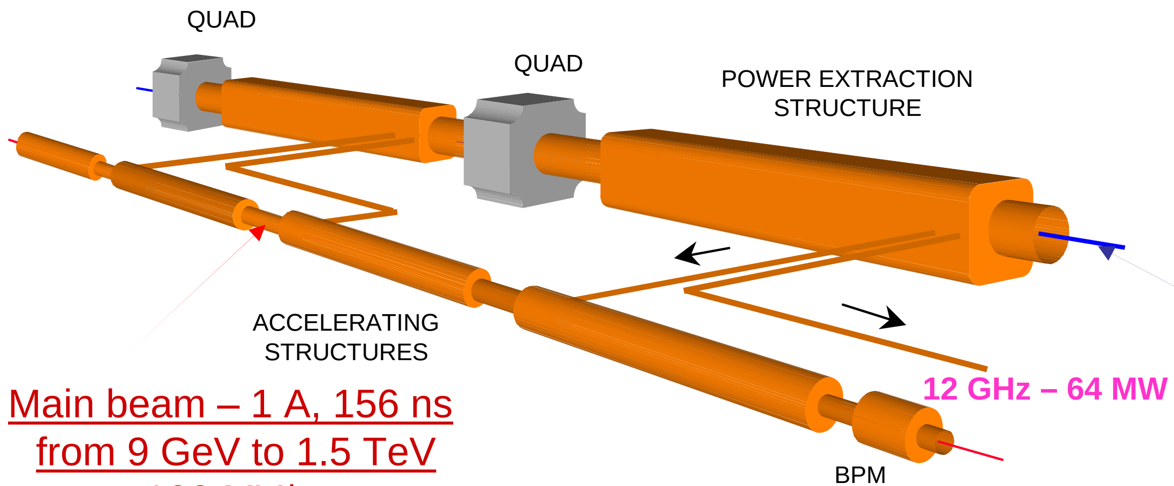
- **High acceleration gradient: > 100 MV/m**
- "Compact" collider – total length < 50 km at 3 TeV
- Normal conducting acceleration structures at high frequency

- **Novel Two-Beam Acceleration Scheme**
  - Cost effective, reliable, efficient
  - Simple tunnel, no active elements
  - Modular, easy energy upgrade in stages

CLIC TUNNEL CROSS-SECTION

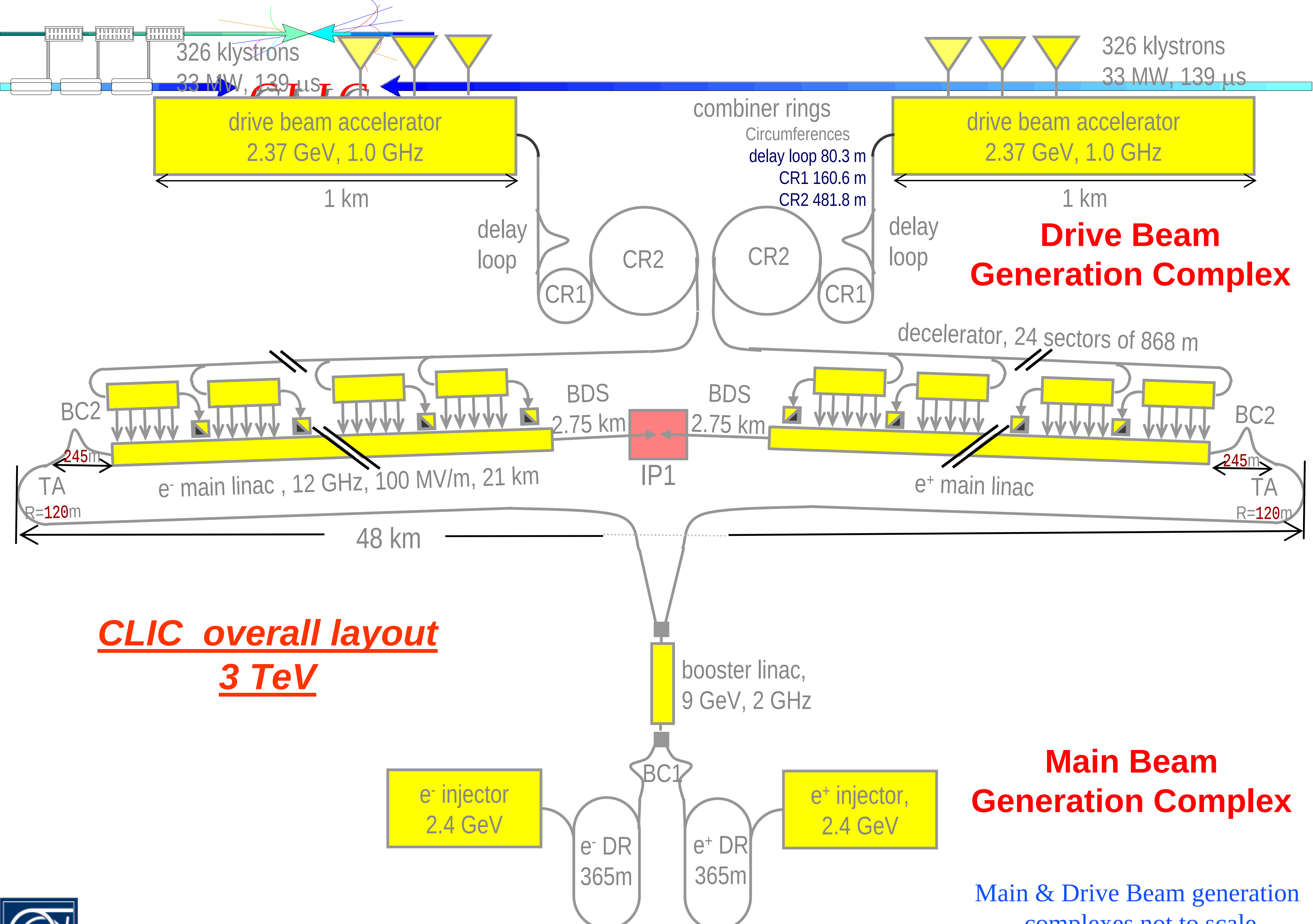


4.5 m diameter



Main beam – 1 A, 156 ns
from 9 GeV to 1.5 TeV
100 MV/m

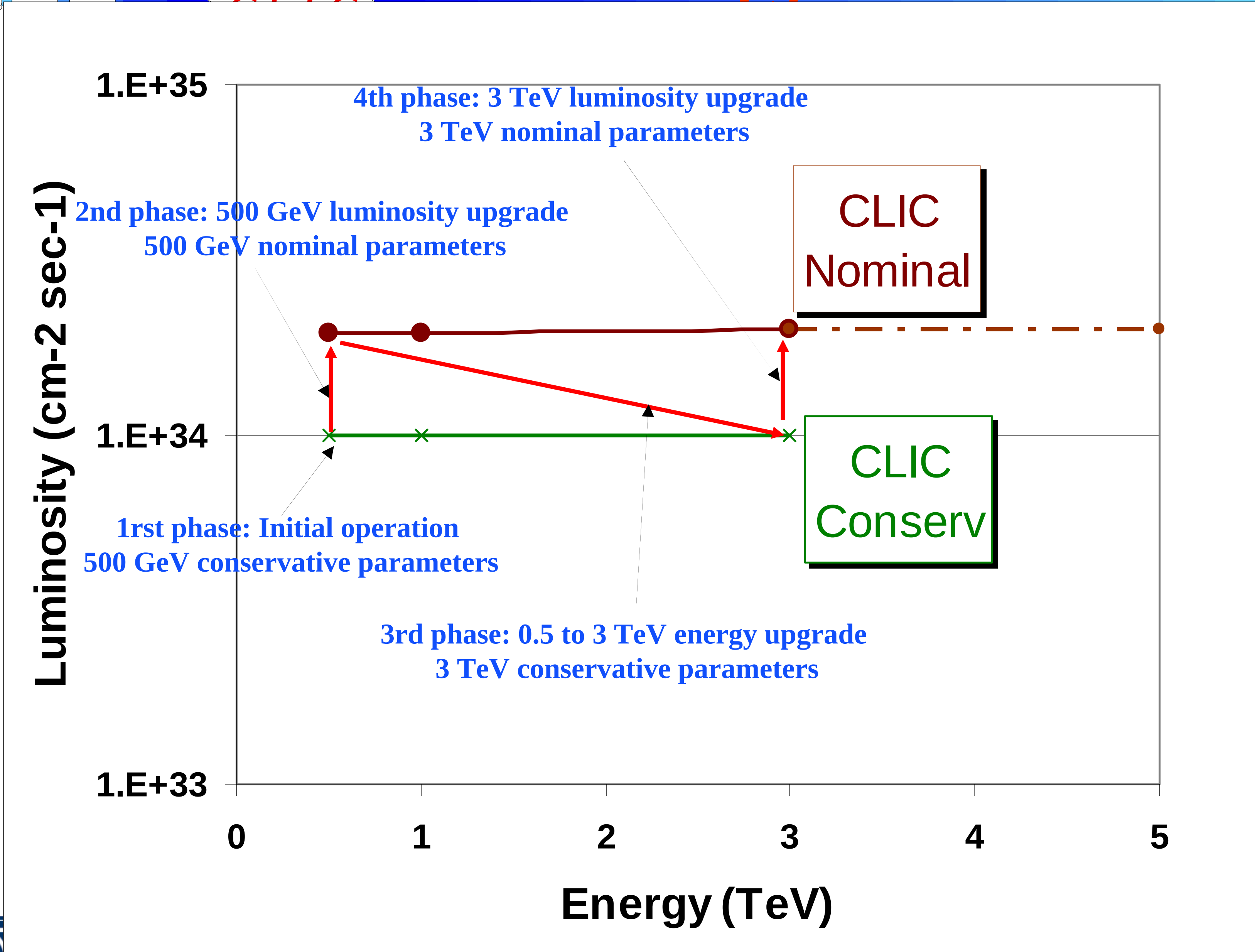
Drive beam - 95 A, 240 ns
from 2.4 GeV to 240 MeV



CLIC overall layout 3 TeV

Main & Drive Beam generation complexes not to scale

CLIC upgrade scenario



New CLIC main parameters

http://clic-meeting.web.cern.ch/clic-meeting/clictable2007.html

http://cdsweb.cern.ch/record/950185

Center-of-mass energy	CLIC 500 G		CLIC 3 TeV	
Beam parameters	Conservative	Nominal	Conservativ	Nominal
Accelerating structure	502		G	
Peak luminosity (1% of energy)	$1.0 \cdot 10^{34}$	$2.0 \cdot 10^{34}$	$1.1 \cdot 10^{34}$	$2 \cdot 10^{34}$
Repetition rate (Hz)	50			
Loaded accel. gradient MV/m	80		100	
Main linac RF frequency GHz	12			
Overall linac length km	4.4		20.8	
Bunch charge10^9	6.8		3.72	
Bunch separation ns	0.5			
Beam pulse duration (ns)	177		156	
Beam power/beam MWatts	4.9		14	
Hor./vert. norm. emitt (10^{-6}/10^{-9})	3 / 40	1 / 30	1 / 30	0.66 / 20
Hor/Vert FF focusing (mm)	8 / 0.1			4 / 0.1
Hor./vert. IP beam size (nm)	221 / 2.8	128 / 2.5	70 / 1.1	40 / 1
Total site length km	12.8		48.3	
Wall plug to beam transfert eff	7.8%		7.2%	
Total power consumption MW	125.6		389	

New CLIC main parameters *(under progress)*

http://clic-meeting.web.cern.ch/clic-meeting/clictable2007.html;

http://cdsweb.cern.ch/record/950185

Center-of-mass energy	NLC 500 GeV	ILC 500 GeV	CLIC 500 G Conservativ	CLIC 500 G Nominal
Peak luminosity (1% of energy)	$2 \cdot 10^{34}$	$2 \cdot 10^{34}$	$1.0 \cdot 10^{34}$	$2.0 \cdot 10^{34}$
Repetition rate (Hz)	120	5	50	
Loaded accel. gradient MV/m	50	33.5	80	
Main linac RF frequency GHz	11.4	1.3 (SC)	12	
Overall linac length km	7	11	4.4	
Bunch charge 10^9	7.5	20	6.8	
Bunch separation ns	1.4	176	0.5	
Beam pulse duration (ns)	400	1000	177	
Beam power/linac (MWatts)	6.9	10.2	4.9	
Hor./vert. norm. emitt ($10^{-6}/10^{-9}$)	3.6/40	10/40	3 / 40	1 / 30
Hor/Vert FF focusing (mm)	8/0.11	20/0.4	8/0.1	
Hor./vert. IP beam size (nm)	243/3	640/5.7	221 / 2.8	128/ 2.5
Total site length (km)	18	31	12.8	
Wall plug to beam transfer eff.	7.1%	9.4%	7.8%	
Total power consumption MW	195	216	125.6	

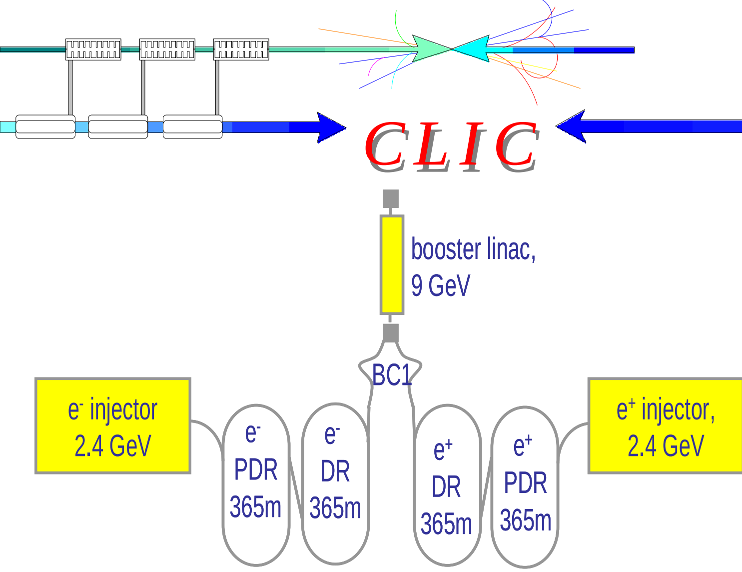
Linear Collider major parameters and challenges

- **Luminosity:**

$$L = \frac{k_b N_b^2 f_{rep}}{4\pi U_{cm}\, \sigma_x^{*}\, \sigma_y^{*}} \propto \frac{\underbrace{\delta_B^{1/2}}_{\text{energy loss by beamstrahlung}} \times \underbrace{\eta_{beam}^{AC}}_{\text{wall-plug to beam efficiency}} \times \underbrace{P_{AC}}_{\text{wall-plug power}}}{\underbrace{U_{cm}}_{\text{center-of-mass energy}}\ \underbrace{\varepsilon_{ny}^{*\ 1/2}}_{\text{Vertical emittance}}}$$

- High Beam Power (several MWatts)
- Wall-plug to beam transfer efficiency as high as possible (several %)
- Generation & preservation of beam emittances at I.P. as small as possible (few nmrad)
- Beam focusing to very small dimentions at IP (few nm)
- Beamstrahlung energy spread increasing with c.m. colliding energies

Beam Emittances

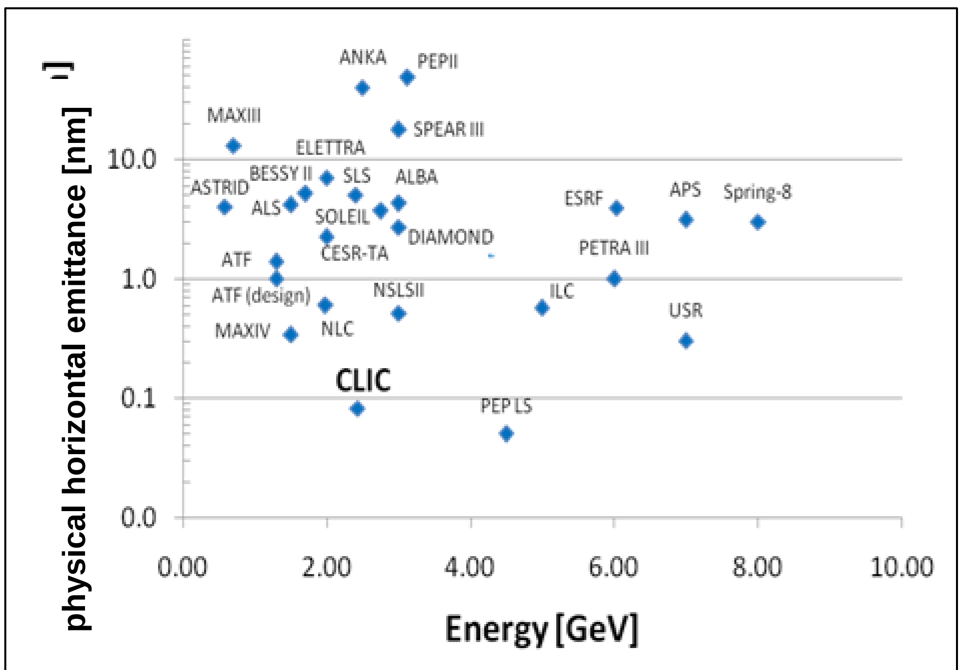


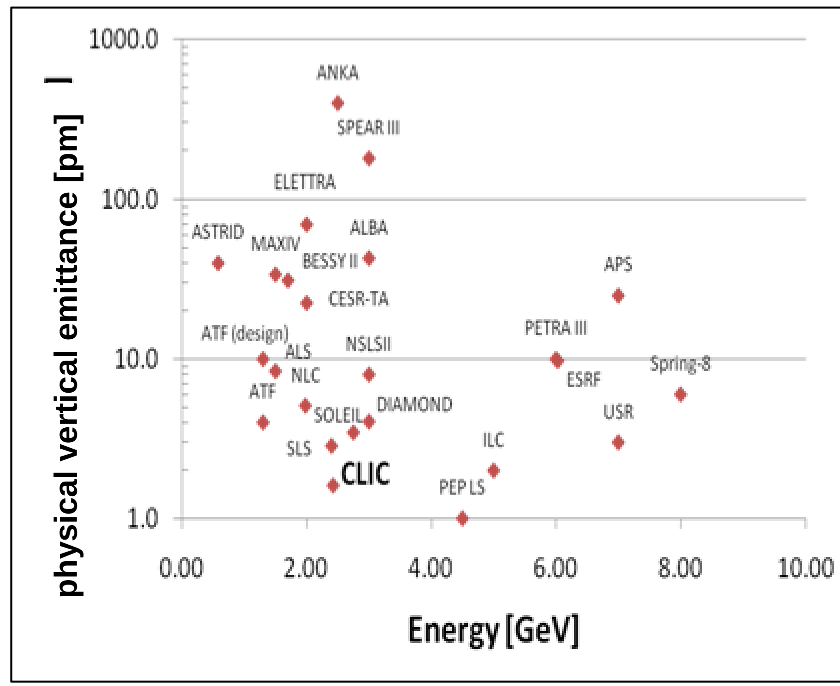
CLIC has two damping rings each for e$^+$ and e$^-$

$\gamma\varepsilon_x$=381 / $\gamma\varepsilon_y$= 4.1 nm rad for 4.1*10^9 particles at 2.4 GeV

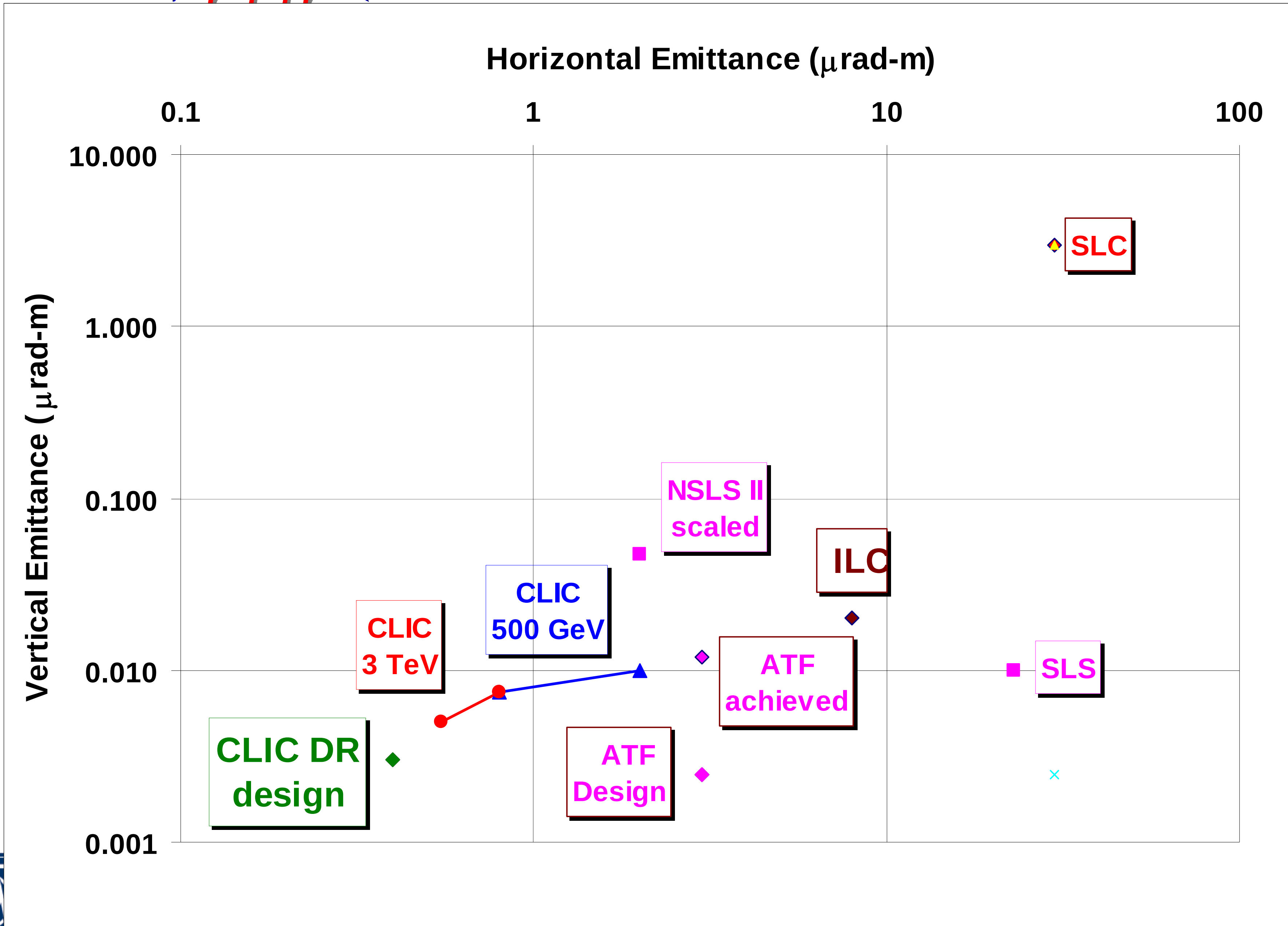
Design based on wigglers with short period and high field

Superconducting and Room Temp. versions being considered

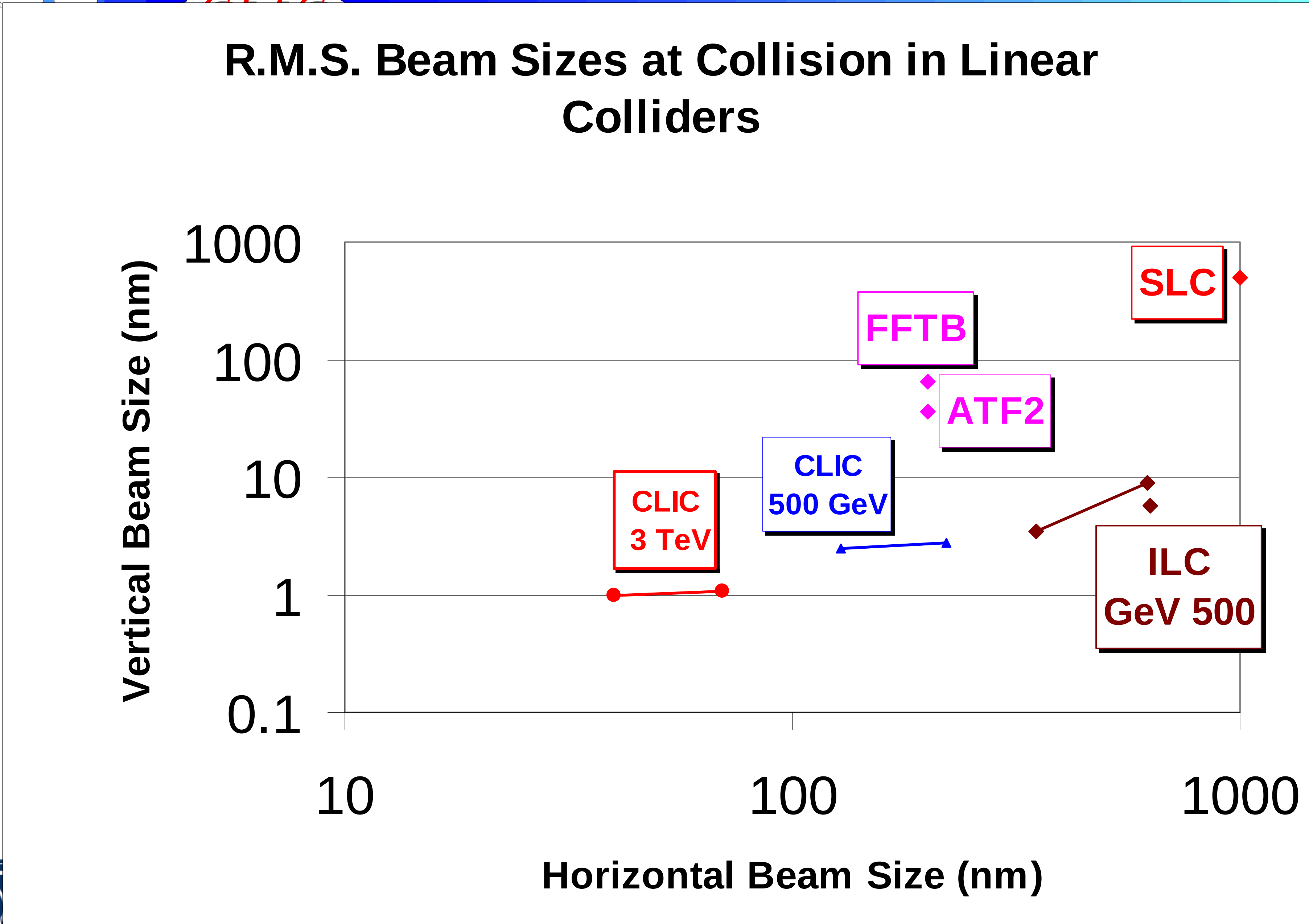




Beam emittances at Damping Rings

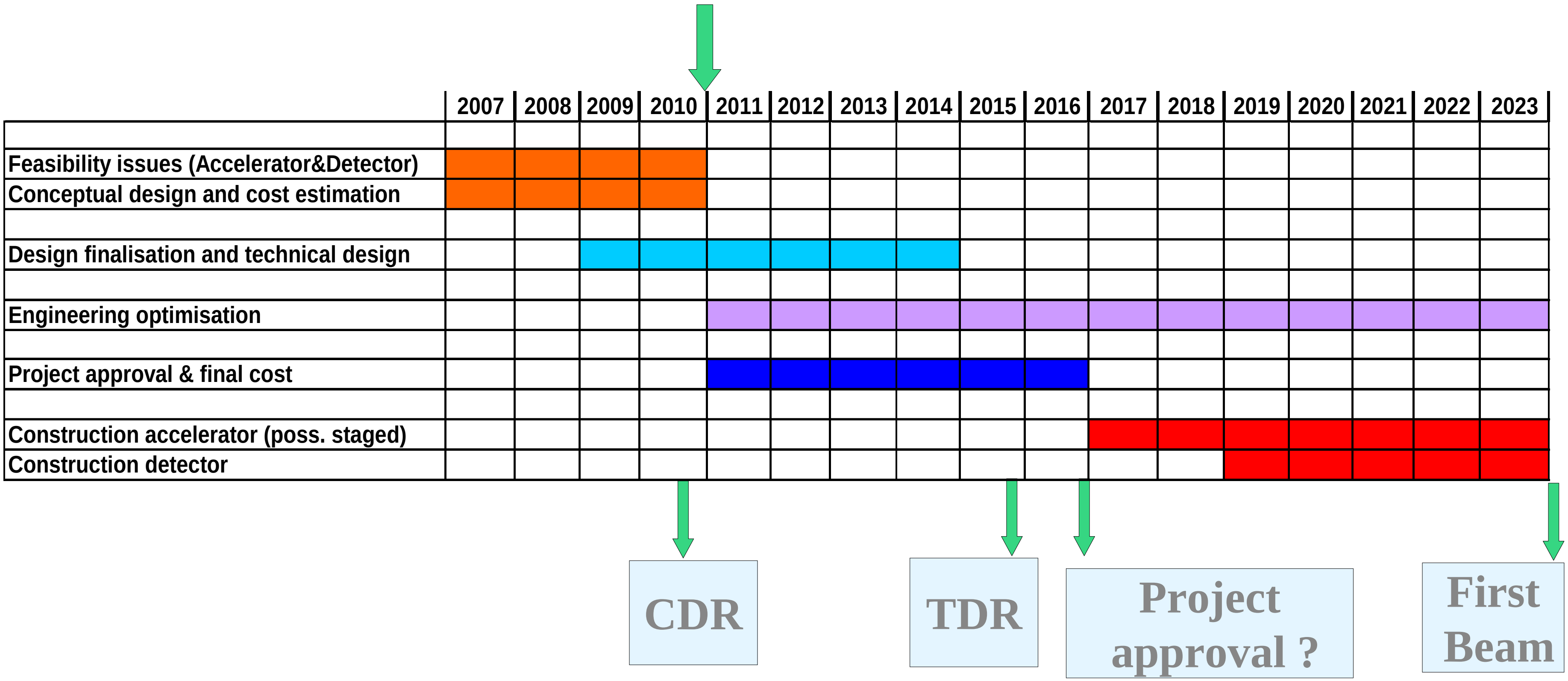


Beam sizes at Collisions



Tentative long-term CLIC scenario
Shortest, Success Oriented, Technically Limited Schedule

Technology evaluation and Physics assessment based on LHC results for a possible decision on Linear Collider funding with staged construction starting with the lowest energy required by Physics



CLIC/CTF3 Multi-Lateral Collaboration of Volunteer Institutes

27 institutes involving 17 funding agencies from 15 countries

Organized as a Physics Detector Collaboration

Collab. Board: Chair: M.Calvetti/INFN; Spokesperson: G.Geschonke/CERN

MoU with addenda describing specific contribution (& resources)

http://clic-meeting.web.cern.ch/clic-meeting/CTF3_Coordination_Mtg/Table_MoU.htm

Members *(full responsibility of work packages and providing corresponding resources):*

- **CERN members with additional voluntary contributions:**

CERN, Finland (HIP), France (IRFU, LAL, LAPP, LURE), Italy (LNF), Norway (Oslo U.), Spain (CIEMAT, UPC, IFIC), Sweden (Uppsala), Switzerland (PSI), UK (Cockcroft, JAI, RHUL)

- **CERN non members with voluntary contributions:**

India (RRCAT), Pakistan (NCP), Russia (BINP, IAP, JINR), Turkey (Ankara U., Gazi U.), Ukraine (IAP), USA (NWU, SLAC, JLAB)

MoU under discussion: China (Tsinghua Univ.), Iran (IPM),

World-wide CLIC / CTF3 collaboration

http://clic-meeting.web.cern.ch/clic-meeting/CTF3_Coordination_Mtg/Table_MoU.htm

24 members representing 27 institutes involving 17 funding agencies of 15 countries

Ankara University (Turkey)
Berlin Tech. Univ. (Germany)
BINP (Russia)
CERN
CIEMAT (Spain)
Finnish Industry (Finland)
Gazi Universities (Turkey)

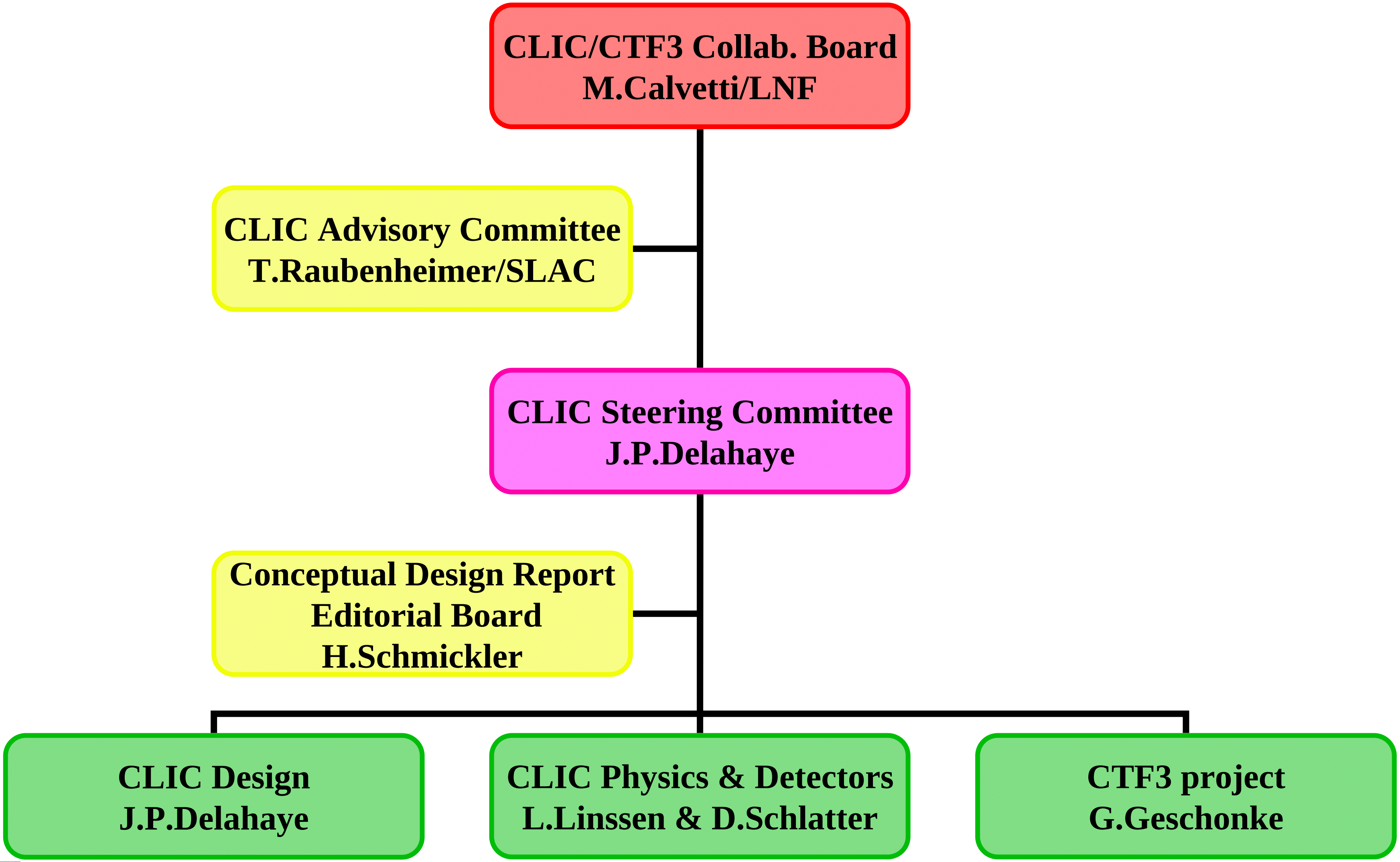
IRFU/Saclay (France)
Helsinki Institute of Physics (Finland)
IAP (Russia)
IAP NASU (Ukraine)
Instituto de Fisica Corpuscular (Spain)
INFN / LNF (Italy)
J.Adams Institute, (UK)

JASRI (Japan)
JINR (Russia)
JLAB (USA)
KEK (Japan)
LAL/Orsay (France)
LAPP/ESIA (France)
LLBL/LBL (USA)
NCP (Pakistan)
North-West. Univ. Illinois (USA)

Oslo University
PSI (Switzerland),
Polytech. University of Catalonia (Spain)
RAL (England)
RRCAT-Indore (India)
Royal Holloway, Univ. London, (UK)
SLAC (USA)
Svedberg Laboratory (Sweden)
Uppsala University (Sweden)

CLIC organizational Chart

http://clic-study.web.cern.ch/CLIC-Study/Mtgs_Wkg_Grp.htm



CLIC Work program till 2010

- Demonstrate feasibility of CLIC technology
  - Major key issues addressed in CTF3
- Design of a linear Collider based on CLIC technology

  http://clic-study.web.cern.ch/CLIC-Study/Design.htm
- Estimation of its cost in the CERN area
- CLIC Physics study and detector development:

  http://clic-meeting.web.cern.ch/clic-meeting/CLIC_Phy_Study_Website/default.html
- Conceptual Design Report including cost by 2010

Strategy to address key issues

- Key issues common to all Linear Collider studies independently of the chosen technology in close collaboration with the International Linear Collider (ILC) study:
  - On Accelerator Test Facility (ATF1&ATF2@KEK)
  - With European Laboratories in the frame of the Coordinated Accelerator Research in Europe (CARE) and of a "Design Study" (EUROTeV) funded by EU Framework Programmes (FP6 presently and FP7 "EUCARD" Integrated Activity from 2009)
- Key issues specific to CLIC technology:
  - Focus of the CLIC study
  - All R1 (feasibility) and R2 (design finalisation) key issues addressed in test facilities: CTF1,2,3@CERN

Fruitful CLIC /ILC Collaboration

- Constructive exchange of view with B.Barish during his visit at CERN in Nov 07

  http://www.linearcollider.org/cms/?pid=1000465

- Collaboration meeting with ILC Project managers and specific experts on 08/02/08 at CERN for collaboration on subjects with strong synergy between CLIC and ILC:

  1) Civil Engineering and Conventional Facilities
  2) Beam Delivery Systems & Machine Detector Interf.
  3) Detectors
  4) Cost & Schedule
  5) Beam dynamics & Beam Simulations

- Mandate and work plan by nominated conveners:

  http://indico.cern.ch/conferenceDisplay.py?confId=27435

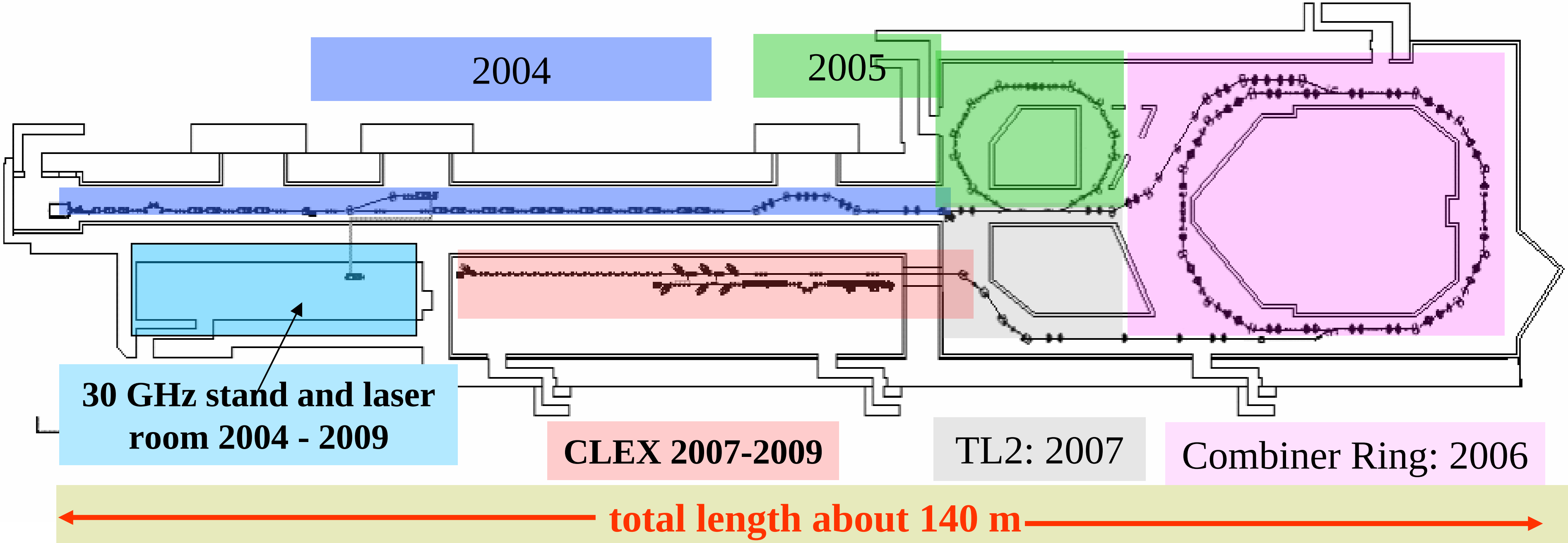
CLIC R&D Major Test Facilities
(* common issue with ILC)

CLIC

Test Facility	Name	Host Lab	Organized by	Issues	Tentative Date of demonstration
CLIC Test Facility	CTF3	CERN	CLIC/CTF3 collaboration	*Test of damped accelerating structure at design gradient and pulse length* *Validation of the drive beam generation scheme with a fully loaded linac* *Design & test of PETS ON-OFF* *Validation of beam stability and losses in the drive beam decelerator,* *Test of a relevant linac sub-unit with beam*	TBTS in CL:EX:2009 CTF3 complex: 2005 to 2009 TBL in CLEX: 2010 TBTS in CLEX: 2009 TBTS in CLEX: 2009
SLAC	NLCTA	SLAC	SLAC	Accelerating Structures	2007-2010
KEK		KEK	KEK	Accelerating structures	2008-2010
Accelerator Test Facility	ATF	KEK	ATF Collaboration	Damping Ring*	2009-2010
Cornell Test Accelerator	CESR-TA	Cornell	Cornell	Damping Ring:* electron cloud*	2009-2010
National Synchr. Light Source	NSLSII	BNL	BNL	Damping Ring: Hor. Emittance: 2 micrometer	2010
Swiss Light Source	SLS	PSI	PSDI	Damping Ring: Vert. emittance: 10 nm	2010
Beam Delivery Test Facility	ATF-2	KEK	ATF Collaboration	Beam Delivery: strong focusing* & 35 nm vert beam sizes*	2010

All major CLIC technology key issues addressed in CLIC Test Facility (CTF3)

First Accelerator R&D recognized as Physics Experiment (Grey Book)



Key issues

From 2005: Accelerating structures Development& Tests (R2.1)

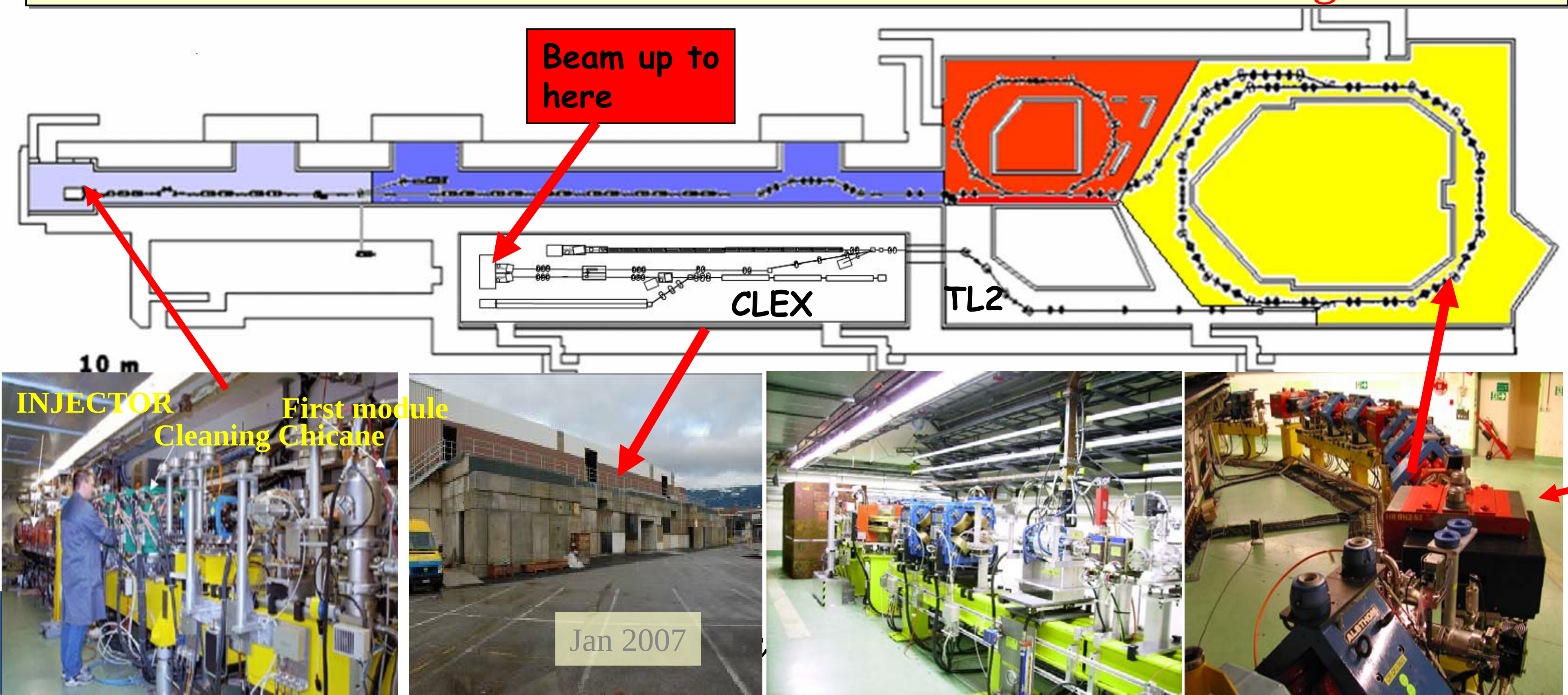
2007- 2008: Drive beam generation scheme (R1.2)

2008- 2009: Damped accelerating structure with nominal parameters (R1.1)
ON/OFF Power Extraction Structure (R1.3)
Drive beam stability bench marking (R2.2)
CLIC sub-unit (R2.3)

CTF3 Continuous 0peration (10months/year)

HW & Beam Commisioning and RF power production for structure tests

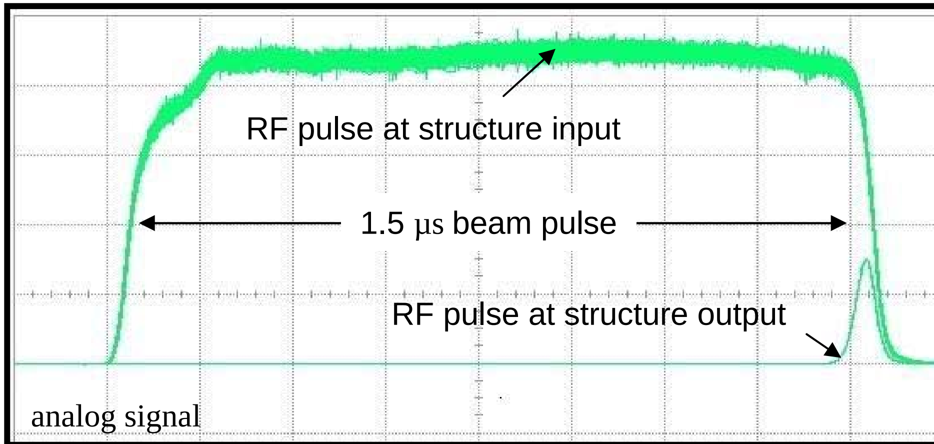
- Demonstrate Drive Beam generation
  (fully loaded acceleration, beam intensity and bunch frequency multiplication x8)
- Demonstrate RF Power Production and test Power Structures (PETS)
- Demonstrate Two Beam Acceleration and test Accelerating Structures



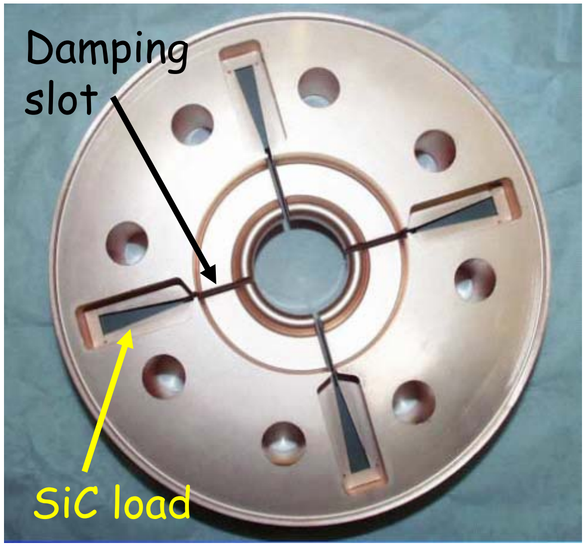
CLIC

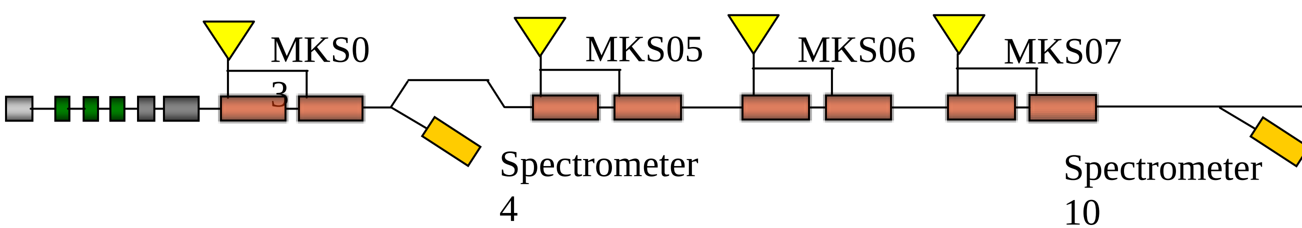
Drive beam generation with full beam-loading acceleration in CTF3 linac

- Measured RF-to-beam efficiency 95.3%
- Theory 96%
(~ 4 % ohmic losses)

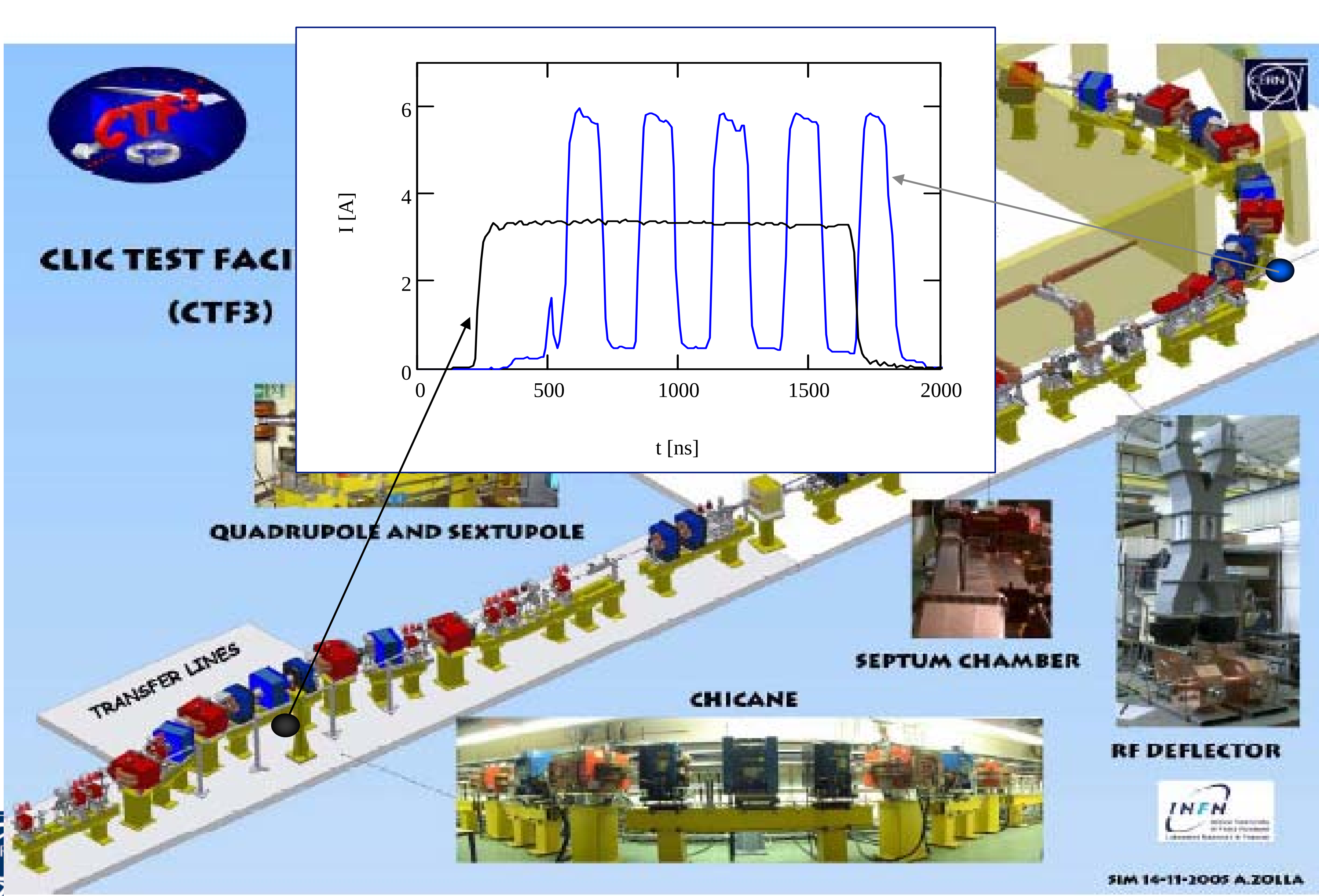


Dipole modes suppressed by slotted iris damping (first dipole's Q factor < 20) and HOM frequency detuning



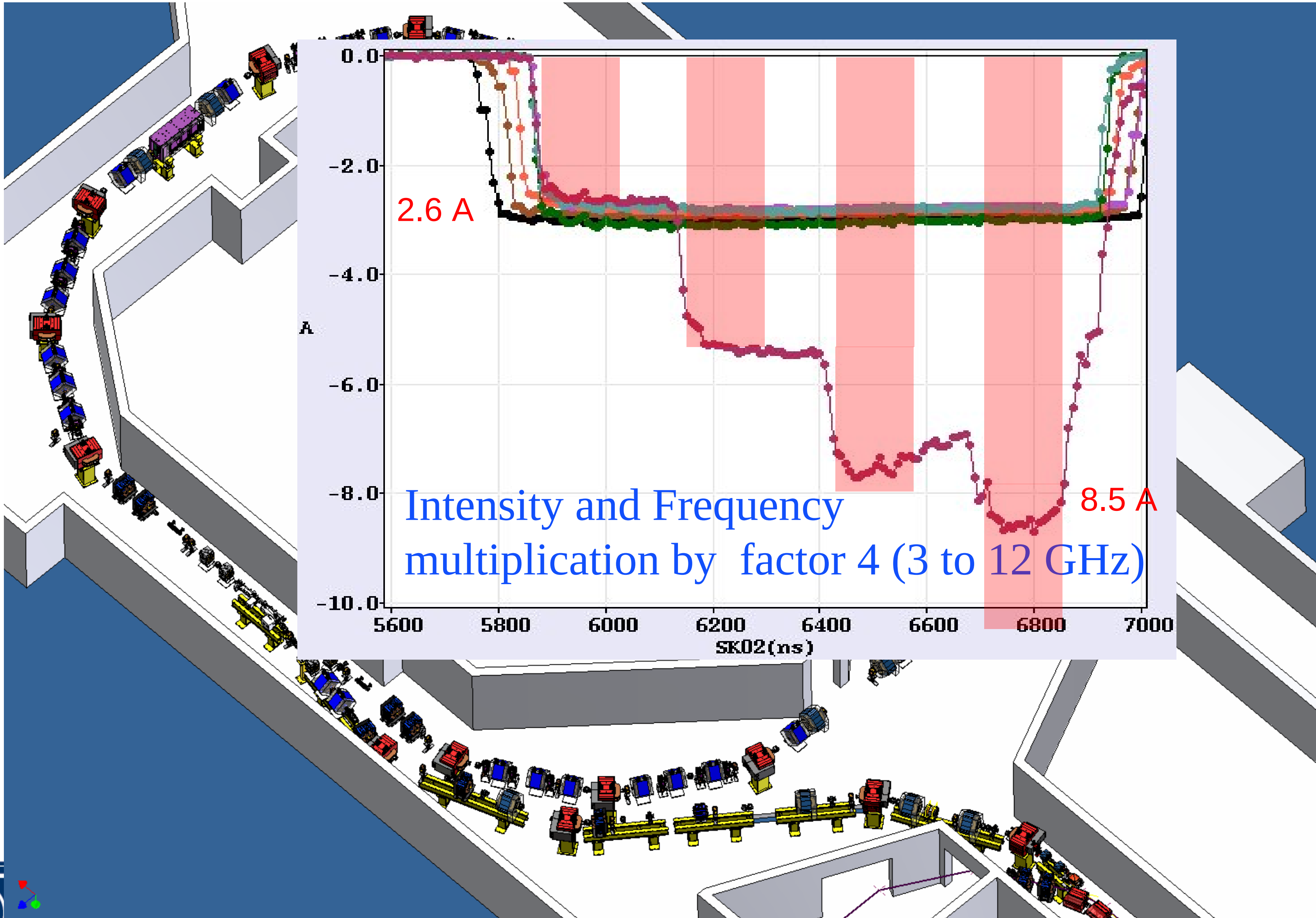


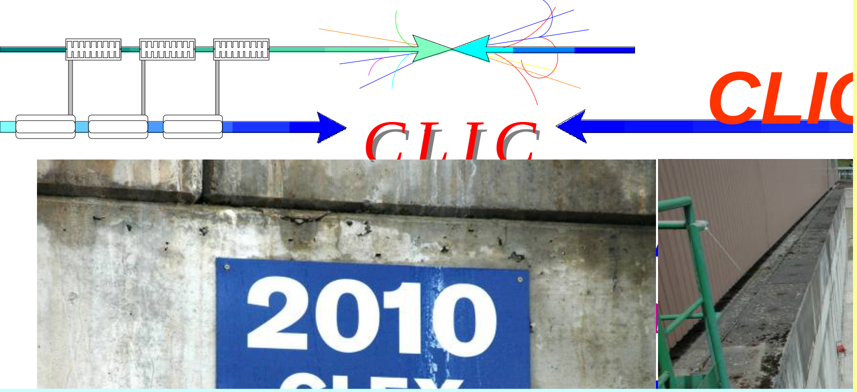
Beam intensity and RF frequency multiplication (factor 2) in CTF3 Delay Loop

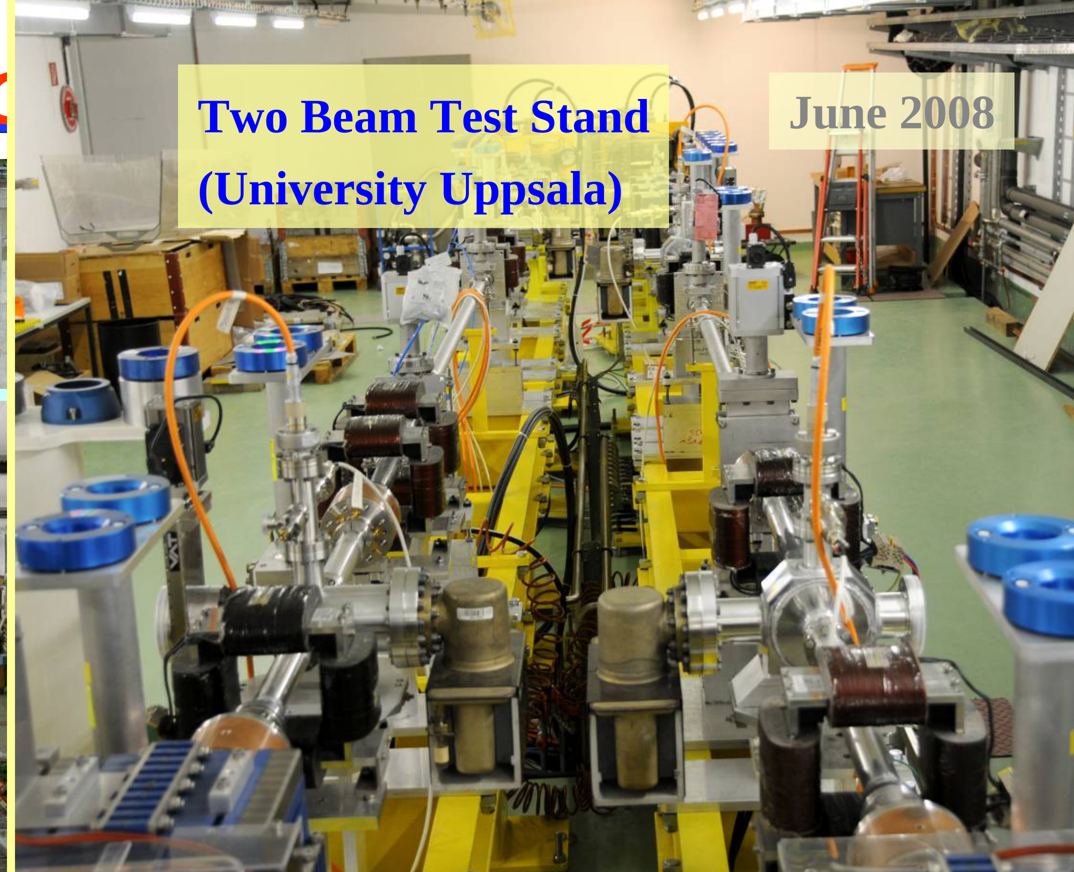


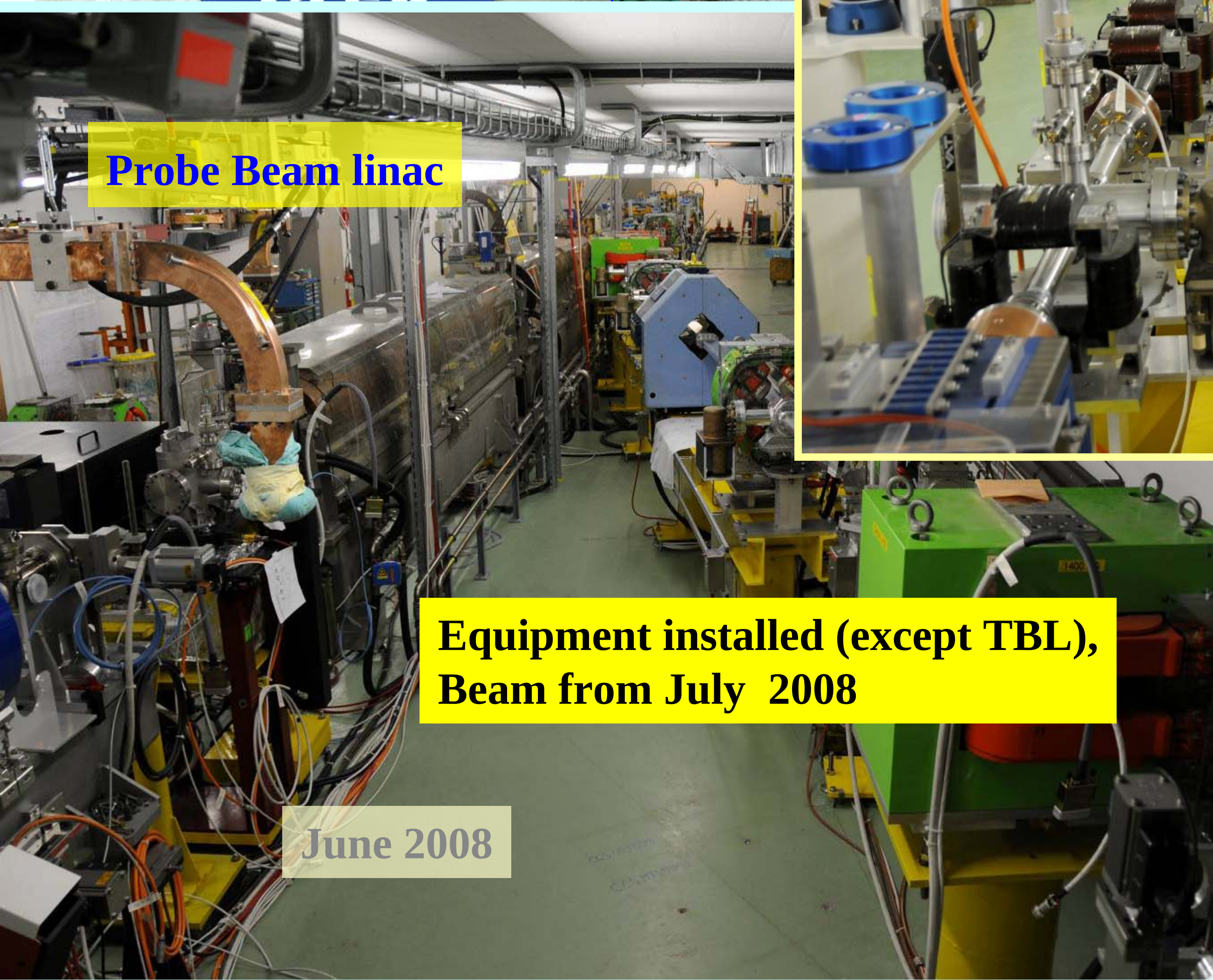
Beam commissioning of the Combiner ring

CLIC



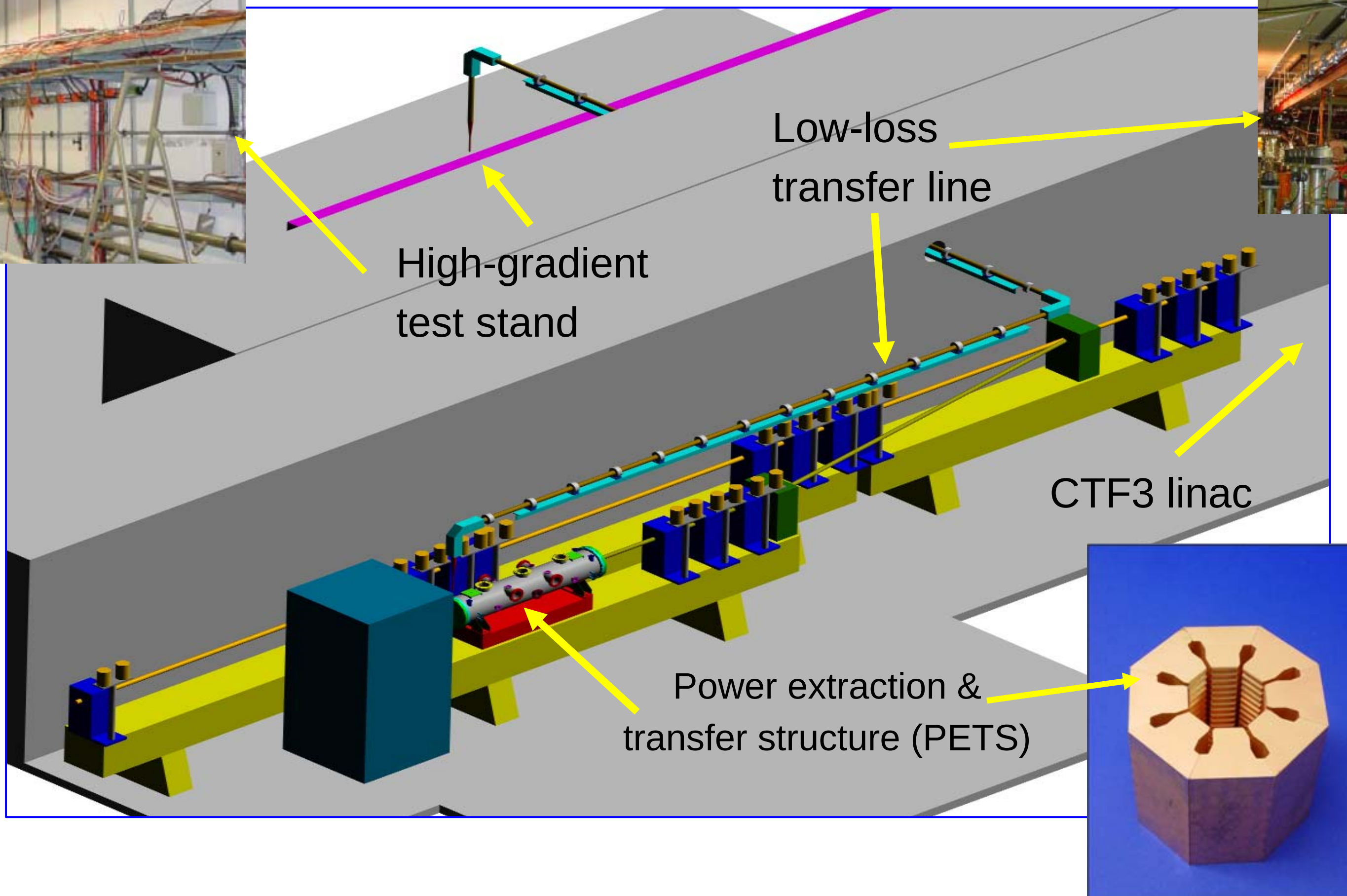

CLIC
2010


Two Beam Test Stand
(University Uppsala)
June 2008


Probe Beam linac
Equipment installed (except TBL),
Beam from July 2008
June 2008


Jan 2008

RF Power production in CTF3



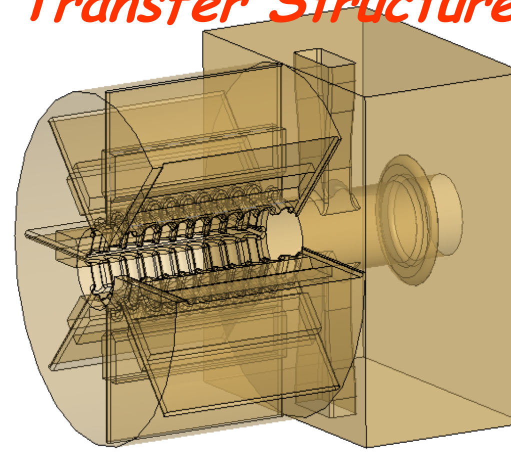
- Produced power at 30 GHz up to about 100 MW – long pulses (up to 300 ns) available for the first time
- Structure tests started in 2005 - 8 structures tested until now

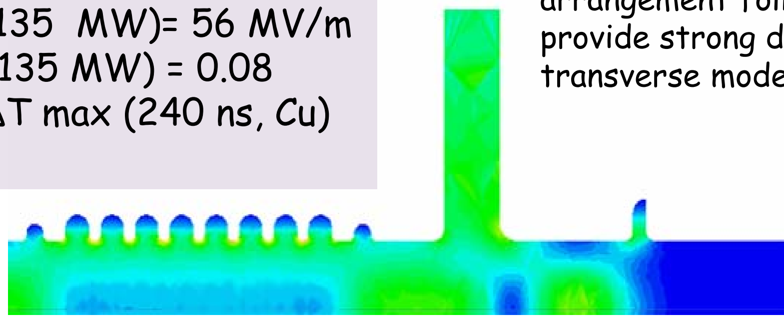
CLIC Power Extraction and Transfer Structure (PETS)

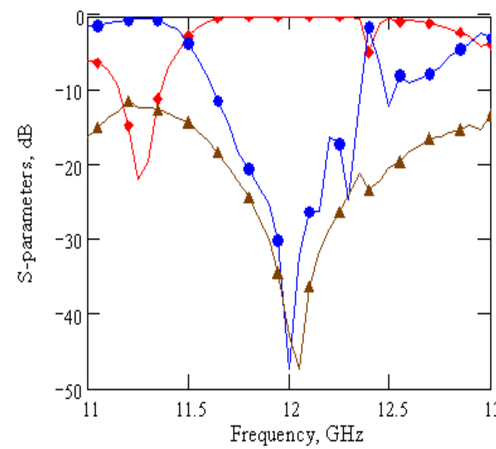
PETS parameters:

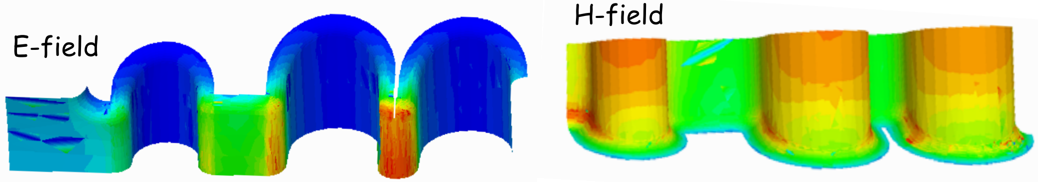
- Aperture = 23 mm
- Period = 6.253 mm (90^0/cell)
- Iris thickness = 2 mm
- R/Q = 2258 Ω
- V group= 0.453
- Q = 7200
- P/C = 13.4
- E surf. (135 MW)= 56 MV/m
- H surf. (135 MW) = 0.08 MA/m   (ΔT max (240 ns, Cu) = 1.8 C^0)

In its final configuration, PETS comprises eight octants separated by the damping slots. Each of the slots is equipped with HOM damping loads. This arrangement follows the need to provide strong damping of the transverse modes.

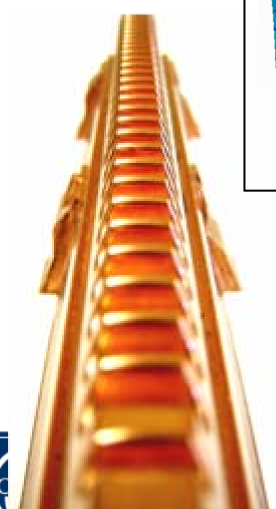


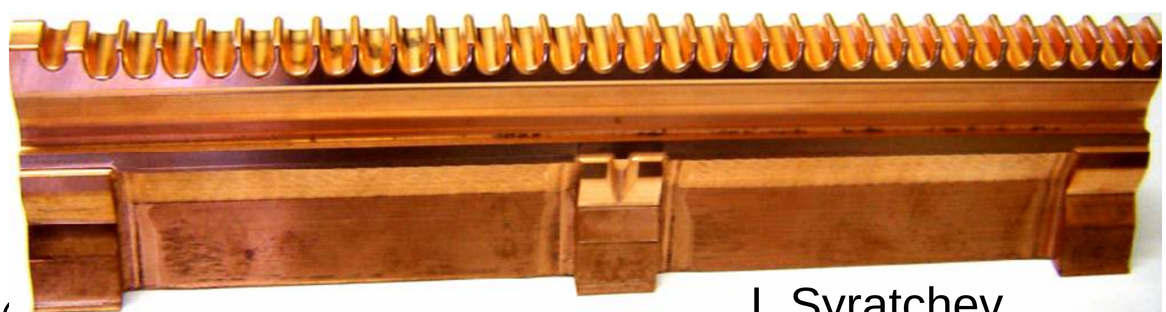




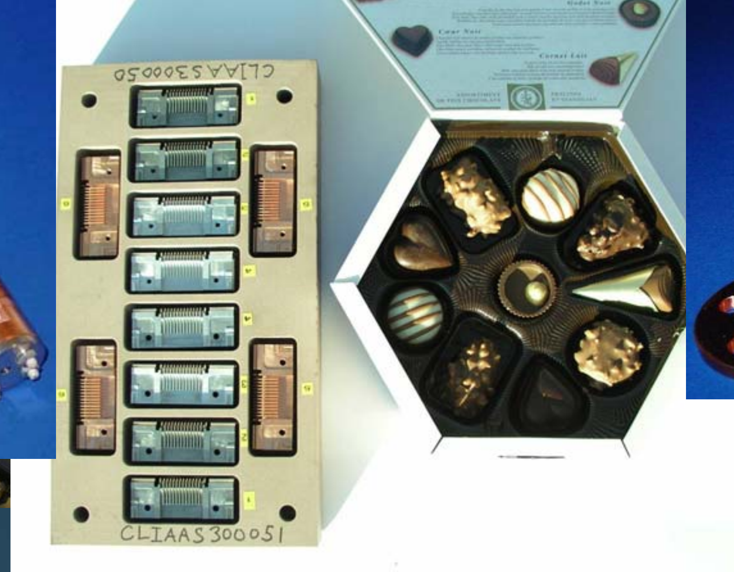


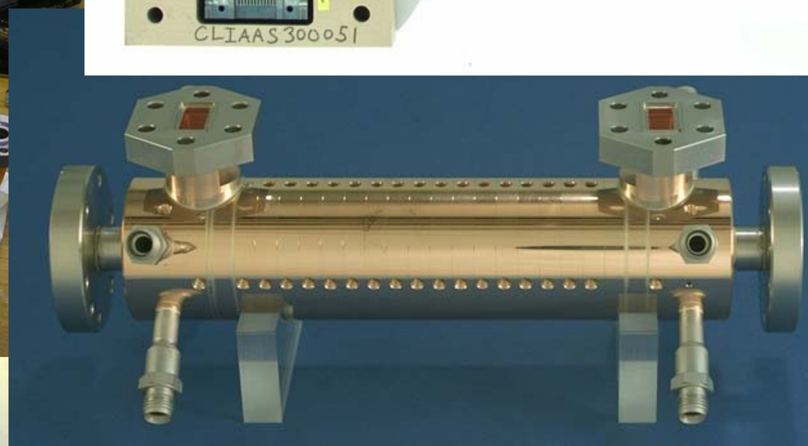
To reduce the surface field concentration in the presence of the damping slot, the special profiling of the iris was adopted.

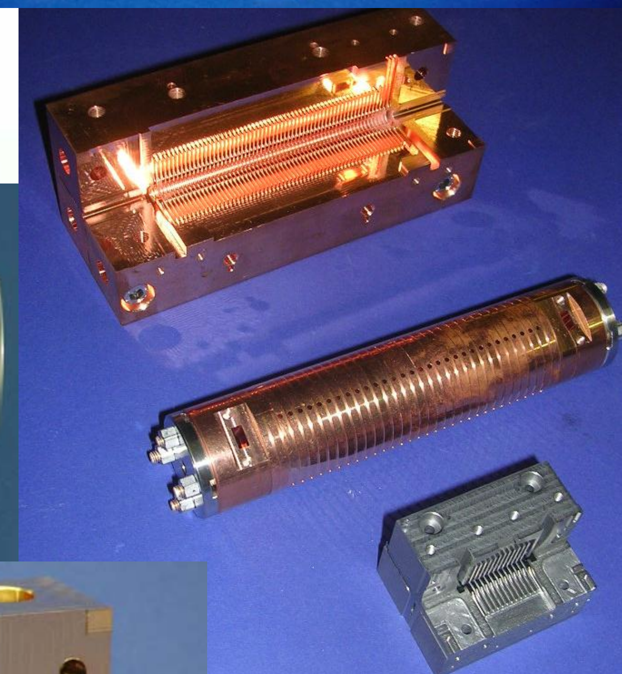


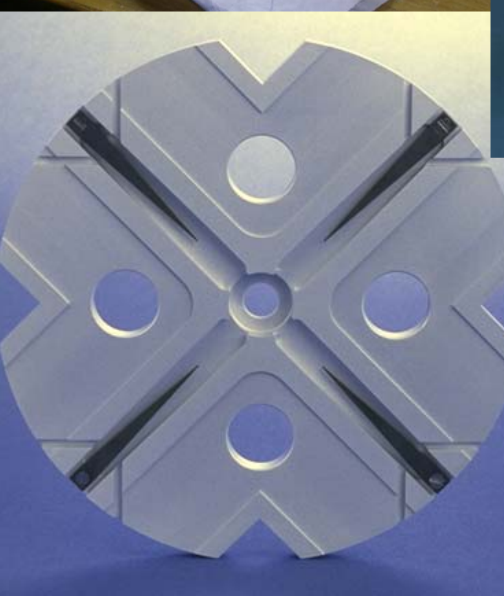


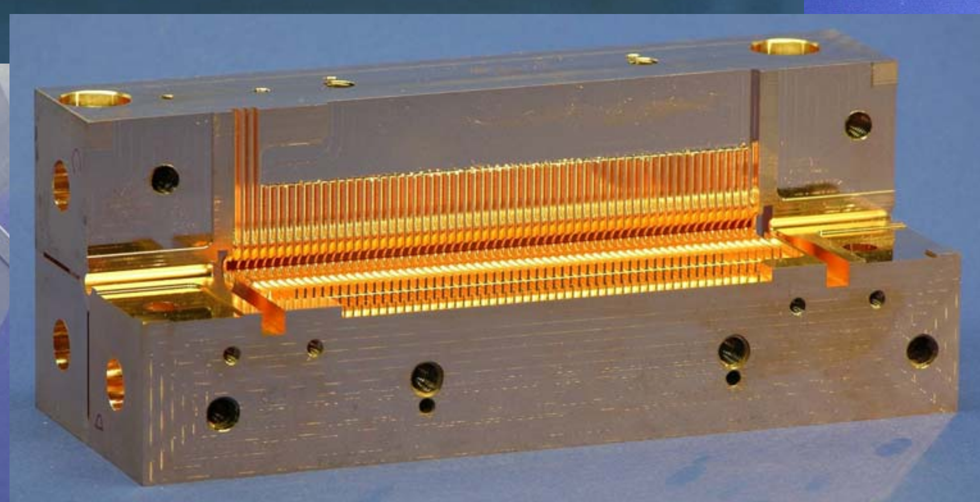
I. Syratchev











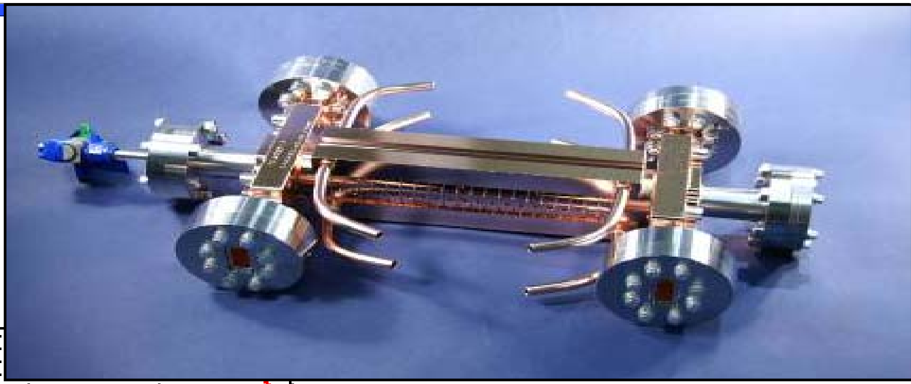
Testing Accelerating Structures

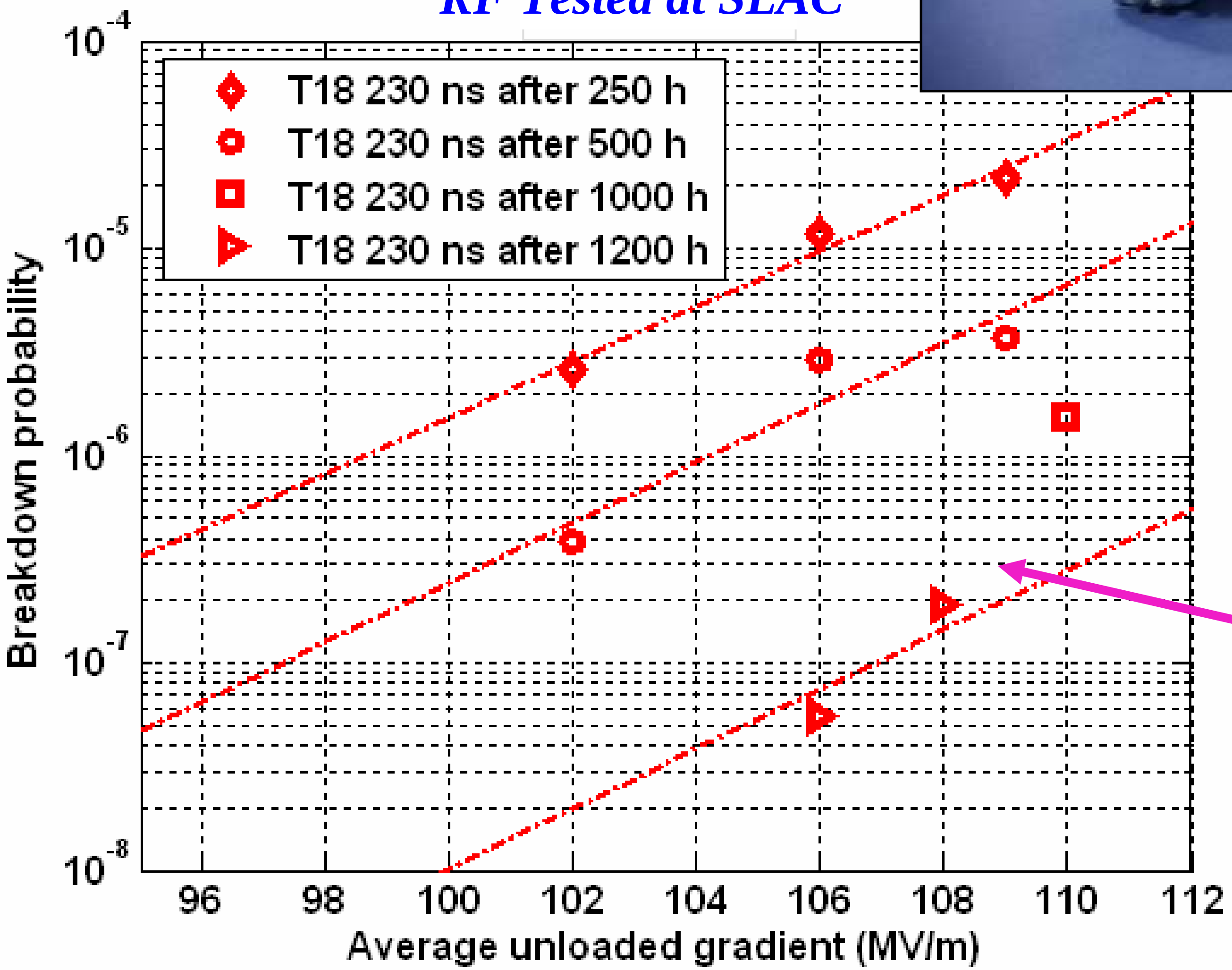
Nominal Structure Performance demonstrated

CLIC

A shining example of fruitful collaboration:

T18_VG2.4_disk: Designed at CERN,
(without damping) Built at KEK,
RF Tested at SLAC



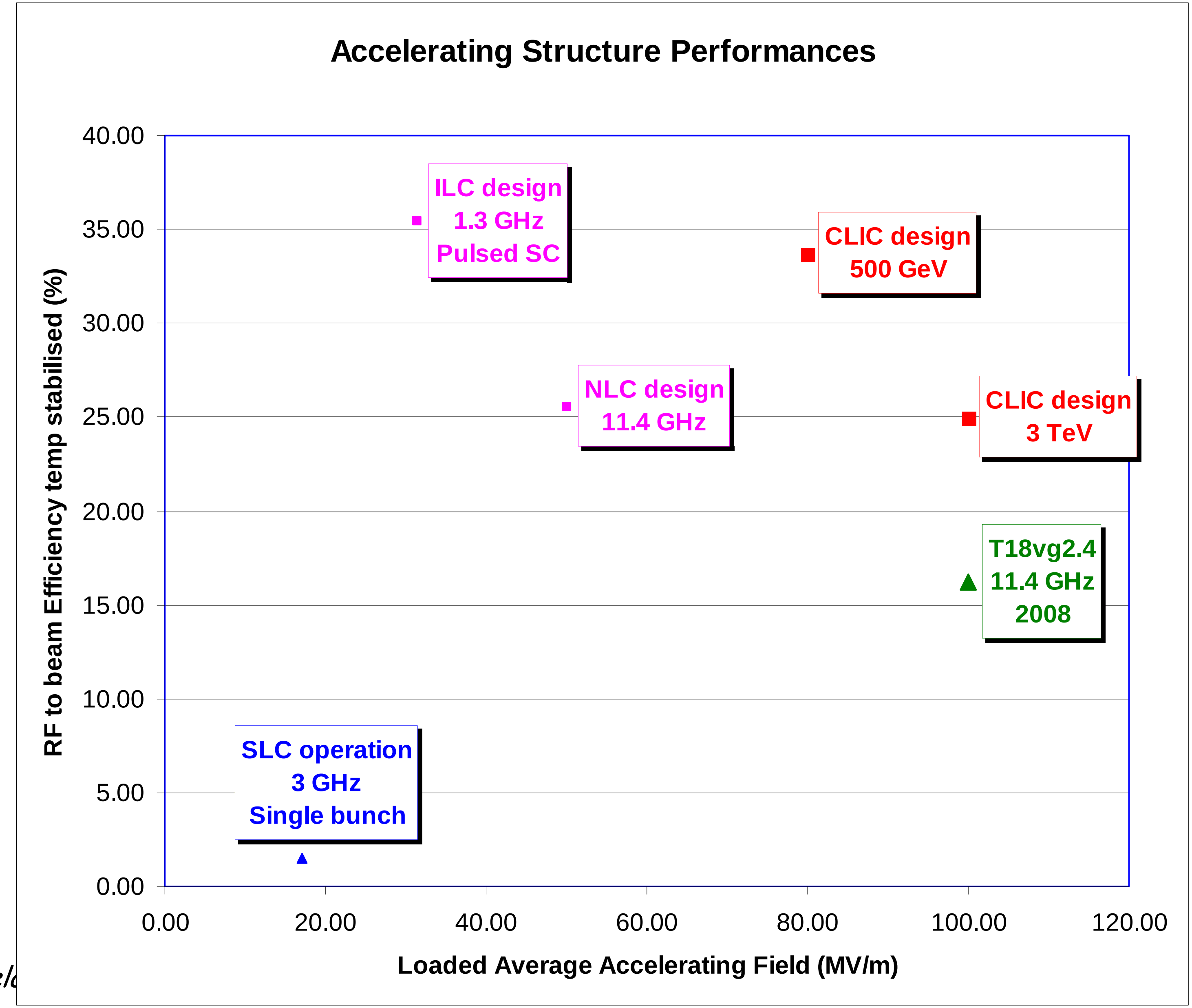


Improvement by RF conditionning

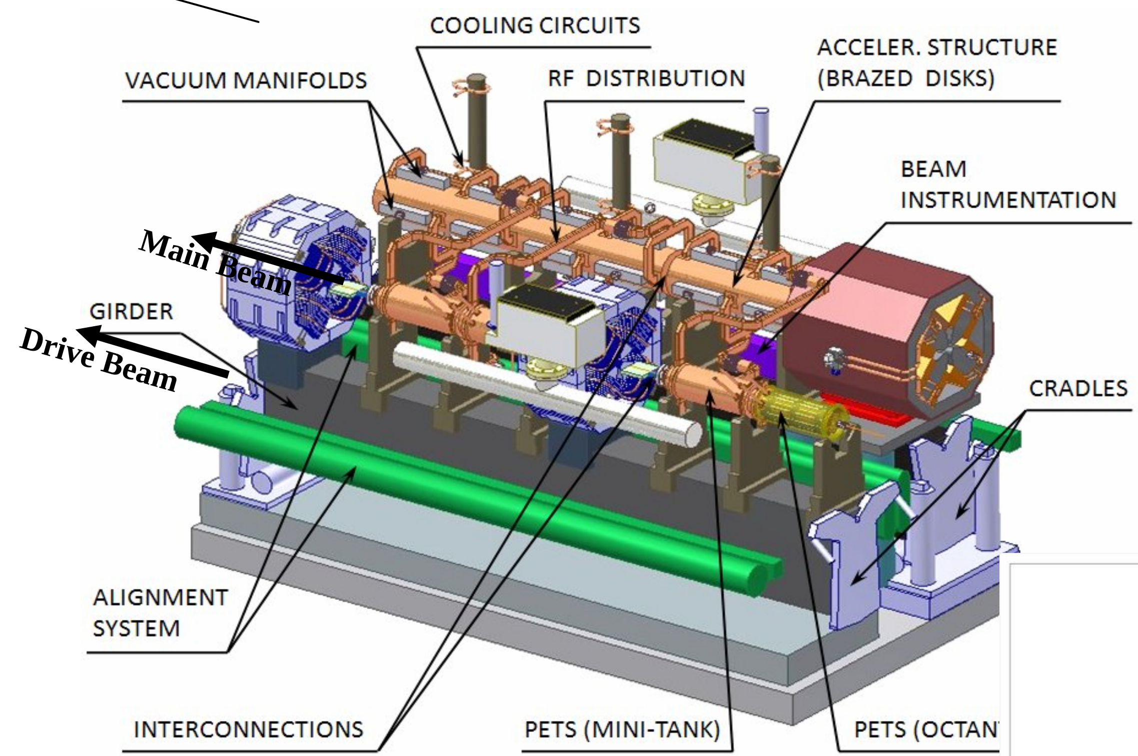
CLIC nominal

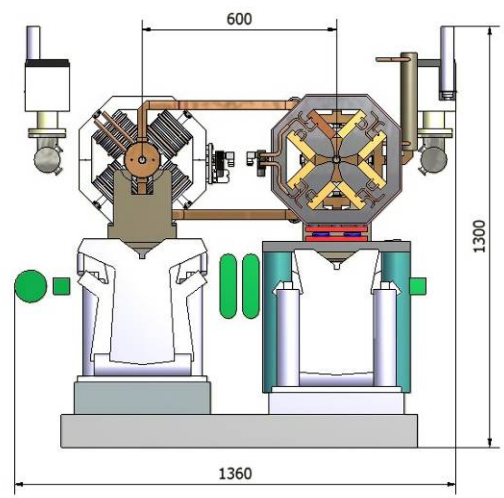
Rf to beam transfer efficiency

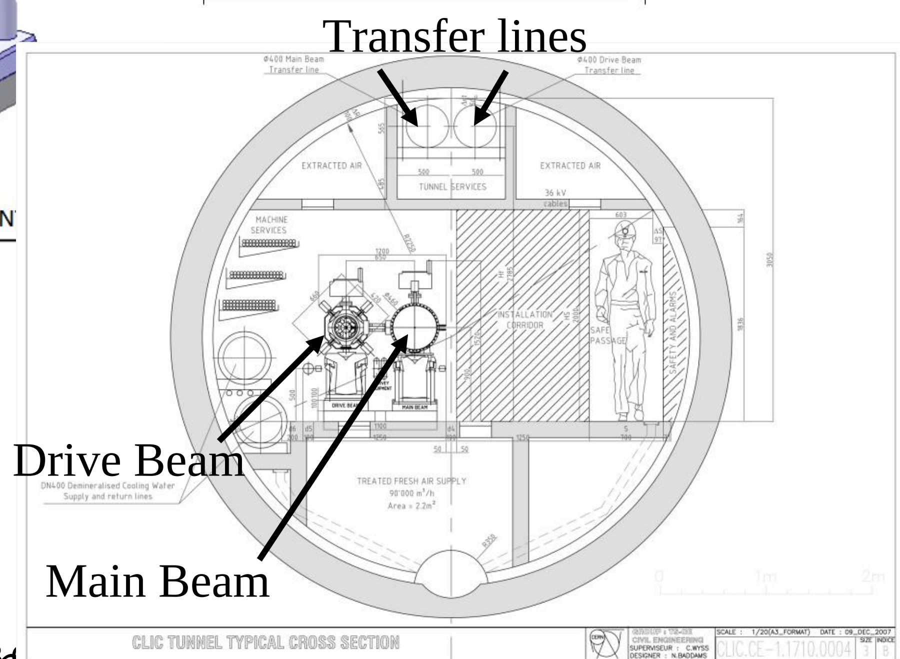
(including power for temperature stabilisation)



CLIC Accelerating Module







20760 modules (2 meters long)

71460 power production structures PETS (drive beam)

143010 accelerating structures (main beam)

Russian Contribution

- **Budker Institute of Nuclear Physics (BINP):**
  - Development and fabrication of quadrupole & sextupole magnets
  - Development of Super-Conducting Wiggler magnet
- **Institute of Applied Physics (IAP)**
  - Experimental studies of Power pulse heating of RF structures at high field with high power gyro-klystron at high frequency
  - Lasers development
  - Design of CLIC drive beam modulators and klystrons
- **Joint Institute of Nuclear Research (JINR/DUBNA)**
  - Computer control of Power Test Stand and automatic RF conditioning
  - Mechanical design

CLIC08 workshop (14-17/10/08)

CLIC08 Workshop

CERN, 14-17 October 2008

You are all kindly invited and welcome to participate

- Home
- Venue Details
- Accommodation
- Registration
- General Information
- Draft Program
- Working Groups
- Information for Speakers
- Program Advisory Committee
- Local Organising Committee

CLIC'08 is an Accelerator and Physics Workshop which follows the very successful 1st Workshop of this kind held at CERN in Oct 2007.

The Aims of CLIC08 are:

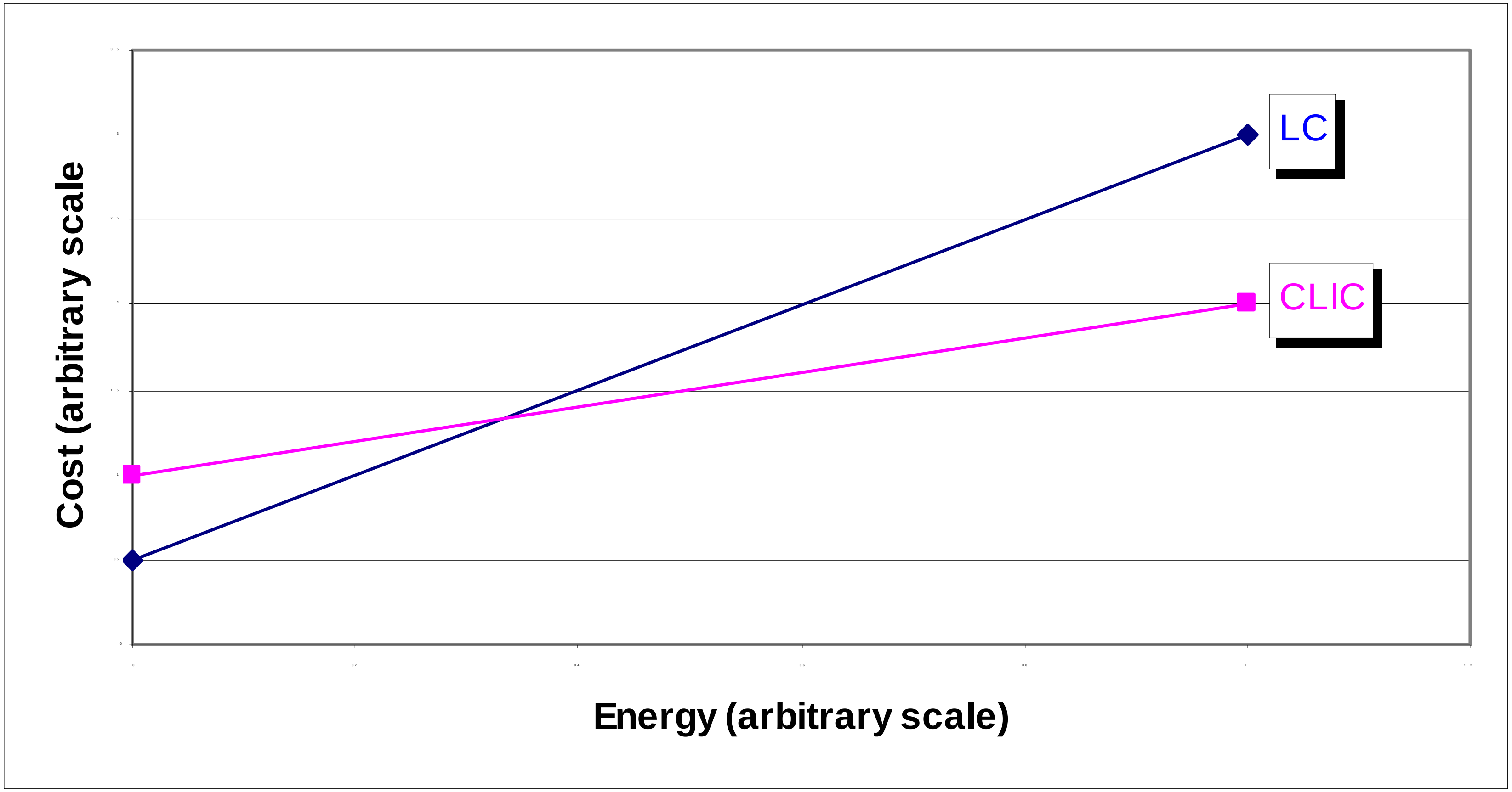
- Review the R&D towards CLIC Feasibility Demonstration and Conceptual Design Report in 2010. This includes Items of ILC-CLIC Common Interest as defined in the recently established ILC-CLIC Collaboration.
- Identify the R&D, Facilities and Engineering Efforts needed in the period after 2010 to progress from a Conceptual Design to a Technical Design.
- Address Particle Physics and Detector Issues of a Multi-TeV Linear Collider.

Conclusion

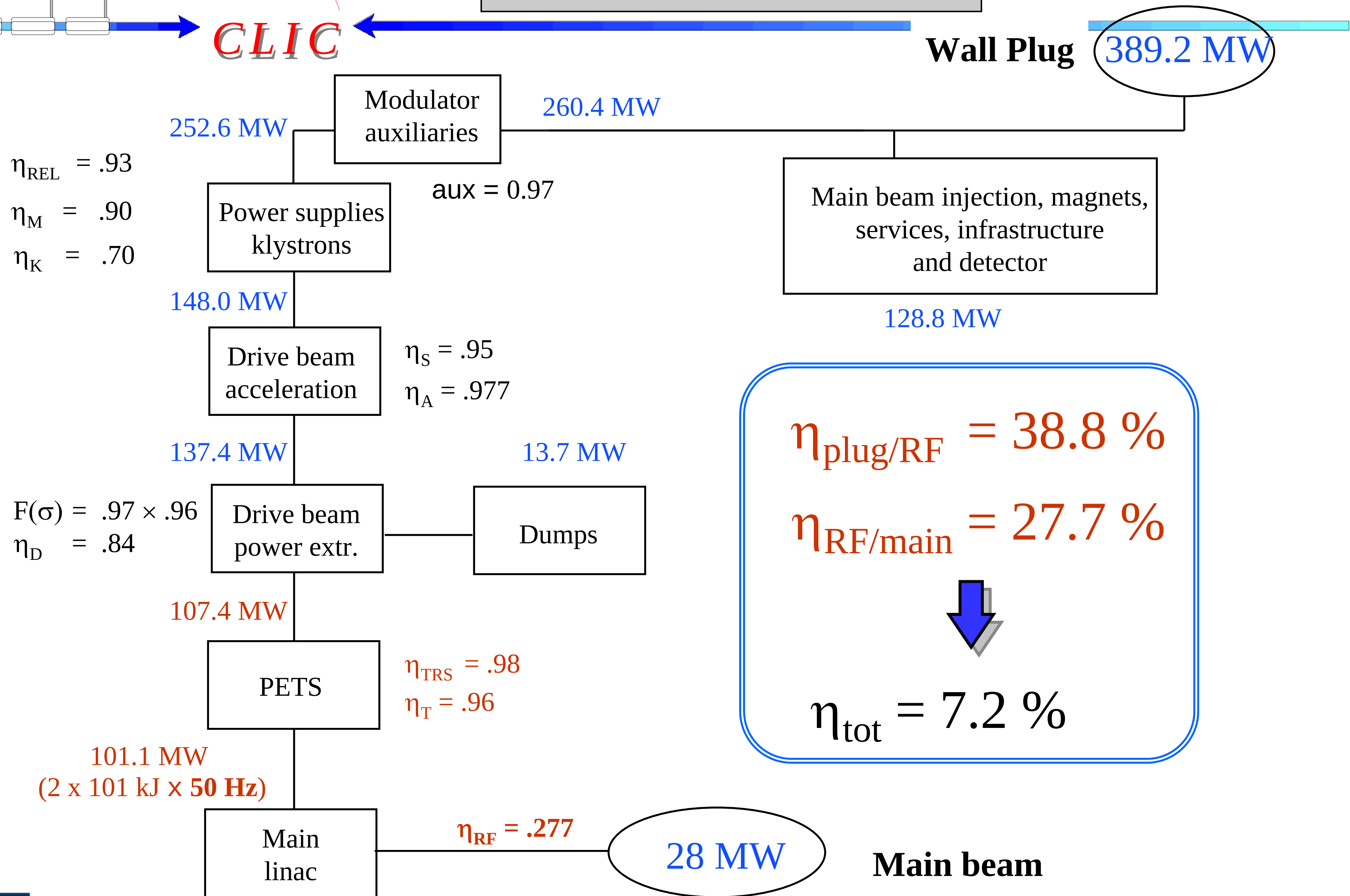
- CLIC study well on track to address major issues and demonstrate feasibility including cost to be published in a Conceptual Design Report by 2010
  - CTF3 on schedule with installation completed (except TBL).
  - Commissioning under progress.
- CLIC/CTF3 collaboration strong of 27 Institutes extremely fruitful and expanding
- Excellent spirit of collaborative competition with ILC
- Contribution of Russian Institutes warmly appreciated:
  - Further participation on CLIC feasibility and technical design welcome

Reserve slides

Relative cost of Linear Colliders



Power flow @ 3 TeV



Luminosity challenges
$>2*10^{34} cm^{-2}s^{-1}$) @ high energy (3 TeV)

Beam size at Interaction Point (rms) : σ_x = 40 nm, σ_y = 1 nm

Issues:
- **generating small emittance beams**
- **emittance preservation**
- **alignment and vibration control**
- **final focus (Beam Delivery System)**

jitter tolerances

	Final Focus quadrupoles	Main beam quadrupoles
Vertical	~0.2 nm > 4 Hz	~1 nm > 1 Hz
Horizontal	2 nm > 4 Hz	5 nm > 1 Hz

work ongoing,

Proof-of-principle: quadrupole stabilized to < 0.5 nm in vertical plane

DG to CERN staff
Jan 08

Prospects for Scientific Activities over the Period 2012 - 2016

To be decided in 2010-2011 in light of first physics results from LHC, and designed and R&D results from the previous years. This programme could most probably comprise:

- An LHC luminosity increase requiring a new injector (SPL and PS).

  The total cost of the investment over 6 years (2011-2016: 1000-1200 MCHF + a staff of 200-300 per year. Total budget: ~200-250 MCHF per year.

- Preparation of a Technical Design for the CLIC programme, for a possible construction decision in 2016 after the LHC upgrade (depending on the ILC future).
  Total CERN M + P contribution + ~250 MCHF + 1000-1200 FTE over 6 years.

- Enhanced infrastructure consolidation: 30 MCHF + 40 FTEs from 2011.

NB: Over the period 2012-2016. Effective participation of CERN in another large programme (ILC or a neutrino factory) will not be possible within the expected resources if positive decisions taken on LHC upgrade and CLIC Technical Design. This situation could totally change *if none of the above programmes is approved* or if a new, more ambitious level of activities and support is envisaged in the European framework.

Large Colliders Technically Driven Scenarii?

A look into the crystal ball !