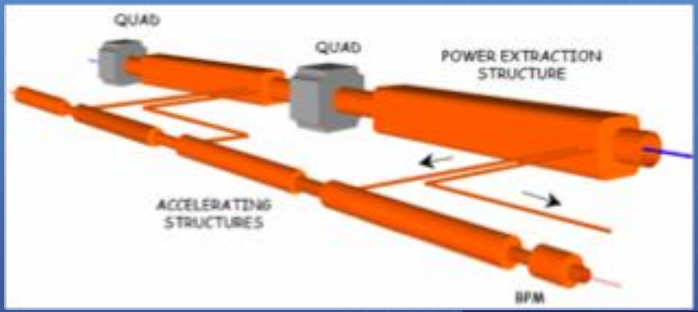
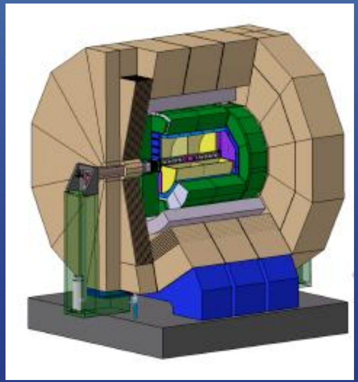
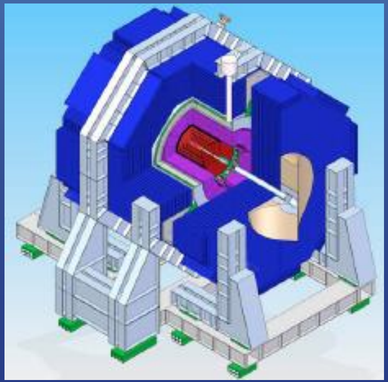
# Towards a future Linear Collider and The Linear Collider studies at CERN

- The International Workshop on Linear Colliders 2010
- Physics reminders
- The ILC and CLIC concepts
- Detector issues
- The activities at CERN
  - Present and 2011-2016
- Conclusions





# Sources

- ICHEP accelerator session talks by Barry Barish and Daniel Schulte:
  - http://indico.cern.ch/materialDisplay.py?contribId=590&sessionId=57&materialId=slides&confId=73513
  - http://indico.cern.ch/materialDisplay.py?contribId=1027&sessionId=57&materialId=slides&confId=73513
  - Additional slides from Jean-Pierre Delahaye, Walter Wuensch and John Osborne
- Physics and Detector slides from many sources:
  - Talks by Klaus Moenig and Dieter Schlatter at CERN, ILC+CLIC workshop (EUDET event), Oct 2009: http://indico.cern.ch/event/69540
  - Frederic Teubert at a UK-Daresbury accelerator workshop, Dec 2008:http://lcd.web.cern.ch/LCD/Documents/Presentations/CLIC-Daresbury.pdf
  - Additional slides from Lucie Linssen
- … plus many others … thanks

# International Workshop on Linear Colliders 2010



## 13:30->*18:30* **Plenary Session** (Convener: Tatsuya Nakada (*CERN/EPFL*) ) (CERN ( Main Auditorium ) )

| | | |
|---|---|---|
| 13:30 | The LC Roadmap (30') | Rolf Heuer (*CERN*) |
| 14:05 | Physics prospects (30') | Raman Sundrum (*JHU*) |
| 14:40 | R&D on Detectors (30') | Jean-Claude Brient (*LLR Palaiseau*) |
| 15:10 | Coffee break (20') | |

## 15:30->*18:00* **Plenary Session** (Convener: Steinar Stapnes (*CERN*) ) (CERN ( Main Auditorium ) )

| | | |
|---|---|---|
| 15:30 | Status of ILC (GDE) (30') | Nick Walker (*DESY*) |
| 16:00 | Status of CLIC (30') | Jean-Pierre Delahaye (*CERN*) |
| 16:30 | Status of Detector Concepts SiD (20') | Andy White (*Univ. Texas, Arlington*) |
| 16:50 | Status of Detector Concepts ILD (20') | Henri Videau (*(L.L.R.)*) |
| 17:10 | Detector studies for CLIC (20') | Marcel Stanitzki (*RAL*) |
| 19:00 | Welcome Reception (1h30') (CERN - Restaurant 1) | |

# Tuesday 19 October 2010

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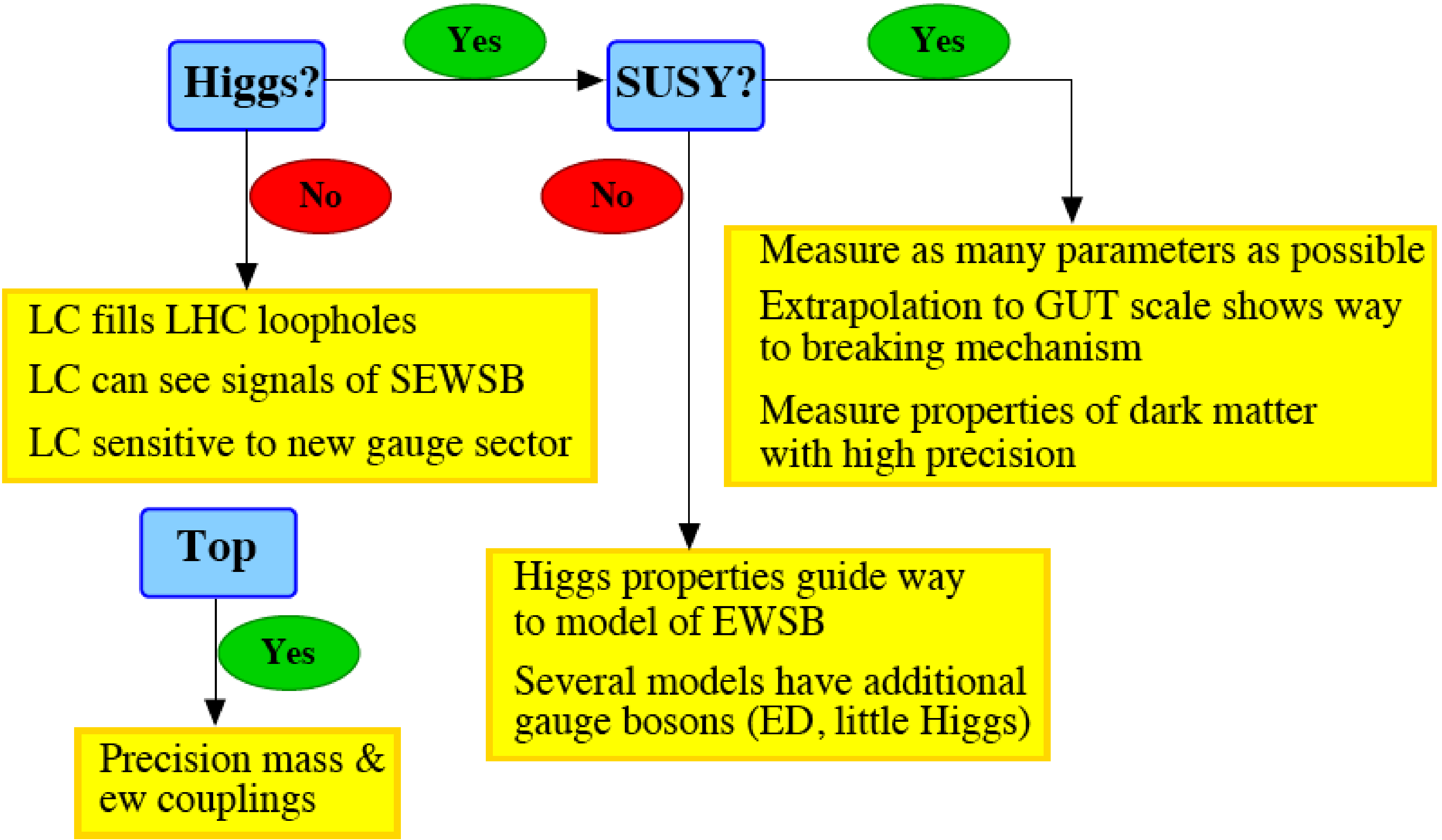
## 08:30->*12:15* **Plenary Session** (CICG ( Room 2 - floor "0" ) )

| | | |
|---|---|---|
| 08:30 | LHC (Machine) (25') | Steve Myers (*CERN*) |
| 09:00 | Fermilab Research Program (25') | Greg Bock (*FNAL*) |
| 09:30 | Basic considerations on LC lumi & energy needs (up to 3 TeV) (25') | Jim Brau (*Eugene Oregon*) |
| 10:00 | Low energy running for CLIC (25') | Daniel Schulte (*CERN*) |
| 10:30 | coffee break (15') | |
| 10:45 | SB2009/ Low energy running for ILC (25') | Andrei Seryi (*JAI*) |
| 11:15 | Discussion (1h00') | |

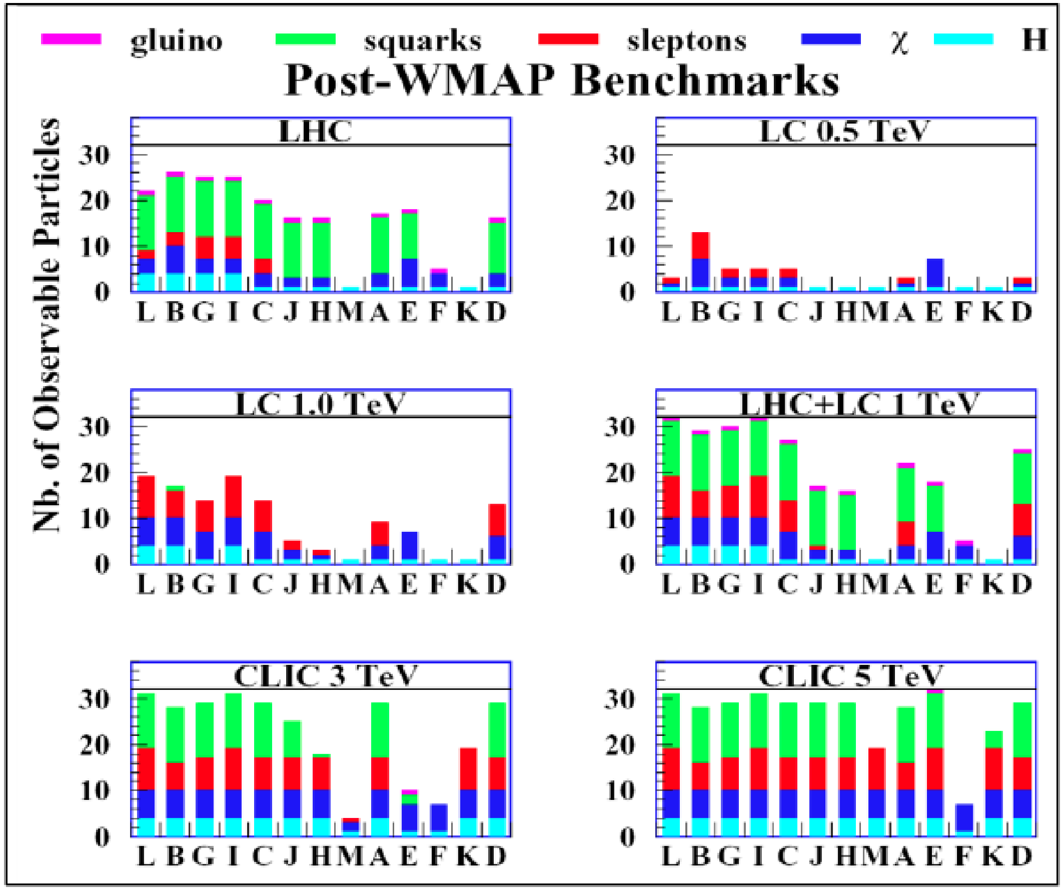
# Physics – very short




Physics potential of a linear e+e- collider (Klaus Moenig):
http://indico.cern.ch/materialDisplay.py?contribId=0&materialId=slides&confId=69540

# SUSY (including extended Higgs sector)

LHC is good with sparticles that mainly interact strongly, (gluino, squarks, …), while a LC could complement the spectra with sparticles that mainly interact weakly (sleptons, neutralinos,…)

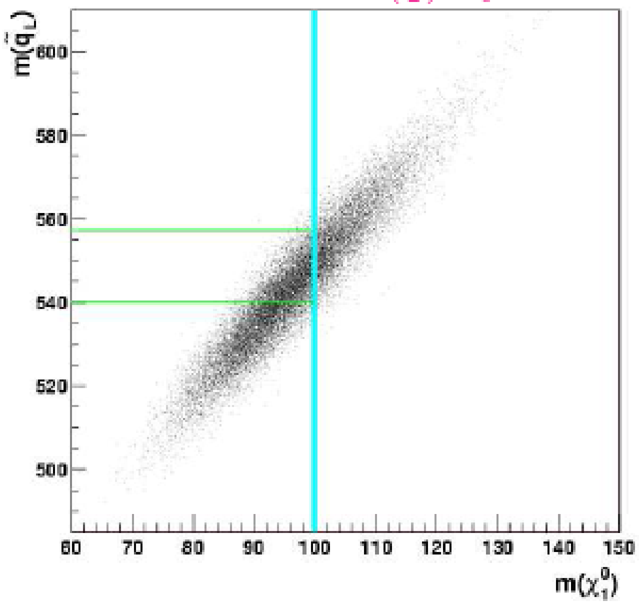



Wednesday, December 3, 2008 Frederic Teubert

- Equally/more important:
  - The precision by which a LC can measure the parameters, masses, mixing, BR, etc in the SUSY and Higgs sectors

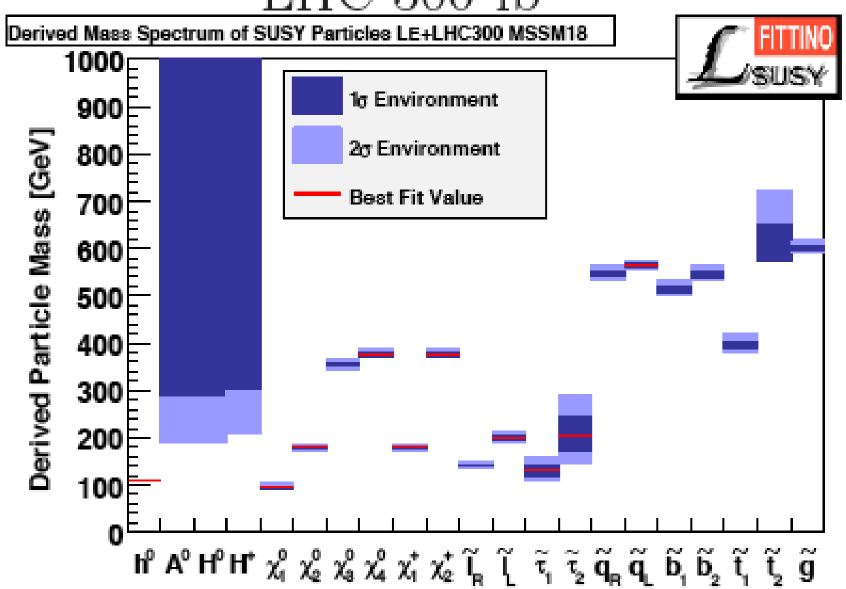
The LC measurements can also improve the LHC precision for heavy superpartners

Improvement of LHC $m(\tilde{q})$ by ILC $m(\tilde{\chi}_1^0)$

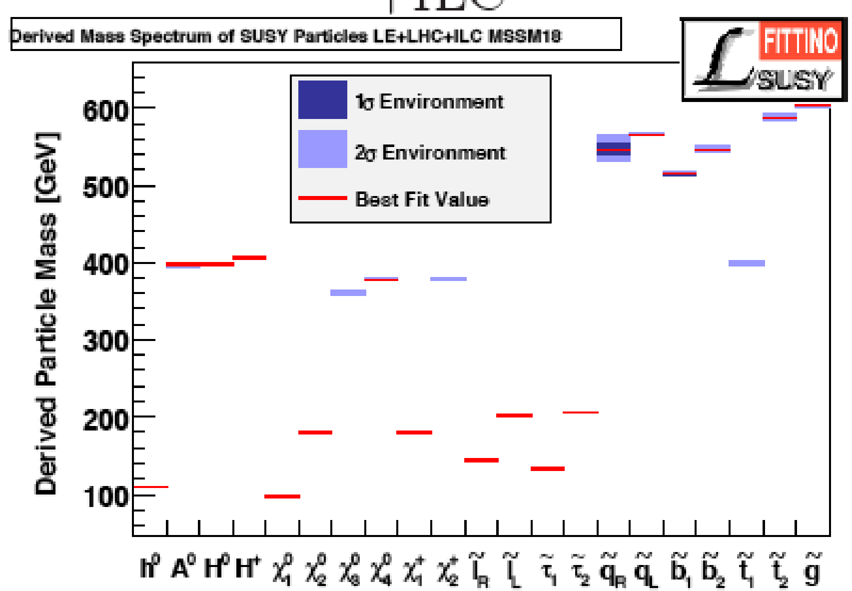



Possible precision in MSSM18:

LHC 300 $\text{fb}^{-1}$

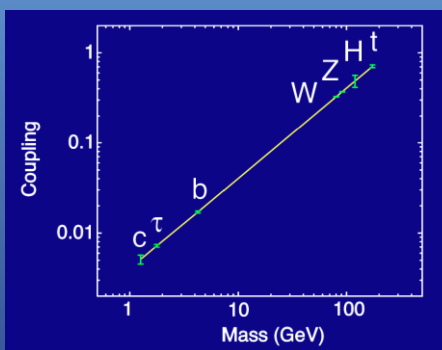



+ILC



# Higgs parameters

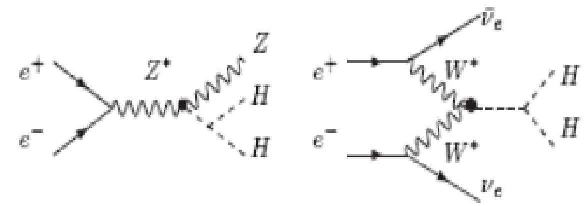
- Also Higgs couplings to many different particles – with small BR




The double Higgs cross-section at ~3TeV is big

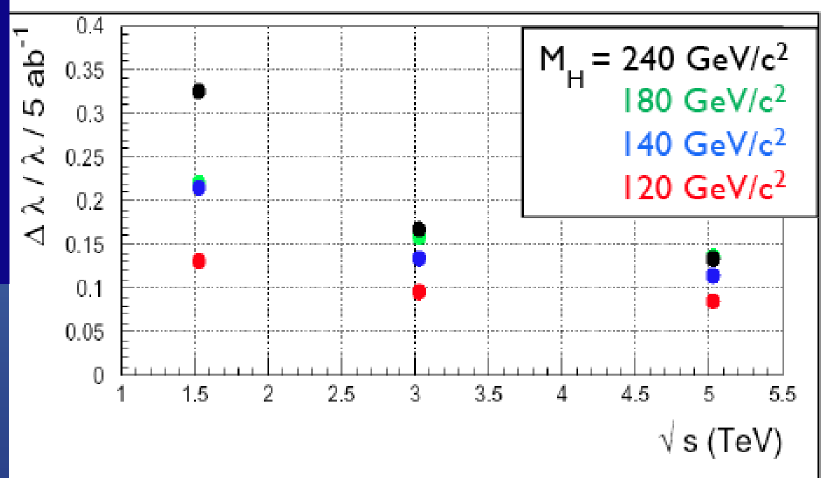
→ access to HHH self coupling, hence Higgs potential!

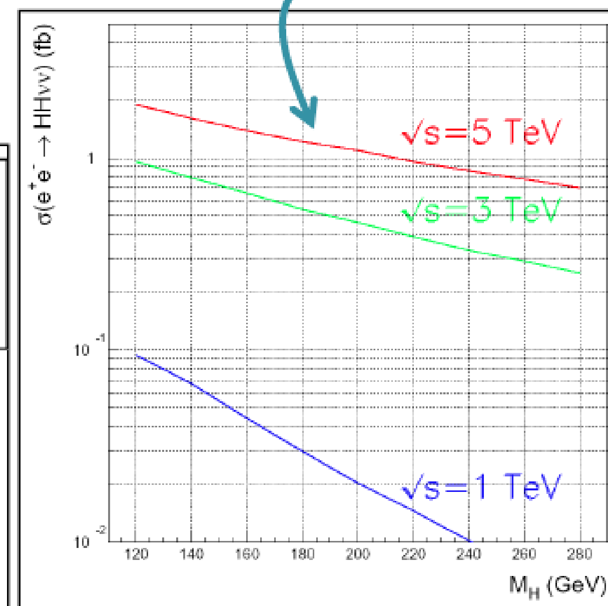
For instance with 5 $ab^{-1}$, we expect to measure the triple HHH coupling with ~10% precision for $M_h$=120 GeV/$c^2$.



$\sigma \propto 1/s$
~0.2 fb @ 0.5 TeV

$\sigma \propto \log(s)$
~1 fb @ 3 TeV



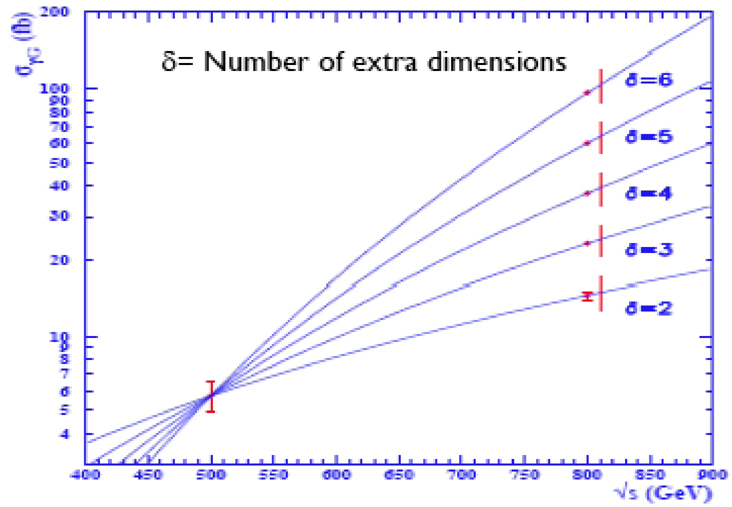
# Physics – exotics – extra dimensions

Any alternative to SUSY that has to deal with the Naturalness problem, will have some visible effects at the TeV scale.

One way to deal with the different scales involved, is to think as gravity living in more dimensions that we can feel, hence its weakness is only apparent, and there is only one fundamental energy scale.

$$e^+e^- \rightarrow \gamma G_{KK}$$

By counting the number of events with missing energy and photons, at different centre-of-mass energies we can measure the number of extra dimensions and the Planck scale.




*Not possible at LHC, easy at a LC with enough energy!*

# LHC/Tevatron in the coming 2 years

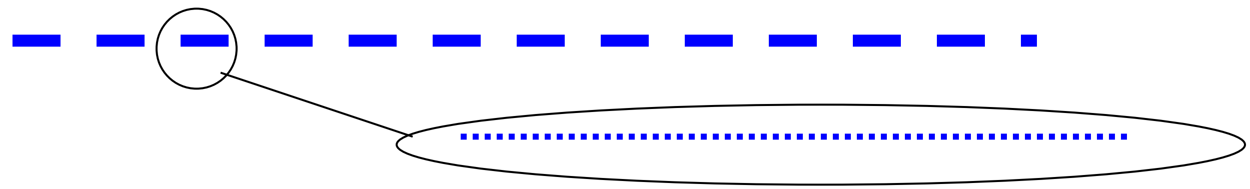
- SM Higgs: Provide 95% CL limits or 3 sigma evidence over large mass-range (~ 125-450 GeV)
- SUSY (squarks and gluinos), sensitivity in the range ~ 700-800 GeV
- W' sensitivities towards ~ 2 TeV
- … need some yes'es in figure shown earlier, or some other new physics …

# Parameters

| | | CLIC | CLIC | ILC |
|---|---|---|---|---|
| $E_{cms}$ | [TeV] | 0.5 | 3.0 | 0.5 |
| $f_{rep}$ | [Hz] | 50 | 50 | 5 |
| $f_{RF}$ | [GHz] | 12 | 12 | 1.3 |
| $G_{RF}$ | [MV/m] | 80 | 100 | 31.5 |
| $n_b$ | | 354 | 312 | 2625 |
| $\Delta t$ | [ns] | 0.5 | 0.5 | 369 |
| $N$ | $[10^9]$ | 6.8 | 3.7 | 20 |
| $\sigma_x$ | [nm] | 202 | 40 | 655 |
| $\sigma_y$ | [nm] | 2.26 | 1 | 5.7 |
| $\epsilon_x$ | [$\mu$m] | 2.4 | 0.66 | 10 |
| $\epsilon_y$ | [nm] | 25 | 20 | 40 |
| $\mathcal{L}_{total}$ | $[10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$ | 2.3 | 5.9 | 2.0 |
| $\mathcal{L}_{0.01}$ | $[10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$ | 1.4 | 2.0 | 1.45 |

# CLIC and ILC time structures

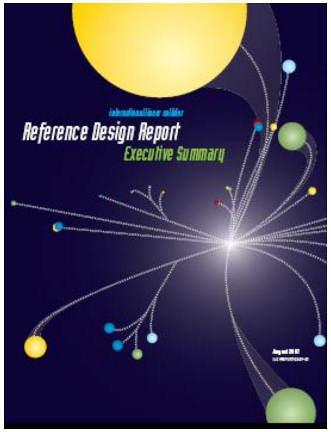
Train repetition rate 5 Hz (ILC) or 50 Hz (CLIC)



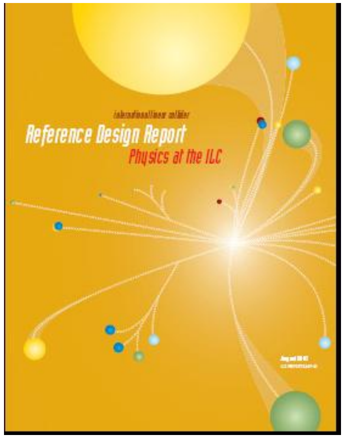
| | | | |
|---|---|---|---|
| **CLIC:** | 1 train = 312 bunches | 0.5 ns apart | 50 Hz |
| **ILC:** | 1 train = 2625 bunches | 369 ns apart | 5 Hz |

# RDR Complete

- **Reference Design Report (4 volumes)**

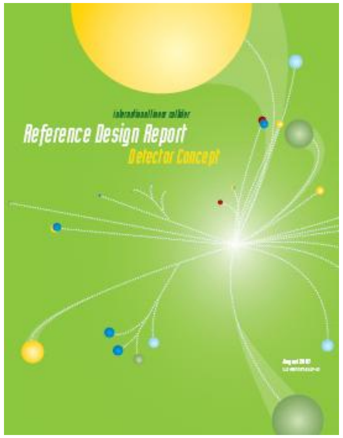



Executive Summary




Physics at the ILC


Accelerator




Detectors

# RDR Design Parameters

| | | |
|---|---|---|
| Max. Center-of-mass energy | 500 | GeV |
| Peak Luminosity | ~$2x10^{34}$ | $1/cm^2s$ |
| Beam Current | 9.0 | mA |
| Repetition rate | 5 | Hz |
| Average accelerating gradient | 31.5 | MV/m |
| Beam pulse length | 0.95 | ms |
| Total Site Length | 31 | km |
| Total AC Power Consumption | ~230 | MW |

# Major R&D Goals for Technical Design

## Accelerator Design and Integration (AD&I)

- **Studies of possible cost reduction designs and strategies for consideration in a re-baseline in 2010**

## SCRF

- **High Gradient R&D - globally coordinated program to demonstrate gradient by 2010 with 50%yield;**

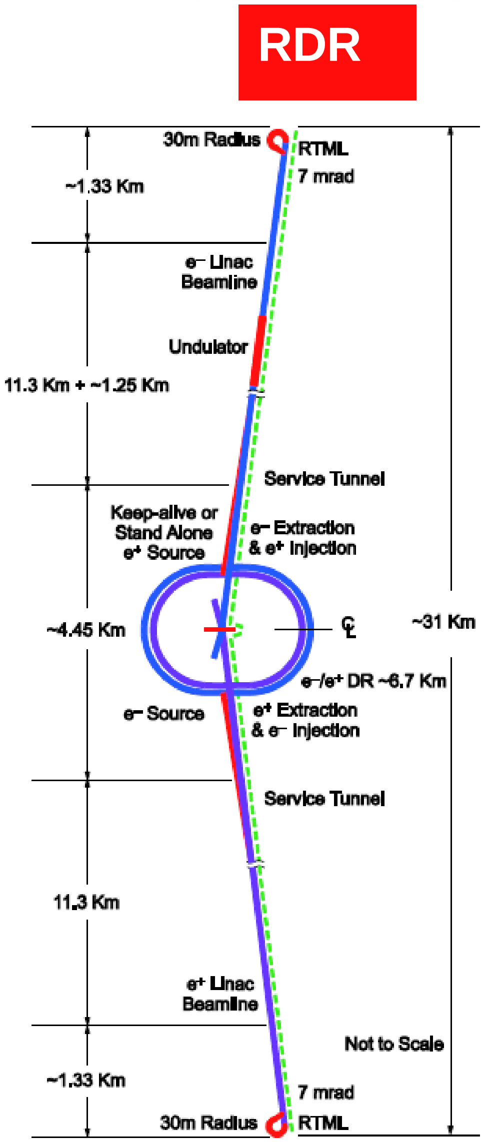
## ATF-2 at KEK

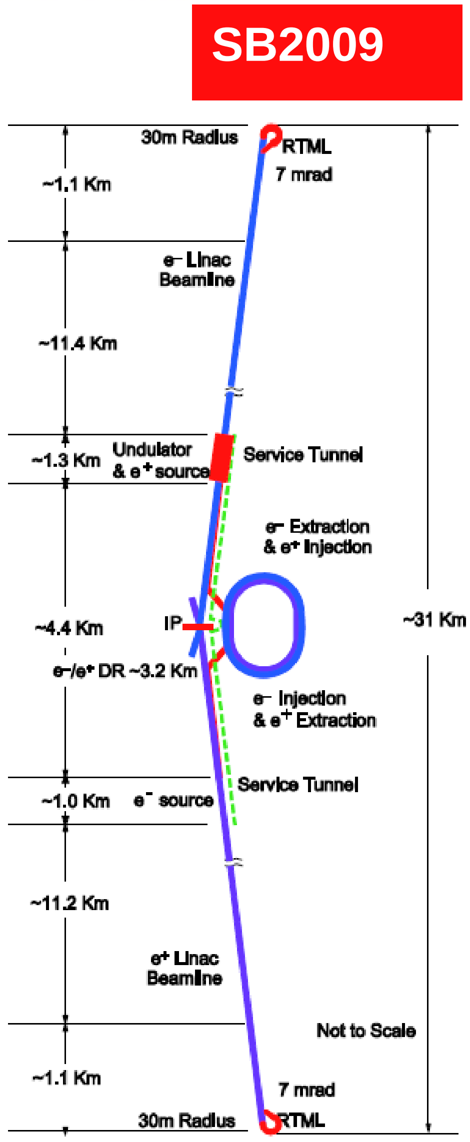
- **Demonstrate Fast Kicker performance and Final Focus Design**

## Electron Cloud Mitigation – (CesrTA)

- **Electron Cloud tests at Cornell to establish mitigation and verify one damping ring is sufficient.**

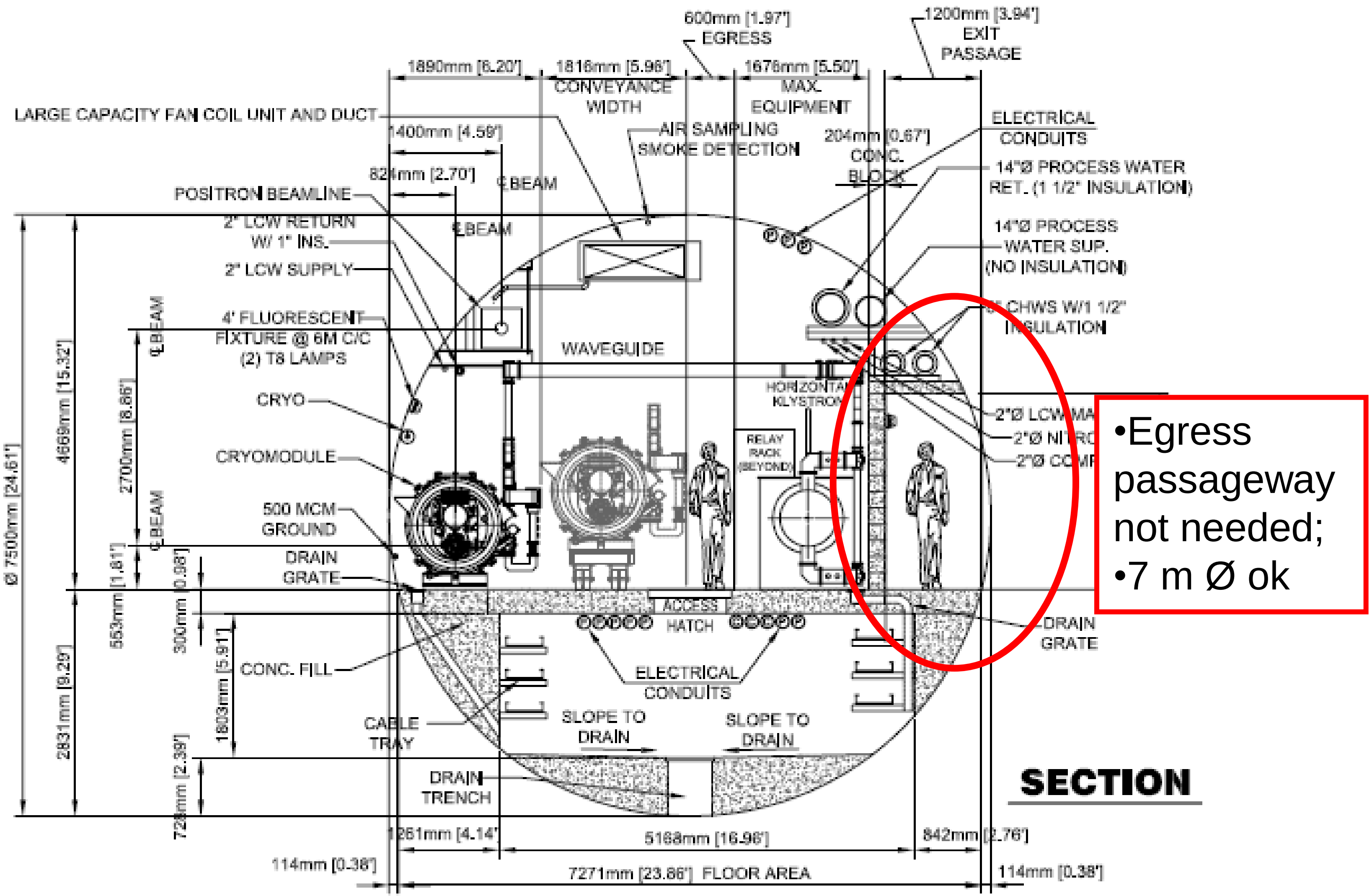
# Proposed Design changes for TDR




- Single Tunnel for main linac
- Move positron source to end of linac ***
- Reduce number of bunches factor of two (lower power) **
- Reduce size of damping rings (3.2km)
- Integrate central region
- Single stage bunch compressor

# 7.5 m Diameter Single Tunnel

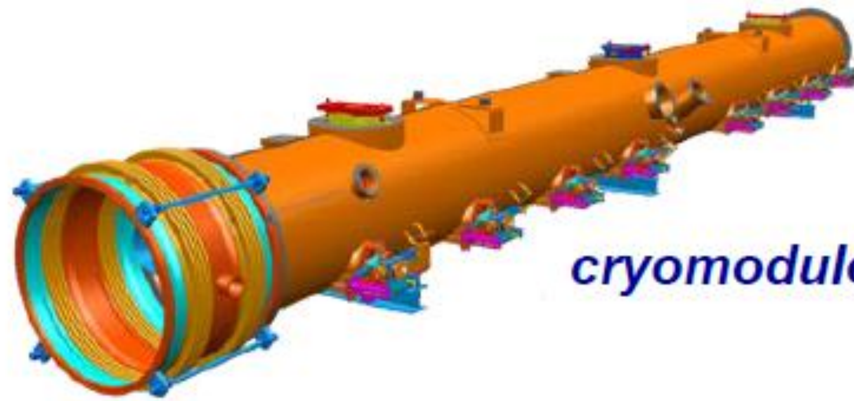


# 7.5 m Diameter Single Tunnel
## *High-Level RF Solution*

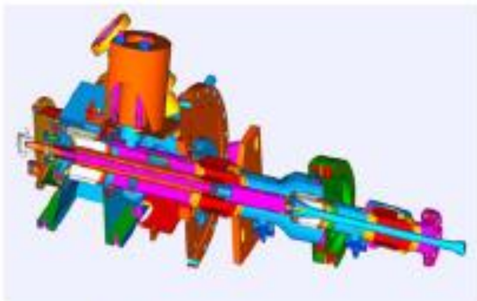
- **Critical technical challenge for one-tunnel option is the high level RF distribution.**
- **Two proposed solutions :**
  - **Distributed RF Source (DRFS)**
    - **Small 750kW klystrons/modulators in tunnel**
    - **One klystron per four cavities**
    - **~1880 klystrons per linac**
    - **Challenge is cost and reliability**
  - **Klystron Cluster Scheme (KCS)**
    - **RDR-like 10 MW Klystrons/modulators on surface**
    - **Surface building & shafts every ~2 km**
    - **Challenge is novel high-powered RF components (needs R&D)**

# Superconducting RF Linac Technology

**cavity**



***cryomodule***

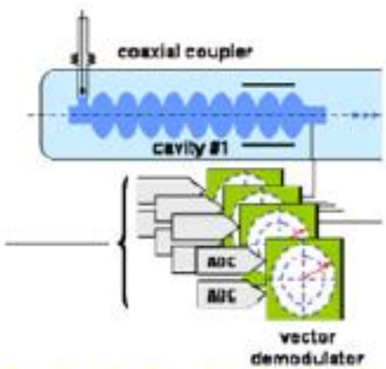


**coupler**

**SCRF Linac Technology**

***tuner***

**LLRF**




**RF**

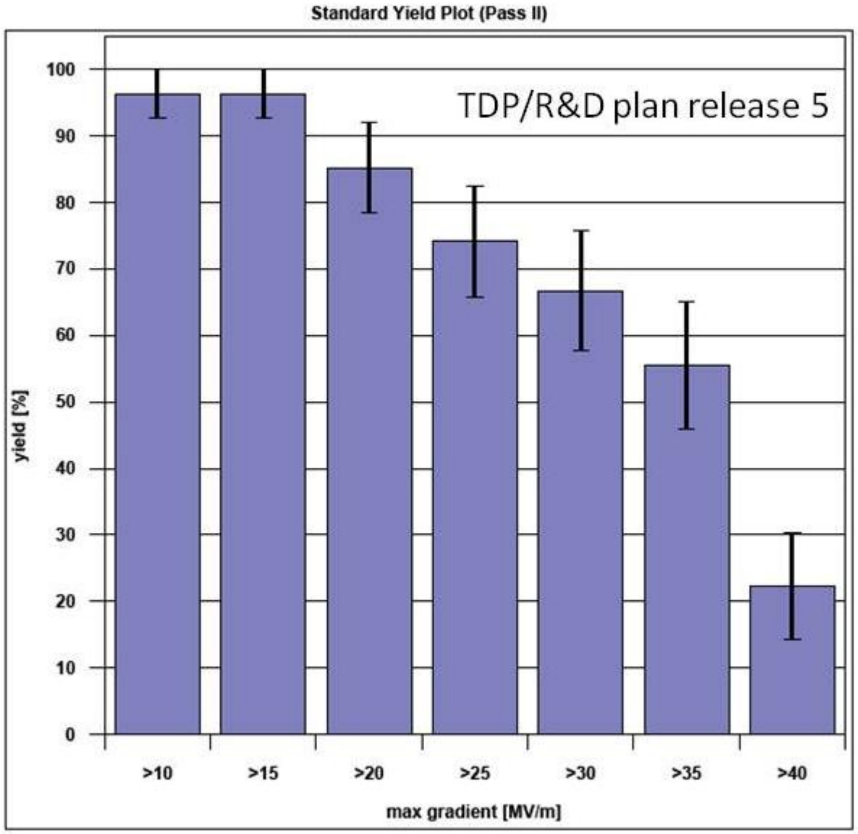
**HOMs**

# The ILC SCRF Cavity

Figure 1.2-1: A TESLA nine-cell 1.3 GHz superconducting niobium cavity.

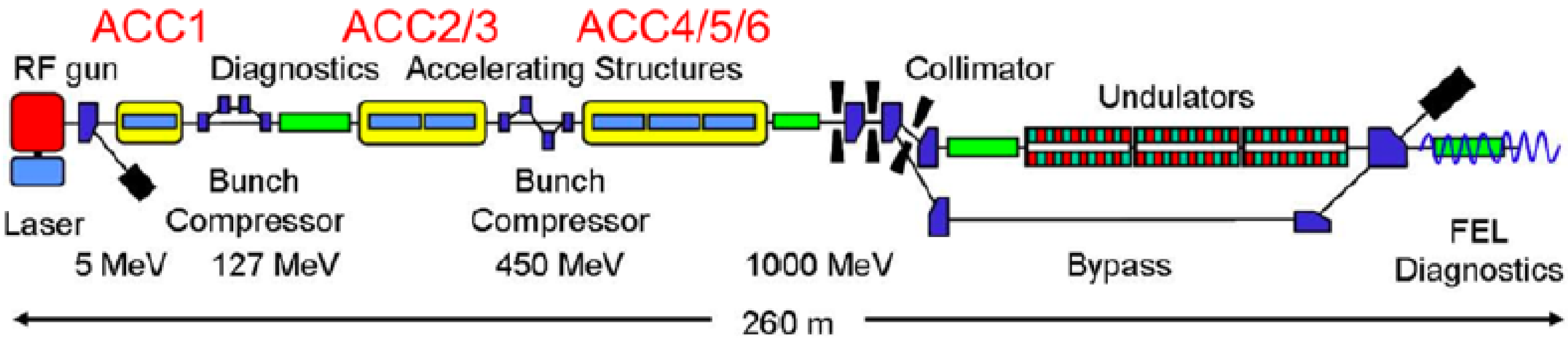
- Achieve high gradient (35MV/m); develop multiple vendors; make cost effective, etc

- Focus is on high gradient; production yields; cryogenic losses; radiation; system performance


Standard Yield Plot (Pass II)
TDP/R&D plan release 5
100
90
80
70
60
50
40
30
20
10
0
yield [%]
>10
>15
>20
>25
>30
>35
>40
max gradient [MV/m]

# TTF/FLASH 9mA Experiment

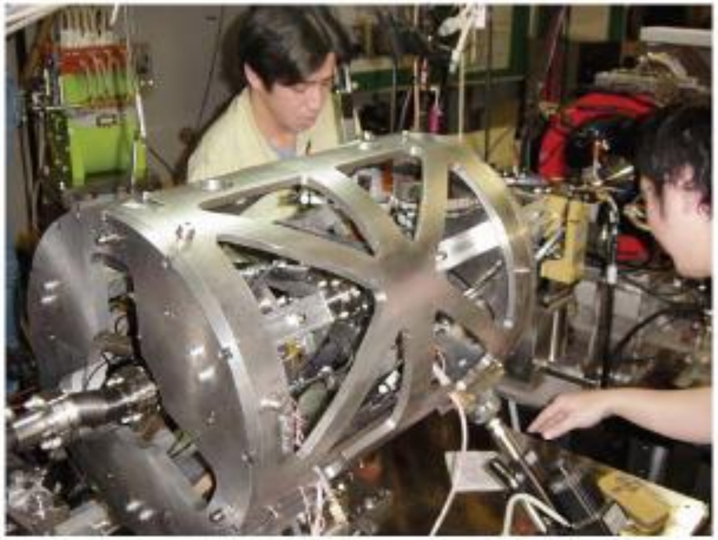
Full beam-loading long pulse operation → "S2"

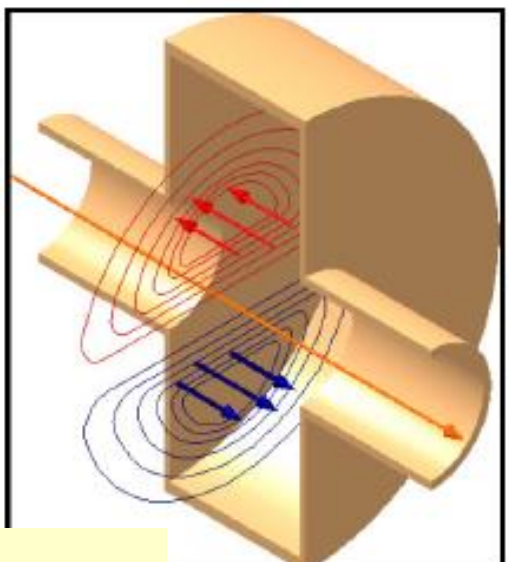
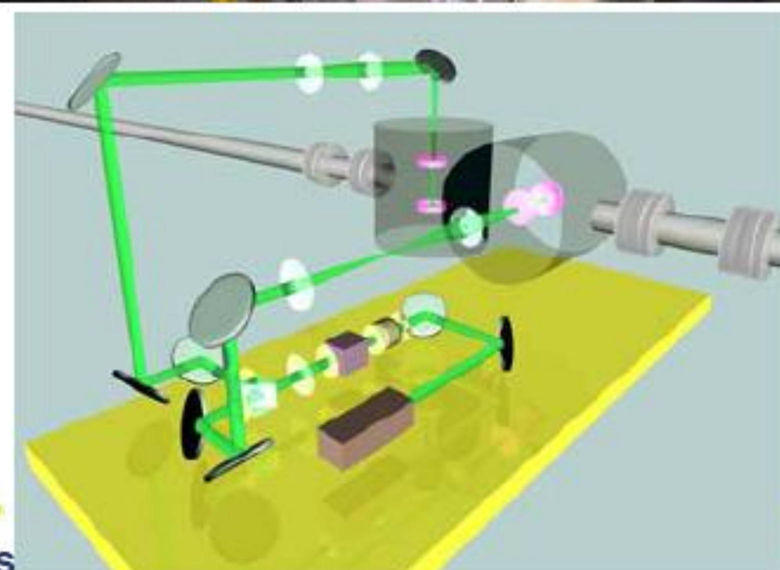



| | | XFEL | ILC | FLASH design | 9mA studies |
|---|---|---|---|---|---|
| Bunch charge | nC | 1 | 3.2 | 1 | 3 |
| # bunches | | 3250 | 2625 | 7200' | 2400 |
| Pulse length | µs | 650 | 970 | 800 | 800 |
| Current | mA | 5 | 9 | 9 | 9 |

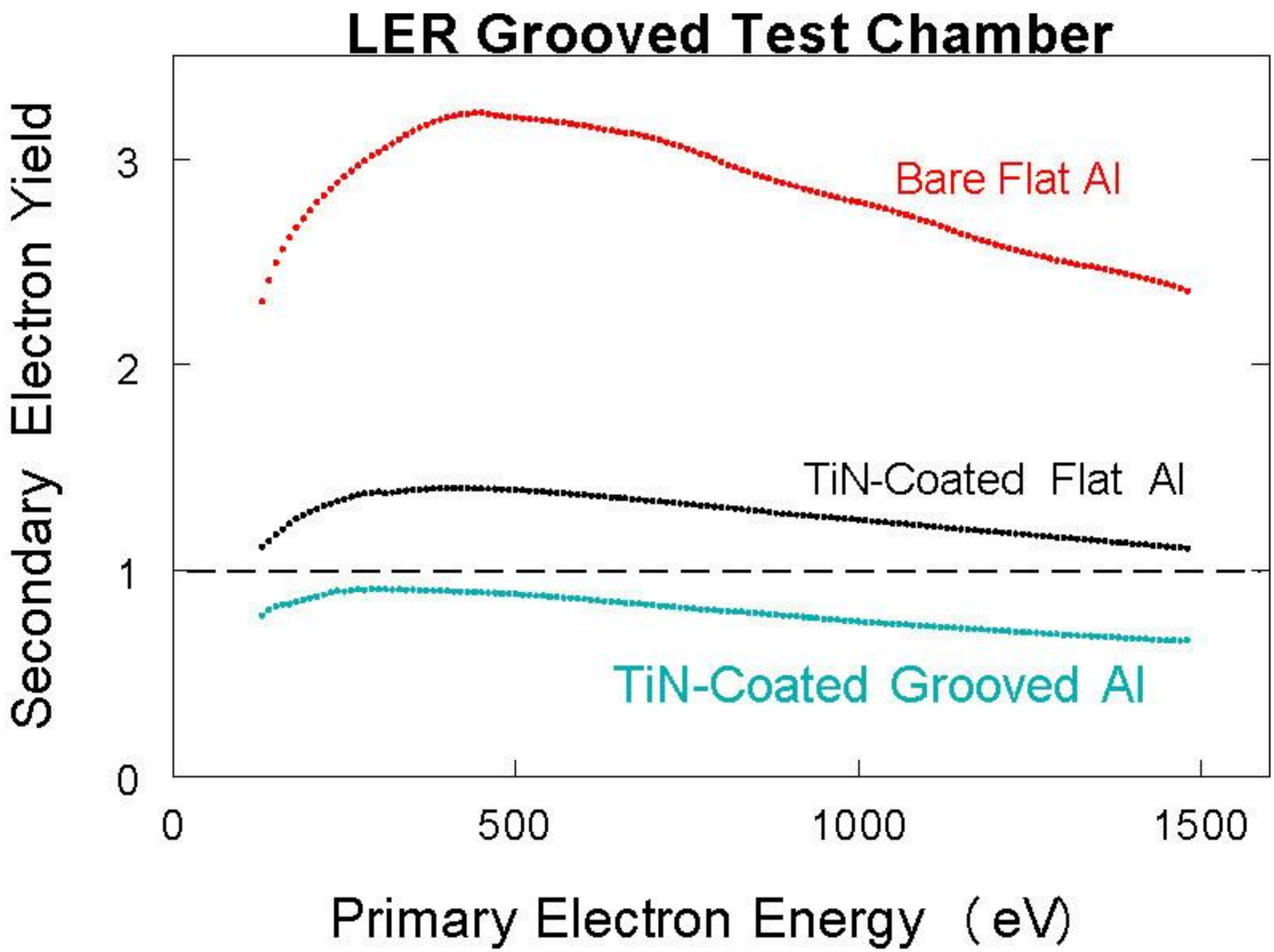
- Stable 800 bunches, 3 nC at 1MHz (800 µs pulse) for over 15 hours (uninterrupted)
- Several hours ~1600 bunches, ~2.5 nC at 3MHz (530 µs pulse)
- >2200 bunches @ 3nC (3MHz) for short periods

# KEK ATF-2 Studies
## *(Beam Sizes at Collision)*



# Cornell E Cloud Studies



# Timescales: TDR to ILC
## *(or beyond 2012)*

- **Steps to a Project – Technical (2-3 years)**
  - R&D for Risk Reduction and Technology Improvement
  - Systems Tests (e.g. S2 completion – ILC-like beam tests)
  - Engineering Design
  - Industrialization
- **Project Implementation**
  - Government Agreements for International Partnership
  - Siting and site-dependent design
  - Governance
- **Time to Construct**
  - 5-6 years construction
  - 2 years commissioning
- **Project Proposal / Decision keyed to LHC results**
- **ILC Could be doing physics by early to mid- 2020s**

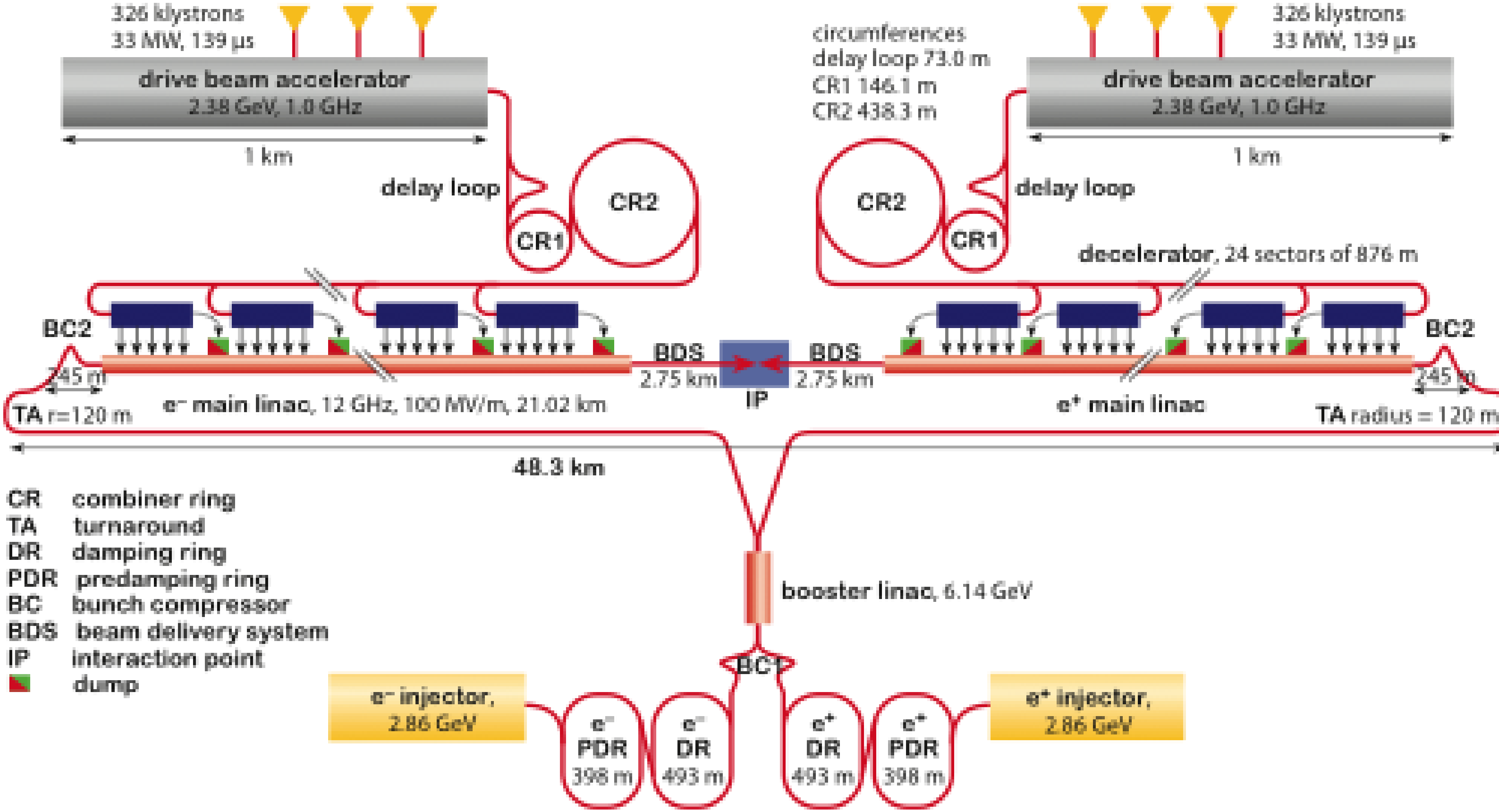
# CLIC/CTF3 Collaboration

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

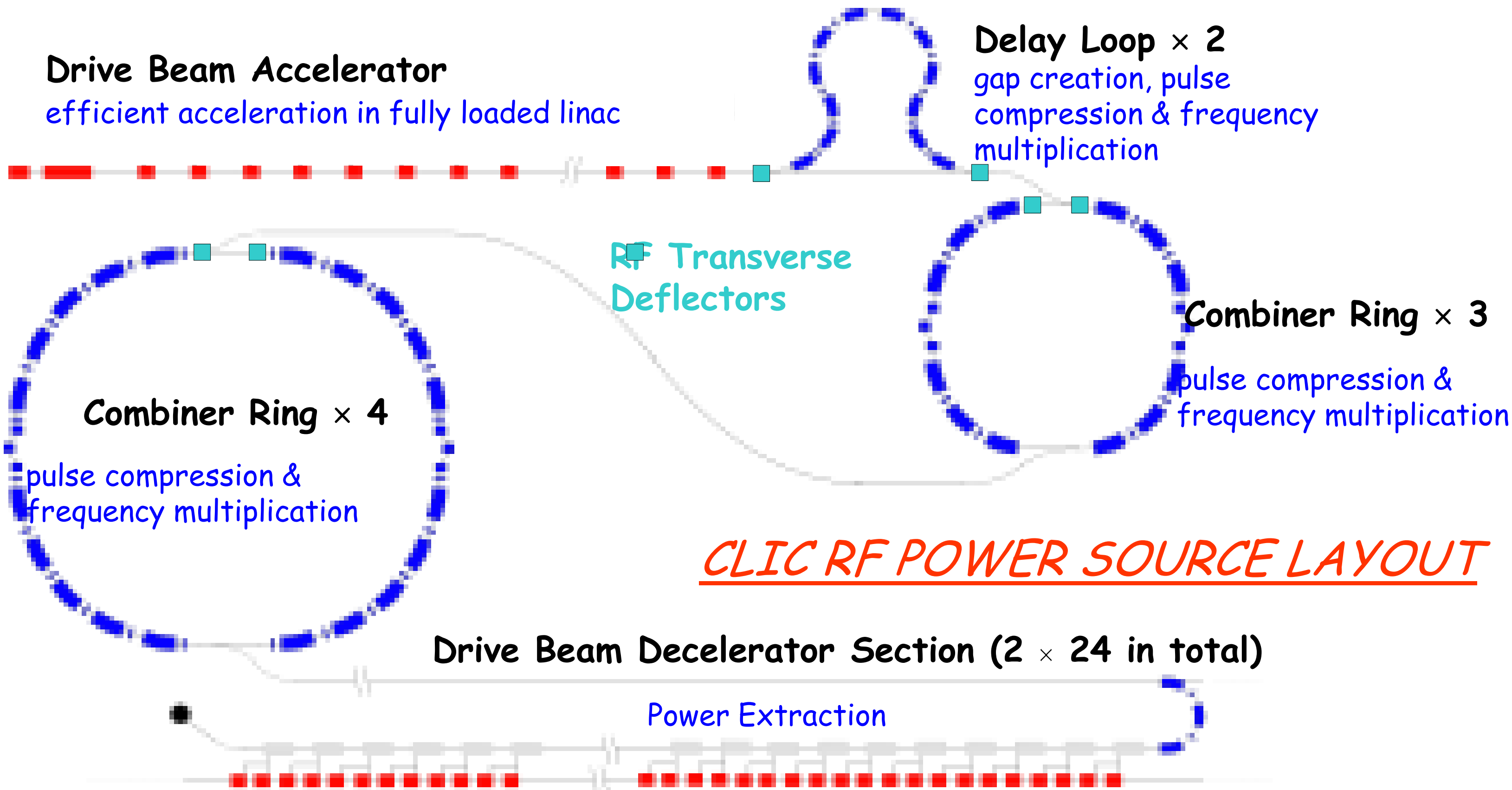
## CLIC multi-lateral collaboration
## 40 Institutes from 21 countries

ACAS (Australia)
Aarhus University (Denmark)
Ankara University (Turkey)
Argonne National Laboratory (USA)
Athens University (Greece)
BINP (Russia)
CERN
CIEMAT (Spain)
Cockcroft Institute (UK)
ETHZurich (Switzerland)
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)
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. University of Catalonia (Spain)
PSI (Switzerland)
RAL (UK)
RRCAT / Indore (India)
SLAC (USA)
Thrace University (Greece)
Tsinghua University (China)
University of Oslo (Norway)
Uppsala University (Sweden)
UCSC SCIPP (USA)

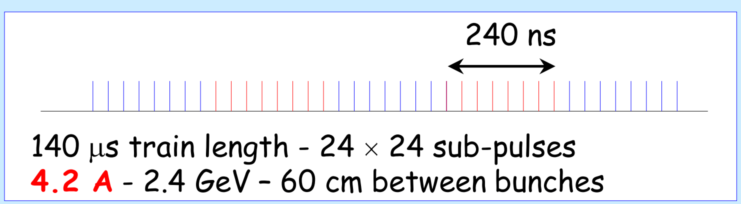
# Reminder: The CLIC Layout



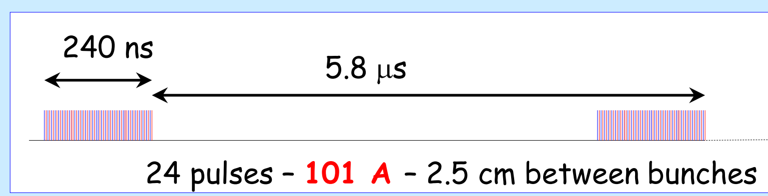
# CLIC Power Source Concept




## Drive beam time structure - initial




## Drive beam time structure - final



# CLIC Main Parameters

http://cdsweb.cern.ch/record/1132079?ln=fr http://clic-meeting.web.cern.ch/clic-meeting/clictable2007.html

## High gradient to reduce cost

- Break down of structures at high fields and long pulses
  - Pushes to short pulses
  - and small iris radii (high wakefields)

## High luminosity

- Improve wall plug to RF efficiency
- Push RF to beam efficiency
  - Push single bunch charge to beam dynamics limit
  - Reduce bunch distance to beam dynamics limit
- Push specific luminosity -> High beam quality
  - Beam-based alignment and tuning
  - Excellent pre-alignment
  - Component stabilisation

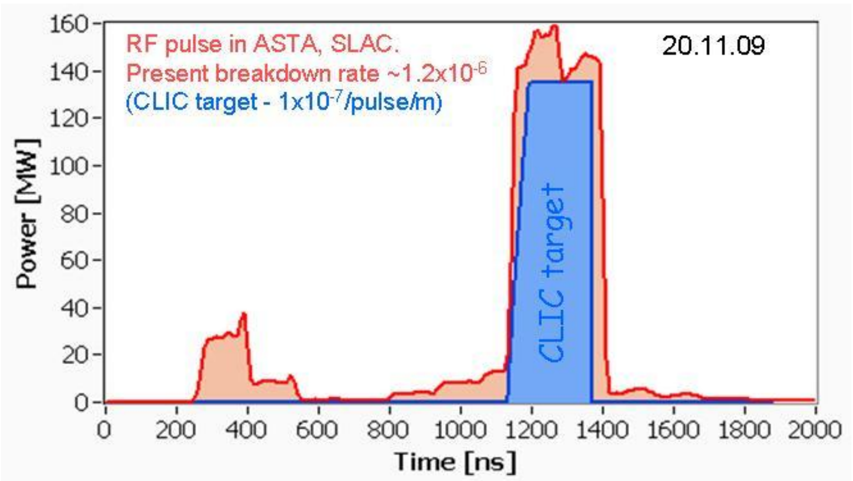
| | | CLIC | CLIC |
|---|---|---|---|
| $E_{cms}$ | [TeV] | 0.5 | 3.0 |
| $f_{rep}$ | [Hz] | 50 | 50 |
| $f_{RF}$ | [GHz] | 12 | 12 |
| $G_{RF}$ | [MV/m] | 80 | 100 |
| $n_b$ | | 354 | 312 |
| $\Delta t$ | [ns] | 0.5 | 0.5 |
| $N$ | $[10^9]$ | 6.8 | 3.7 |
| $\sigma_x$ | [nm] | 202 | 40 |
| $\sigma_y$ | [nm] | 2.26 | 1 |
| $\epsilon_x$ | [$\mu$m] | 2.4 | 0.66 |
| $\epsilon_y$ | [nm] | 25 | 20 |
| $\mathcal{L}_{total}$ | $[10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$ | 2.3 | 5.9 |
| $\mathcal{L}_{0.01}$ | $[10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$ | 1.4 | 2.0 |

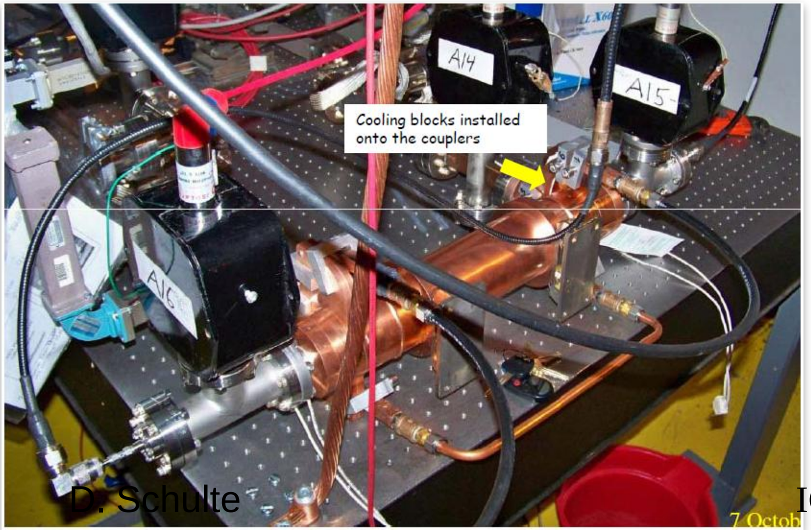
# CLIC feasibility issues

| System | Item | Feasibility Issue | Unit | Nominal |
|---|---|---|---|---|
| Two Beam Acceleration | Drive beam generation | Fully loaded accel effic | % | 97 |
| | | Freq&Current multipl | - | 2*3*4 |
| | | 12 GHz beam current | A | 4.5*24=100 |
| | | 12 GHz pulse length | nsec | 240 |
| | | Intensity stability | 1.E-03 | 0.75 |
| | | Drive beam linac RF phase stability | Deg (1GHZ) | 0.05 |
| | Beam Driven RF power generation | PETS RF Power | MW | 130 |
| | | PETS Pulse length | ns | 170 |
| | | PETS Breakdown rate | /m | < 1·10-7 |
| | | PETS ON/OFF | - | @ 50Hz |
| | | Drive beam to RF efficiency | % | 90% |
| | | RF pulse shape control | % | < 0.1% |
| | Accelerating Structures (CAS) | Structure Acc field | MV/m | 100 |
| | | Structure Pulse length | ns | 240 |
| | | Structure Breakdown rate | /m MV/m.ns | < 3·10-7 |
| | Two Beam Acceleration | Power producton and probe beam acceleration in Two beam module | MV/m - ns | 100 - 240 |
| | | Drive to main beam timing stability | psec | 0.05 |
| | | Main to main beam timing stability | psec | 0.07 |
| Ultra low beam emittance & sizes | Ultra low Emittances | Emitttance generation H/V | nm | 500/5 |
| | | Emittance preservation: Blow-up | nm | 160/15 |
| | Alignment | Main Linac components | microns | 15 |
| | | Final-Doublet | microns | 2 to 8 |
| | Vertical stabilisation | Quad Main Linac | nm>1 Hz | 1.5 |
| | | Final Doublet (assuming feedbacks) | nm>4 Hz | 0.2 |
| Operation and Machine Protection System (MPS) | | 72MW@2.4GeV | | |
| | | main beam power of 13MW@1.5TeV | | |

# PETS Results

Klystron based testing:



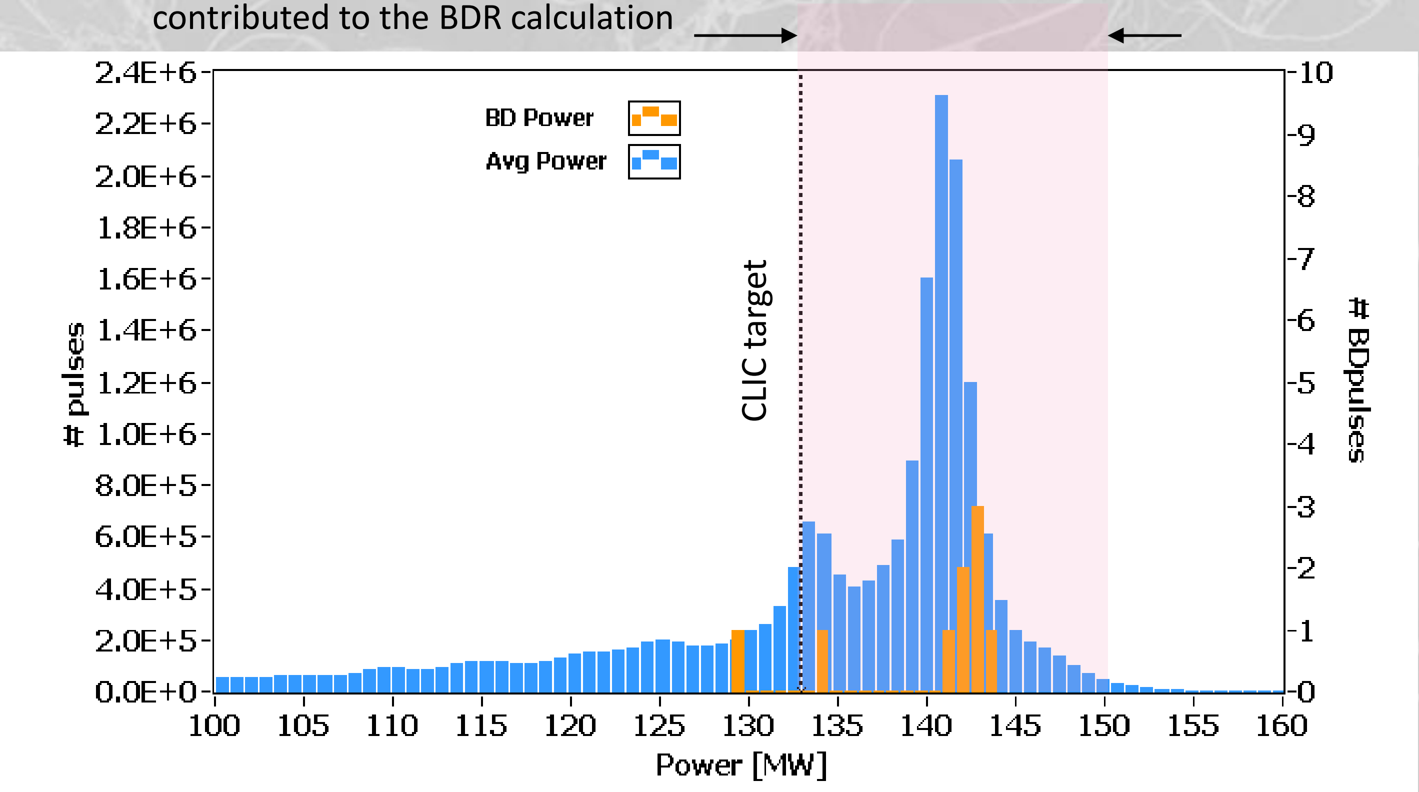




Beam based (with recirculation):

- Power
  - 130 MW peak at 150 ns
  - Limited by attenuator and phase shifter breakdowns
  - Power production according to predictions

# Extraction of PETS breakdown trip rate

Part of the statistical distribution contributed to the BDR calculation

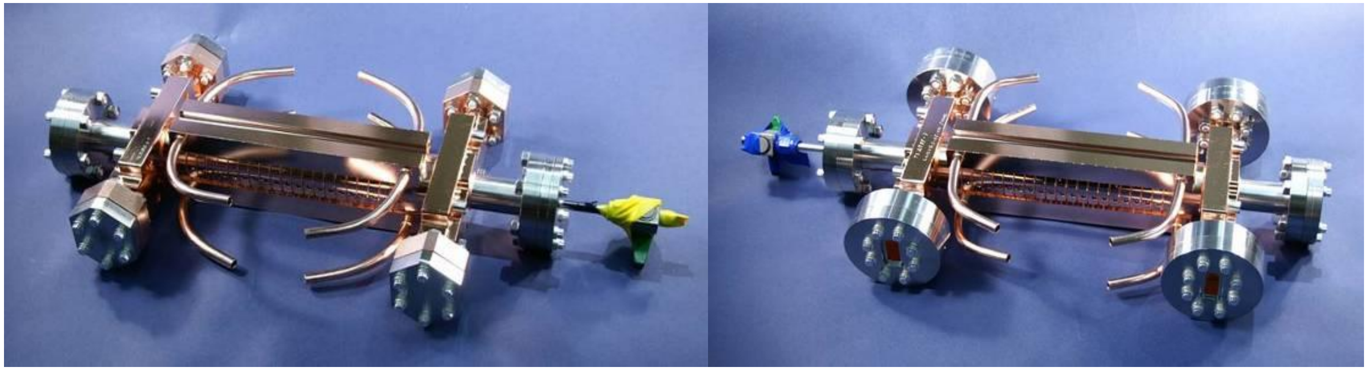



- 1.6x10$^{7}$ pulses were accumulated in a 110 hour run.
- 8 PETS breakdowns were identified giving a breakdown rate of **5x10$^{-7}$/pulse**.
- Most of the breakdowns were located in the upper tail of the distribution, which makes BDR estimate rather conservative.
- During the last 80 hours no breakdowns were registered giving a BDR **<1.2x10$^{-7}$/pulse**.

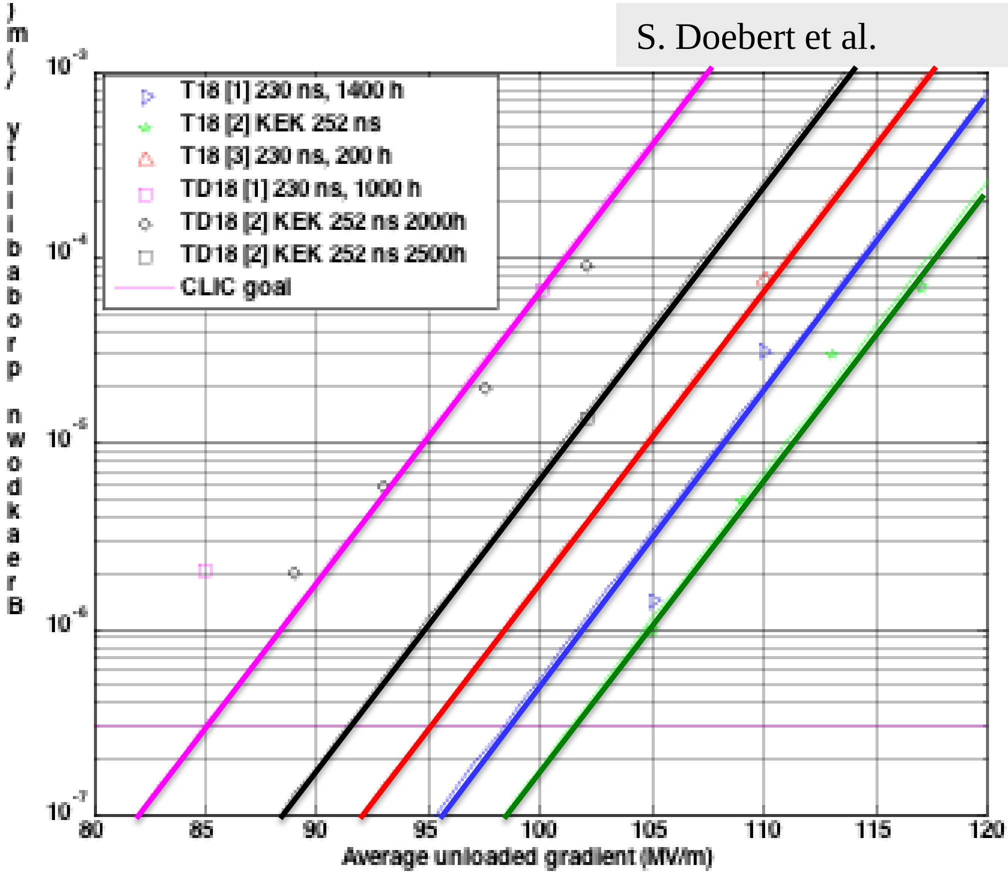
# Accelerating Structure Results

T18 and TD18 built and tested at SLAC and KEK

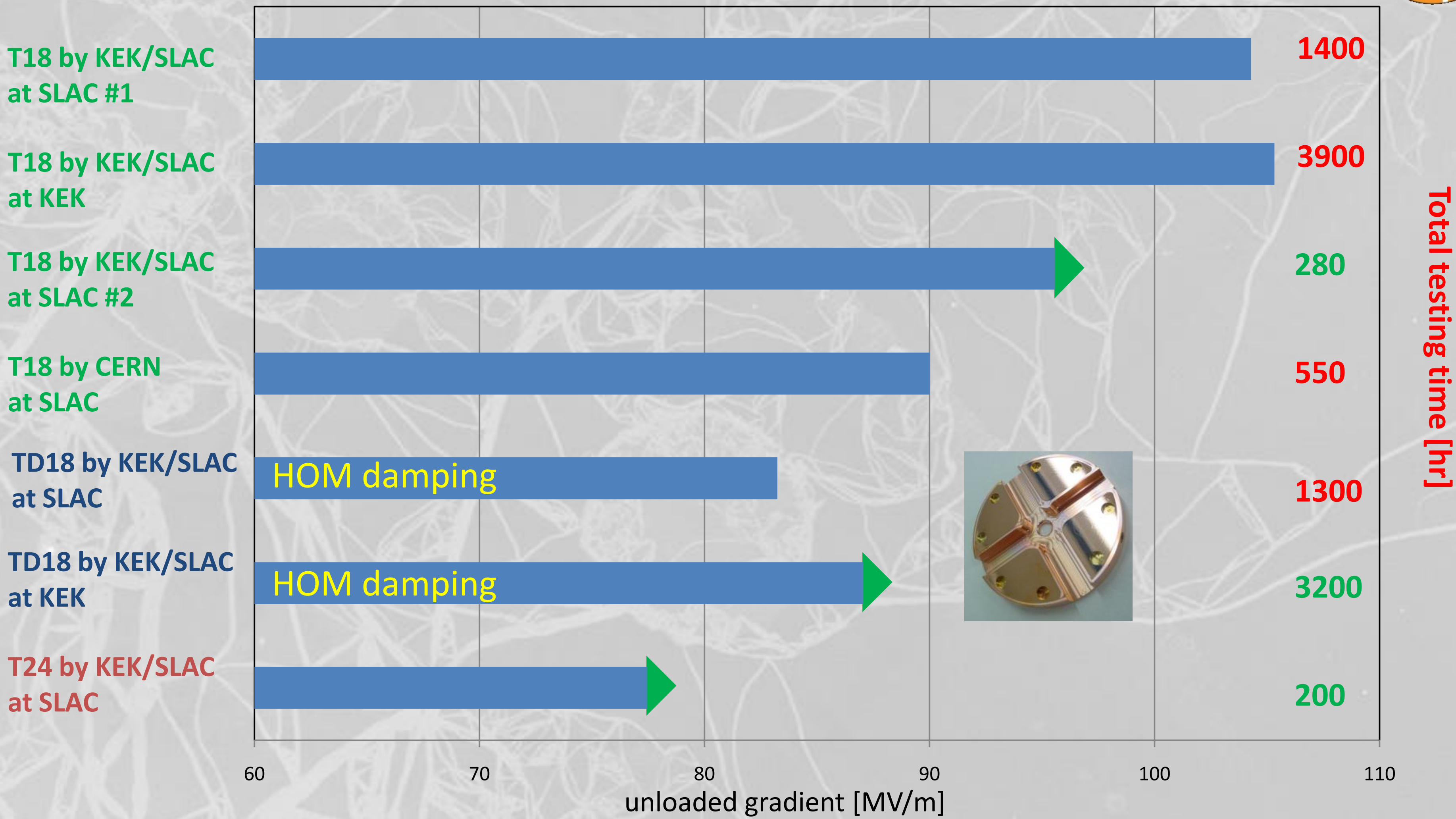
- real prototypes with improved design are TD24



S. Doebert et al.



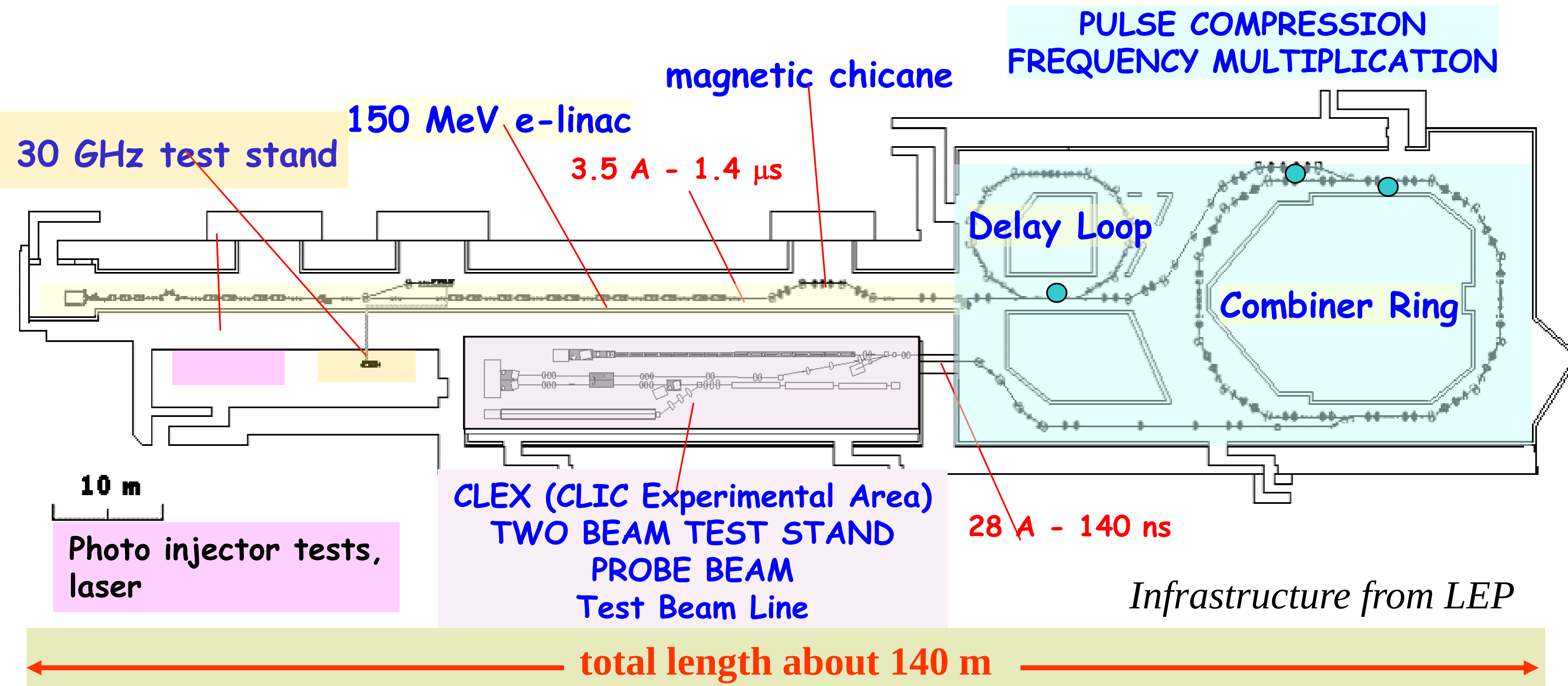
# Synthesis of accelerating structure test results scaled to CLIC breakdown rate




Scaling to CLIC conditions: Scaled from lowest measured BDR to *BDR*=4*10$^{-7}$ and $\tau$=180 ns (CLIC flat-top is 170 ns), using standard $E^{29}\tau^{5}/BDR$=const. Correction to compensate for beam loading not included – expected to be less than about 7%.

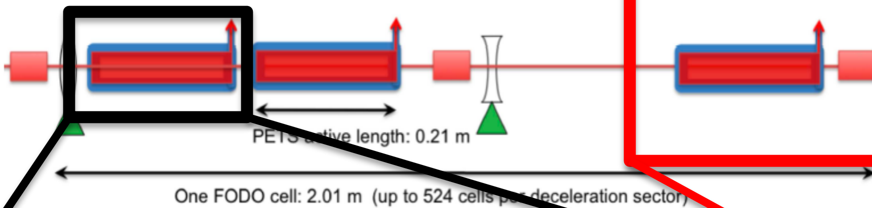
# Two-Beam Acceleration: CLIC Test Facility (CTF3)

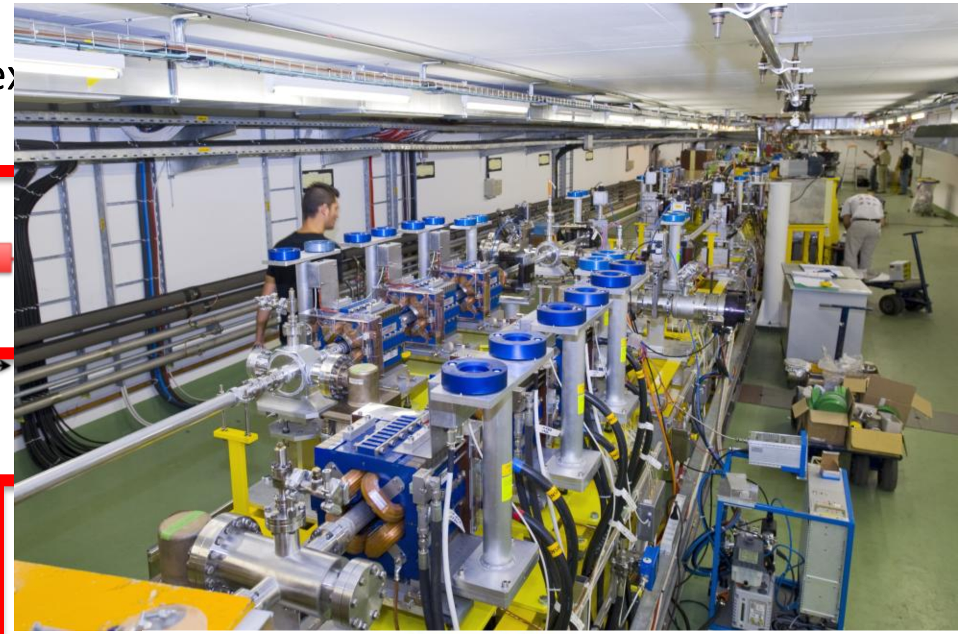
- Demonstrate Drive Beam generation
(fully loaded acceleration, beam intensity and bunch frequency multiplication x8)
- Demonstrate RF Power Production and test Power Structures
- Demonstrate Two Beam Acceleration and test Accelerating Structures



# Drive Beam Deceleration and Module: CLEX

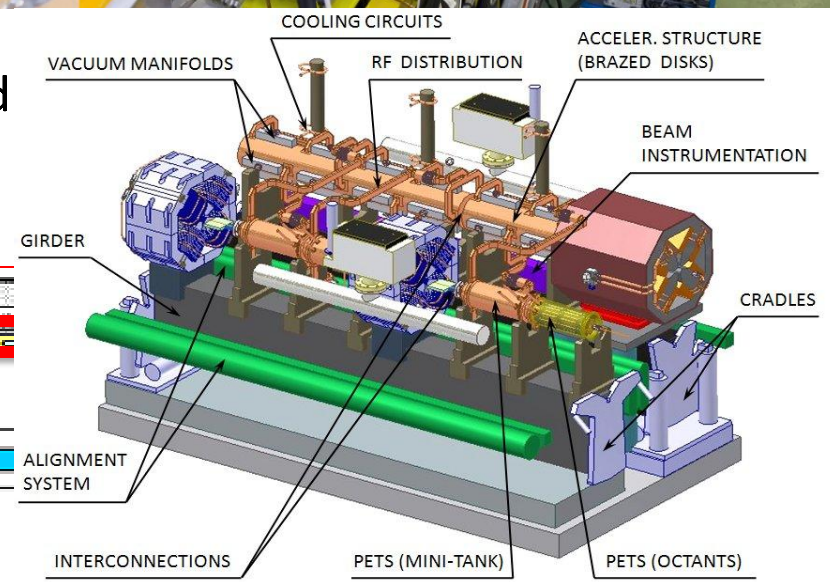
Decelerator sector: ~ 1 km, 90% of energy ex

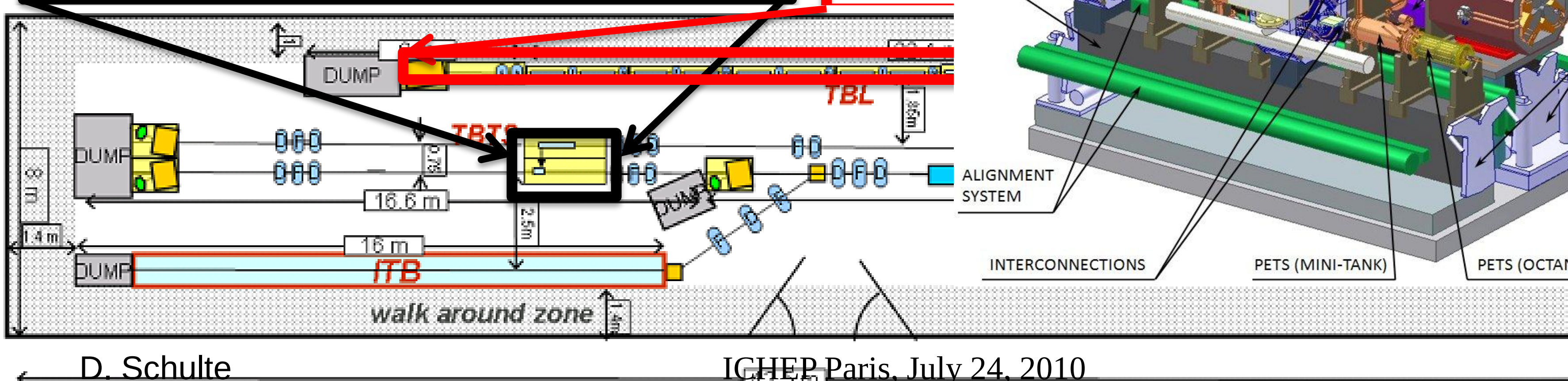


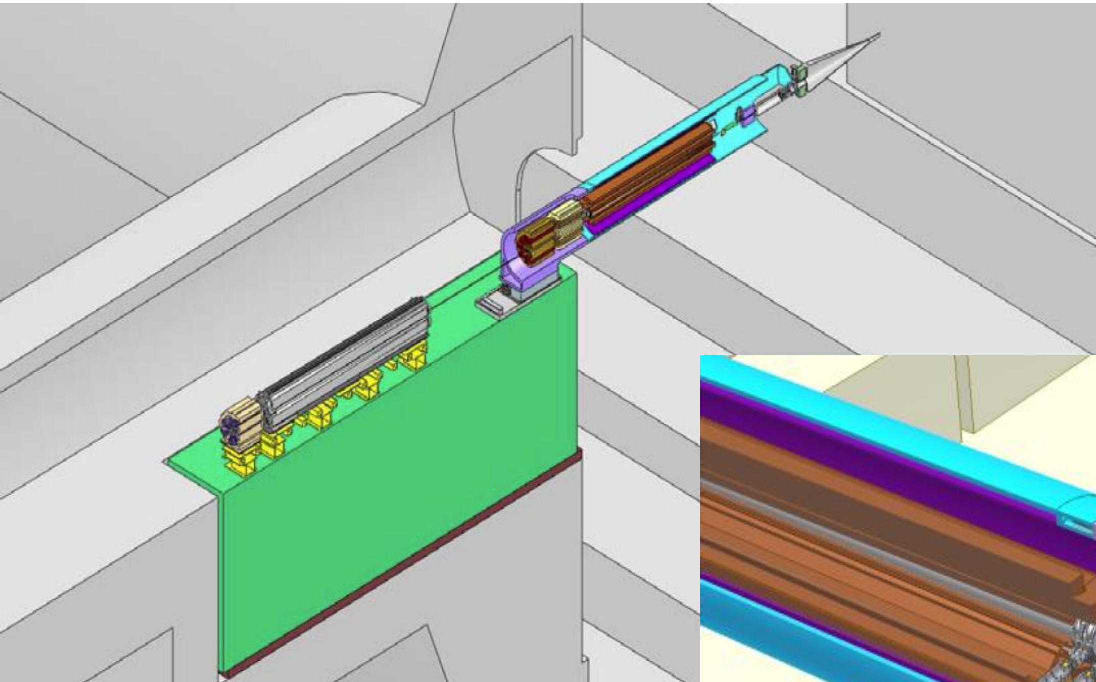
**Two-beam Test Stand:**

- **Single** PETS with beam
- Accelerating structure with beam
  - wake monitor
  - kick on beam from break down
- Integration

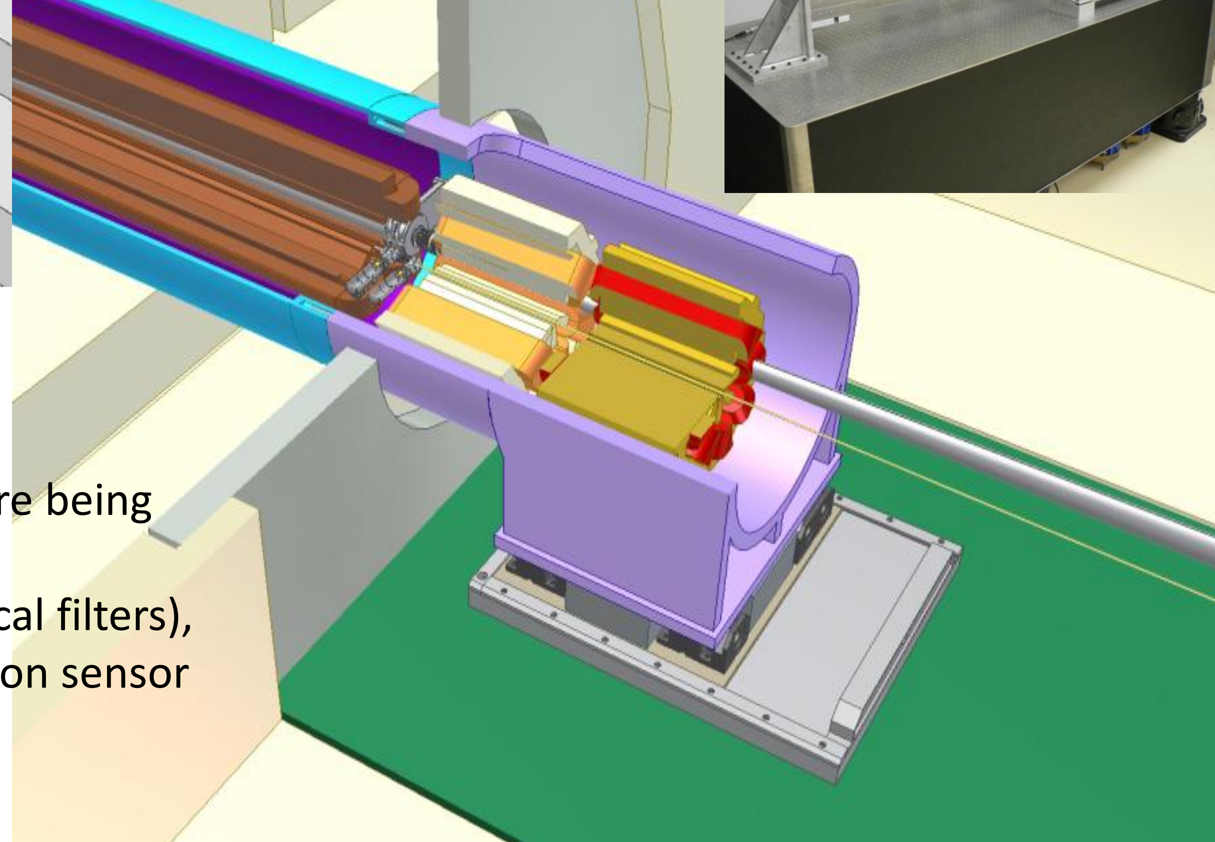


# Machine-detector interface issues



Concrete mass of ~ 80 tons mounted on calibrated springs.
Eigenfrequency ~ 1 Hz.



Designed to reduce vibrations by a factor of ~ 30.

Design, hardware and methods are being developed.
Methods: Stabilisation (mechanical filters), beam-based feedback and vibration sensor based feed-forward used

# Combined ILC/CLIC working groups

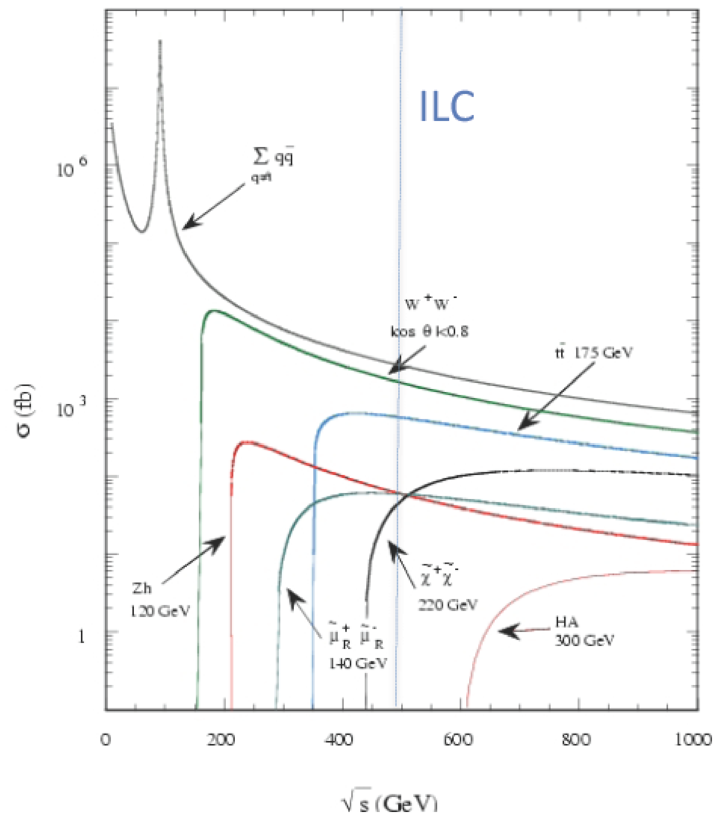
| | CLIC | ILC |
|---|---|---|
| Physics & Detectors | L.Linssen, D.Schlatter | F.Richard, S.Yamada |
| Beam Delivery System (BDS) & Machine Detector Interface (MDI) | L.Gatignon<br>D.Schulte,<br>R.Tomas Garcia | B.Parker, A.Seriy |
| Civil Engineering & Conventional Facilities | C.Hauviller, J.Osborne. | J.Osborne,<br>V.Kuchler |
| Positron Generation | L.Rinolfi | J.Clarke |
| Damping Rings | Y.Papaphilipou | M.Palmer |
| Beam Dynamics | D.Schulte | A.Latina, K.Kubo, N.Walker |
| Cost & Schedule | P.Lebrun, K.Foraz, G.Riddone | J.Carwardine, P.Garbincius, T.Shidara |

# Towards the detectors – the cross-sections

new phenomena at Terascale energies:

- Higgs sector
- SUSY particle spectrum
  (masses, Emiss, high $p_T$)
- extra dimensions
- etc

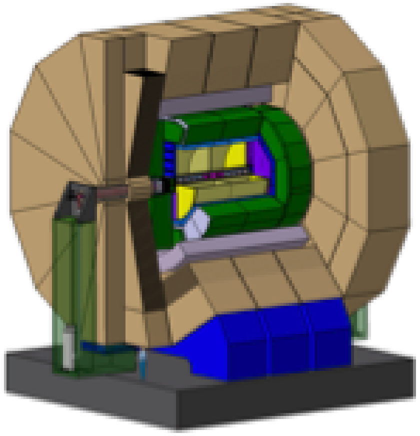
e.g. Precision measurements of
- leptons (including $\tau$)
- Jet energy, missing mass
- W/Z separation



# Validated ILC concepts

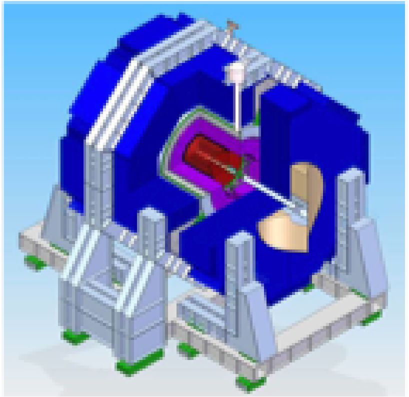
## ILD: International Large Detector

"Large" : tracker radius 1.8m
B-field : 3.5 T
Tracker : TPC + Silicon
Calorimetry : high granularity particle flow
ECAL + HCAL inside large solenoid



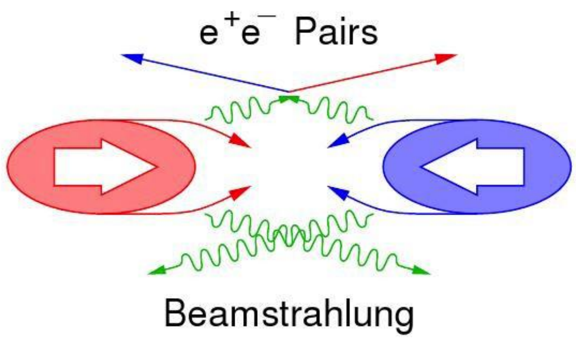
## SiD: Silicon Detector

"Small" : tracker radius 1.2m
B-field : 5 T
Tracker : Silicon
Calorimetry : high granularity particle flow
ECAL + HCAL inside large solenoid

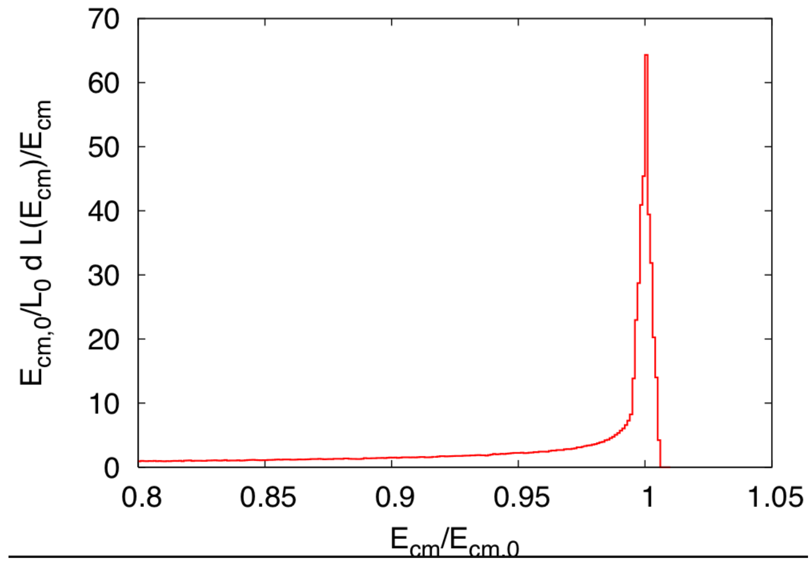


CLIC detector concepts will be based on SiD and ILD.
Modified to meet CLIC requirements

# Beam-Induced Background



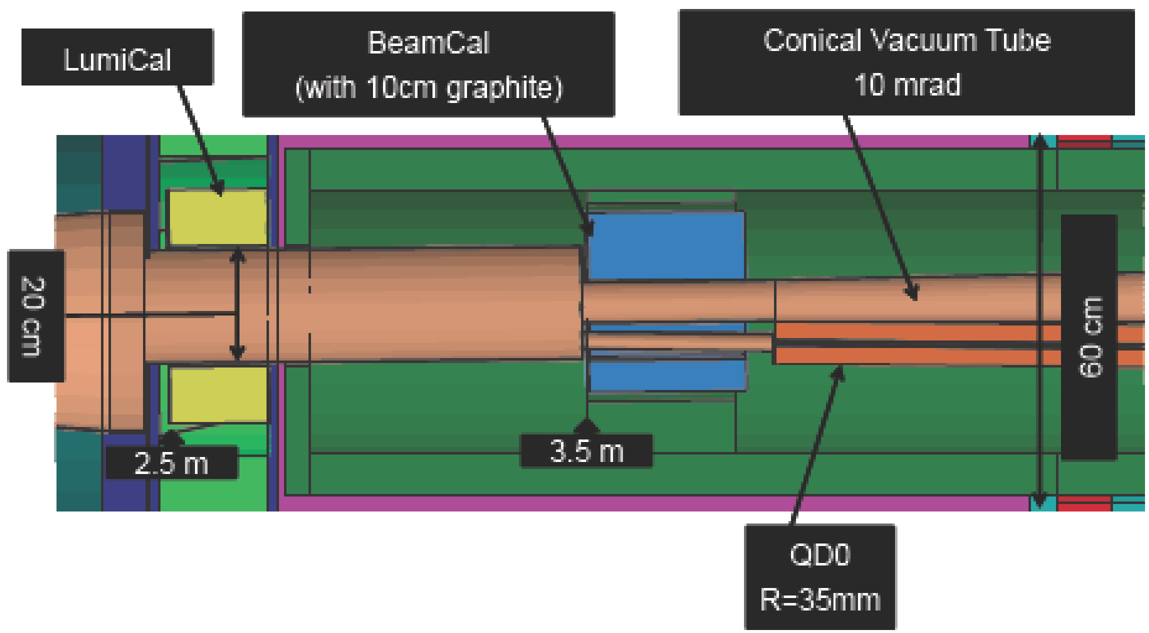

| | | CLIC | CLIC | ILC |
|---|---|---|---|---|
| $E_{cms}$ | [TeV] | 0.5 | 3.0 | 0.5 |
| $f_{rep}$ | [Hz] | 50 | 50 | 5 |
| $n_b$ | | 354 | 312 | 2625 |




- Beamstrahlung photons

**LumiCal**
measure luminosity

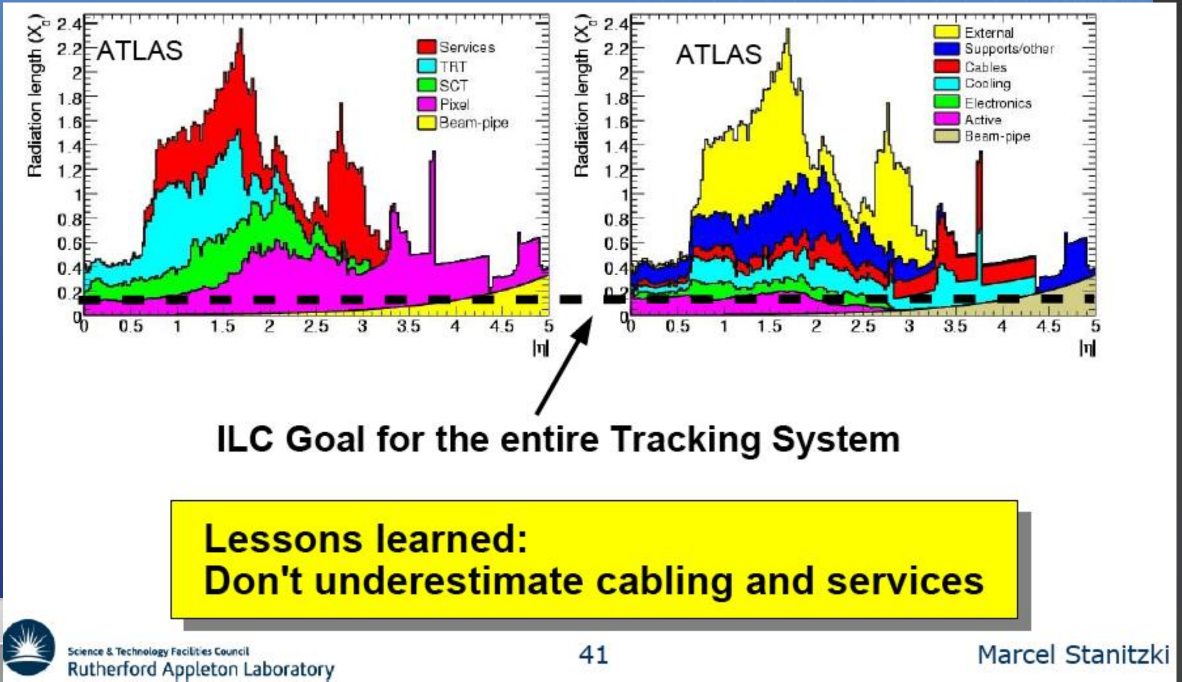
**BeamCal**
Feedback to accel.
Electron veto
QD protection



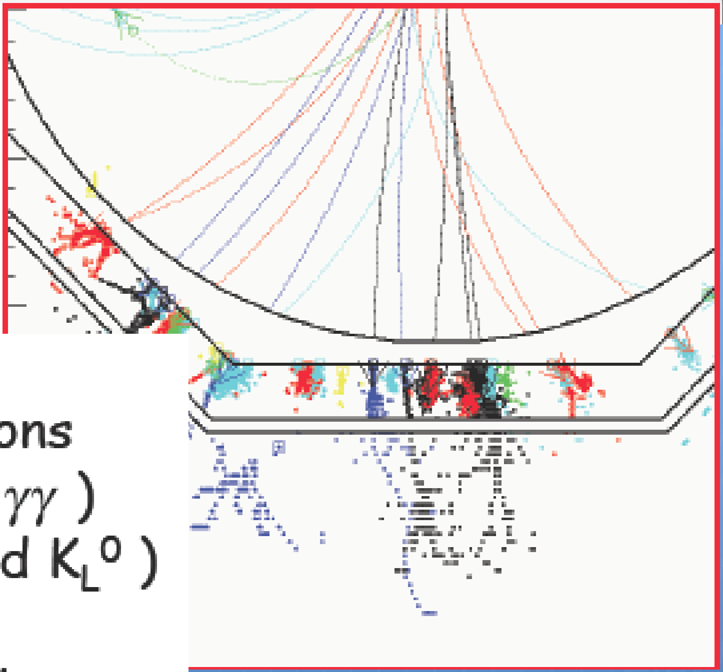
# Very thin trackers



- PIXEL vertex system followed by Silicon Strip/TPC based systems
- Many technologies being pursued, generally not/much less constrained by radiation hardness criteria than the LHC systems allowing a wider choice of technologies
- The most striking feature: very thin (~1/10 of LHC), low power, granular and high resolution systems



# Particle flow calorimetry

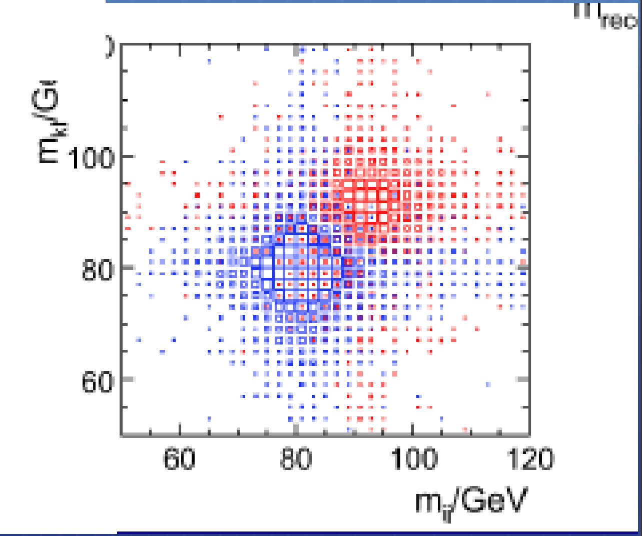


In a typical jet :

- 60 % of jet energy in charged hadrons
- 30 % in photons (mainly from $\pi^0 \rightarrow \gamma\gamma$ )
- 10 % in neutral hadrons (mainly n and $K_L^0$ )

Energy / Particle Flow algorithm:

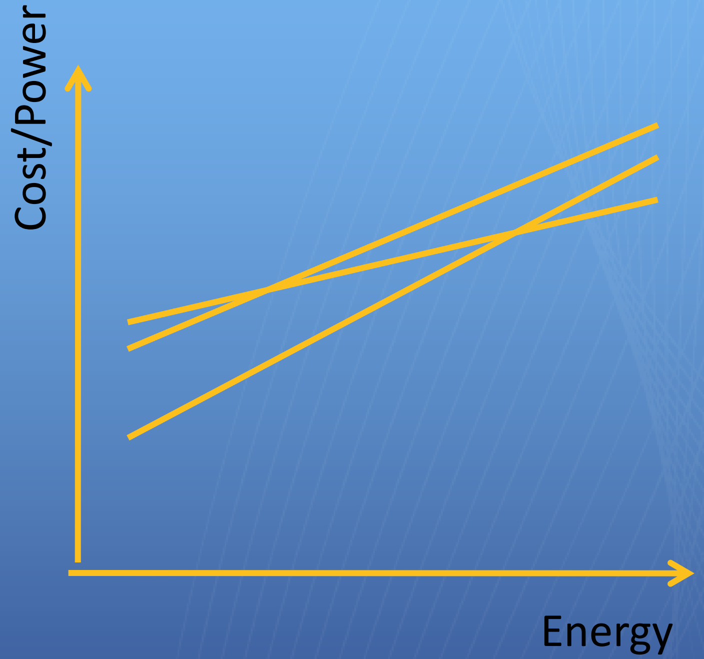
- charged particles, measured in tracker
- Photons in ECAL:
- Neutral hadrons (ONLY) in HCAL




- The result is that very performant and granular trackers and EM calorimeters (Si-W prime example) are needed

# Critical issues (the big ones)

- Physics reach (energy, luminosity) – and how these parameters can develop over time
- Technical risks
- Cost and power
  - Real limits in practice but difficult to specify them in detail, will also depend on energy and luminosity, and creative use of personnel (to keep additional costs down)
  - For example: a 3 TeV, $5.9 \times 10^{34}$ cm-2s-1 CLIC will require substantially more power than the CERN power consumption today
  - Another example: The 500 GeV ILC cost in the RDR is higher than the LHC costs
- The willingness and creativity needed to maintain the global approach down to a final implementation at a specified site
  - With a technical implementation plan and defined sharing of responsibility




Offset/Slope will depend of technology. implementation, luminosity (for power) …

# CERN LC programme 2011-2016

**The following slides: Focus on CLIC specific work in next period but several points equally relevant and in common with ILC and GDE activities - now and in the future.**

- **Before 2011**
  CDR (2011), CLIC feasibility established.

- **2011-2016 – Project Preparation phase**
  This is the current focus for planning in the collaboration
  Will comment on 5 key areas that we are and will continue to discuss in the collaboration:
  - Further development of the CLIC machine technical implementation
  - Machine/Detector interface (in a wide sense)
  - Detector work
  - Site studies
  - Organisation and Governance

  Goal is preparation of a Project Implementation Plan at a defined energy and luminosity ( .. as required by the physics …)

- **After 2016 – Implementation phase, including an initial period to lay the grounds for full approval.**
  Considering the preparation steps foreseen and the resources situation it is clear that several key tasks will need further effort before the project can move into construction.

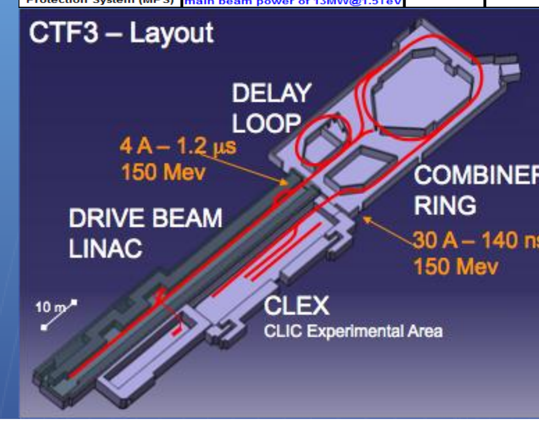
# Accelerator part (mostly CLIC specific)

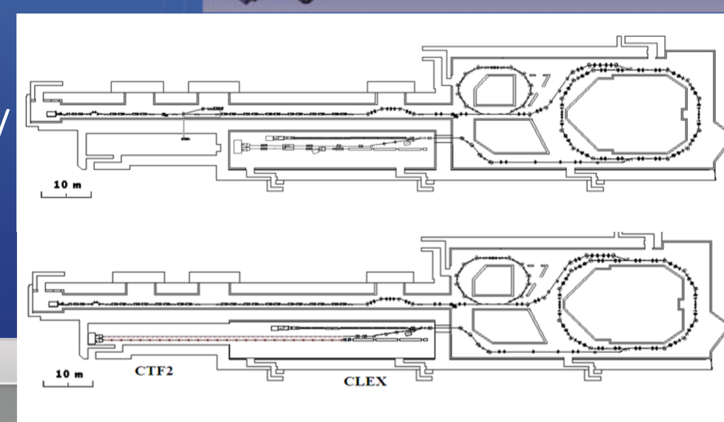
- The programme for 2011-16 needs to be defined carefully, with primary focus:
  - review of the CLIC baseline design, taking into account CDR results and including:
    - cost & power consumption optimization
    - energy staging
    - technical risks and performance risks
  - technical developments and test of critical component and prototypes, using several facilities across the collaboration
  - exploitation and upgrade of CTF3 to CTF3+, construction and commissioning of CLIC drive beam injector

- This programme will address the issues already mentioned above focusing on performance, industrialization, implementation and operational reliability

- Several topics addressed in common working groups CLIC/ ILC and/or using common facilities

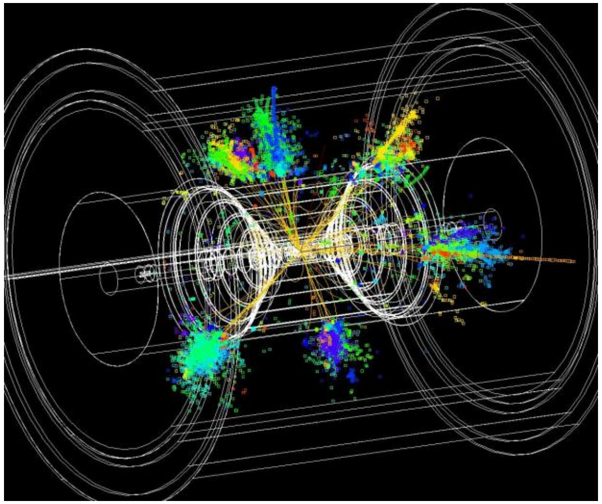
| System | Item | Feasibility Issue | Unit | Nominal |
|---|---|---|---|---|
| Two Beam Acceleration | Drive beam generation | Fully loaded accel effic | % | 97 |
| | | Freq&Current multipl | - | 2*3*4 |
| | | 12 GHz beam current | A | 4.5*24=100 |
| | | 12 GHz pulse length | nsec | 240 |
| | | Intensity stability | 1.E-03 | 0.75 |
| | | Drive beam linac RF phase stability | Deg (1GHZ) | 0.05 |
| | Beam Driven RF power generation | PETS RF Power | MW | 130 |
| | | PETS Pulse length | ns | 170 |
| | | PETS Breakdown rate | /m | < 1·10-7 |
| | | PETS ON/OFF | - | @ 50Hz |
| | | Drive beam to RF efficiency | % | 90% |
| | | RF pulse shape control | % | < 0.1% |
| | Accelerating Structures (CAS) | Structure Acc field | MV/m | 100 |
| | | Structure Pulse length | ns | 240 |
| | | Structure Breakdown rate | /m MV/m.ns | < 3·10-7 |
| | Two Beam Acceleration | Power producton and probe beam acceleration in Two beam module | MV/m - ns | 100 - 240 |
| | | Drive to main beam timing stability | psec | 0.05 |
| | | Main to main beam timing stability | psec | 0.07 |
| Ultra low beam emittance & sizes | Ultra low Emittances | Emitttance generation H/V | nm | 500/5 |
| | | Emittance preservation: Blow-up | nm | 160/15 |
| | Alignment | Main Linac components | microns | 15 |
| | | Final-Doublet | microns | 2 to 8 |
| | Vertical stabilisation | Quad Main Linac | nm>1 Hz | 1.5 |
| | | Final Doublet (assuming feedbacks) | nm>4 Hz | 0.2 |
| Operation and Machine Protection System (MPS) | | 72MW@2.4GeV main beam power of 13MW@1.5TeV | | |



# CLIC Detector Issues

- Detector requirements are close to those for ILC detectors
  - First studies indicate that ILC performances are sufficient
  - Adapt ILD and SID concepts for CLIC
  - Close collaboration with validated ILC designs and work
- Differences to ILC
  - Larger beam energy loss
  - Time structure (0.5ns vs. 370ns)
  - Higher background
    - Higher energy
    - Smaller bunch spacing
  - Other parameters are slightly modified
    - Crossing angle of 20 mradian (ILC: 14 mradian)
  - Larger beam pipe radius in CLIC (30mm)
  - Denser and deeper calorimetry
- Linear collider detector study has been established at CERN beginning of 2009 (led by L. Linssen, see **http://www.cern.ch/lcd)**



# An example of recent work: Hadron Calorimetry at CLIC

**Tungsten-based HCAL motivation:**

- To limit longitudinal leakage CLIC HCAL needs to be ~7.5 $\lambda_i$ deep
- A deep HCAL pushes the coil/yoke to larger radius (would give a significant increase in cost and risk for the coil/yoke)
- A tungsten HCAL (CLIC option) is more compact than Fe-based HCAL, (ILC option) while jet resolution (Geant4) is similar
- Increased cost of tungsten barrel HCAL compensates reduced coil cost

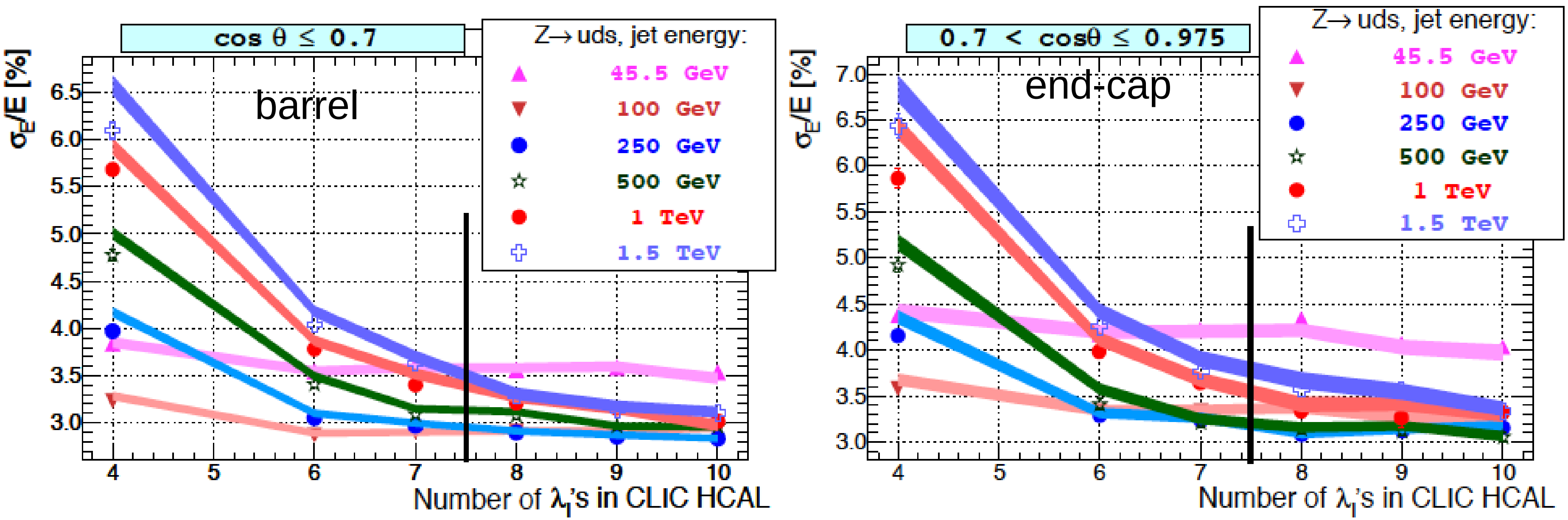
**Particle-flow calorimetry for CLIC:**

- According to simulations PFA can give required jet resolution at CLIC
- Geant4 simulation needs to be confirmed in test beam for W-HCAL
- In particular: time development of hadronic showers is slower in tungsten than in steel => needs to be measured

# HCAL depth studies with PFA

- Studies done with $Z \rightarrow uds$ events, based on a modified CLIC01_ILD model
- Jobs submitted to the GRID, via DIRAC
- Markers: with Tail Catcher
- Bands: WITHOUT Tail Catcher

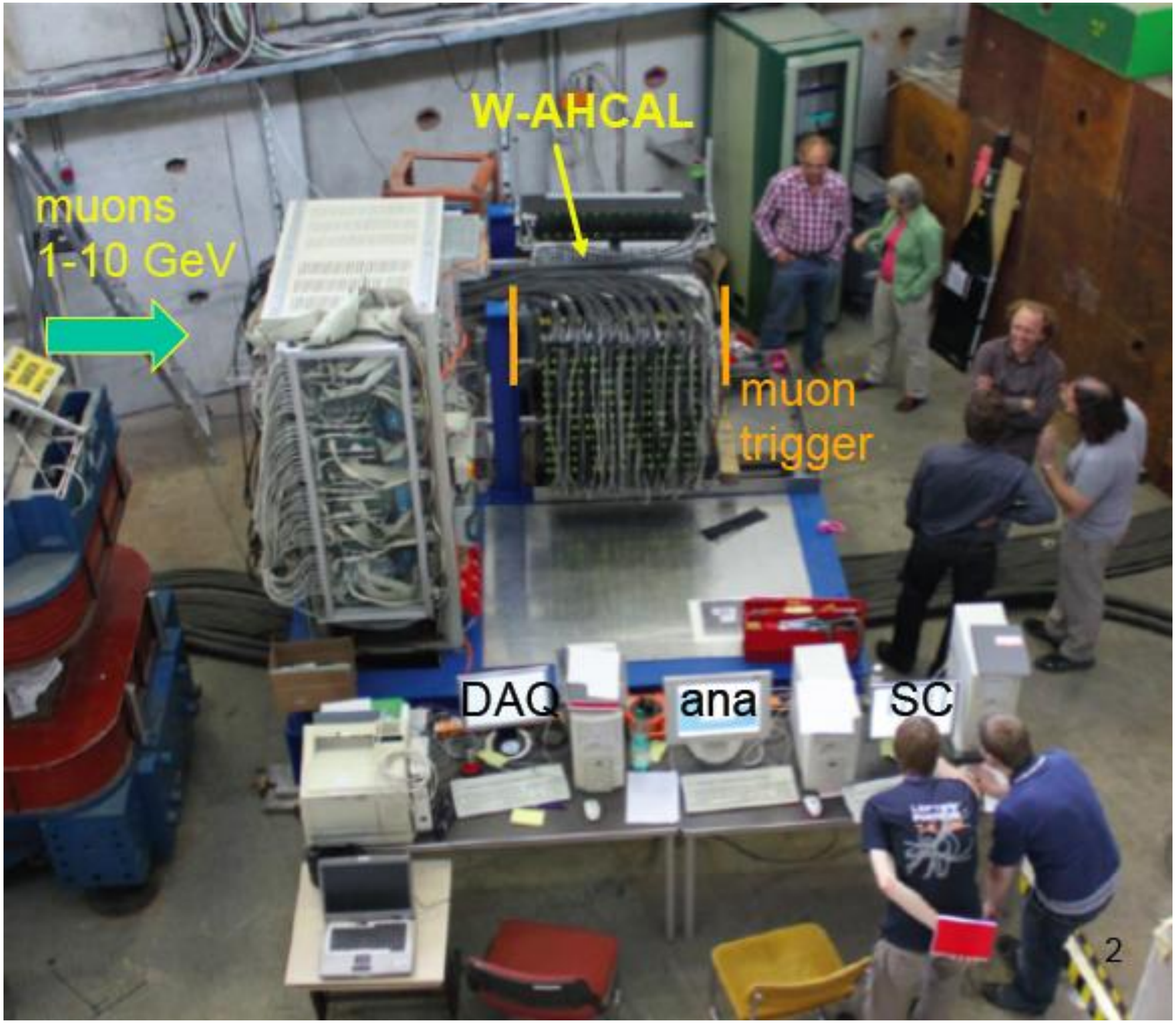
A. Lucaci-Timoce, CERN




**PFA calorimetry can give good ΔE/E for high-E jets !**

- Small influence of the Tail Catcher
- Final decision on HCAL depth: 7.5 $\lambda_I$

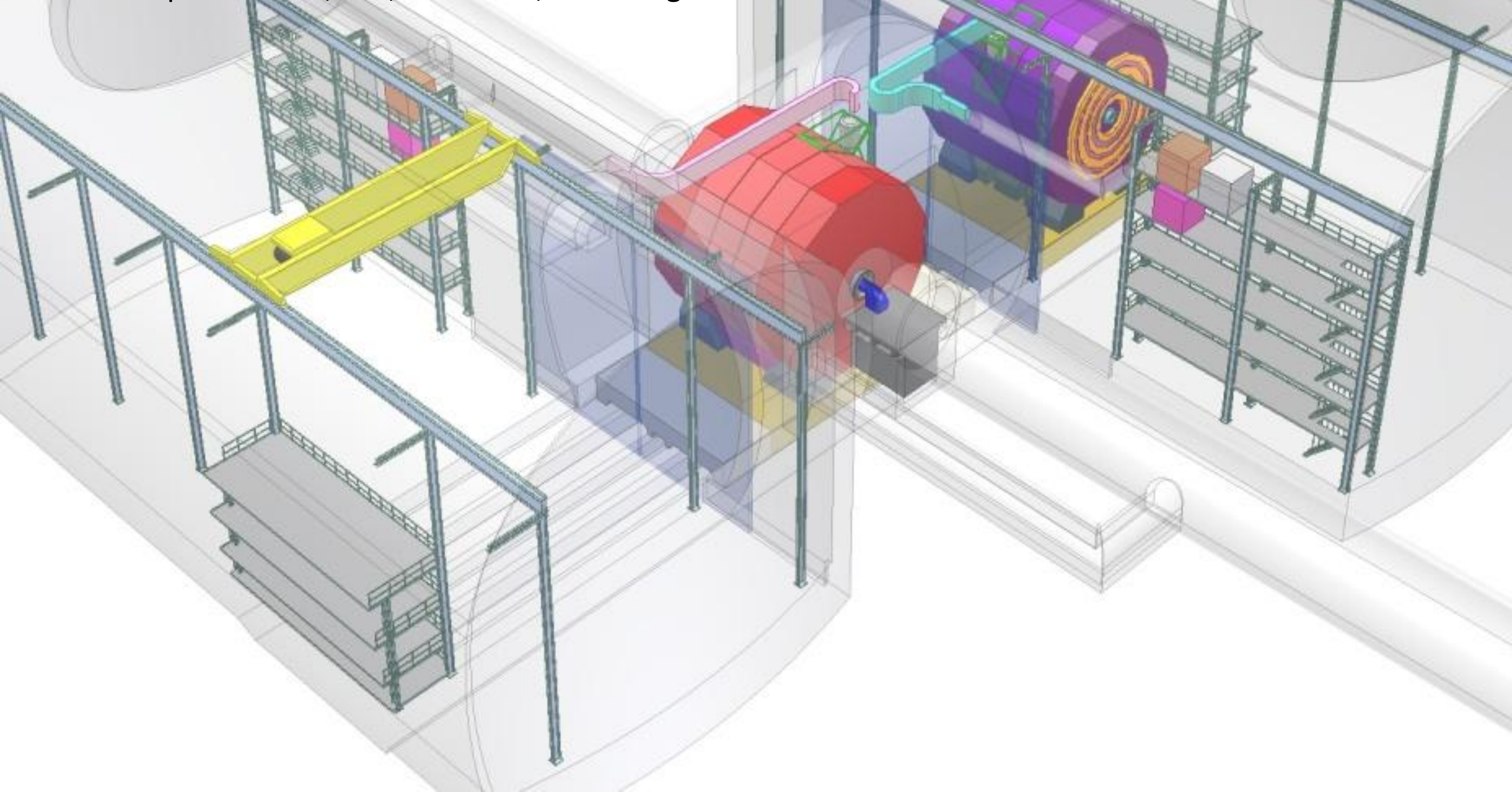
# Tungsten-based HCAL



**Underground areas and machine/detector interface:**

Several related issues (these are general LC issues with some special features for CLIC or ILC):

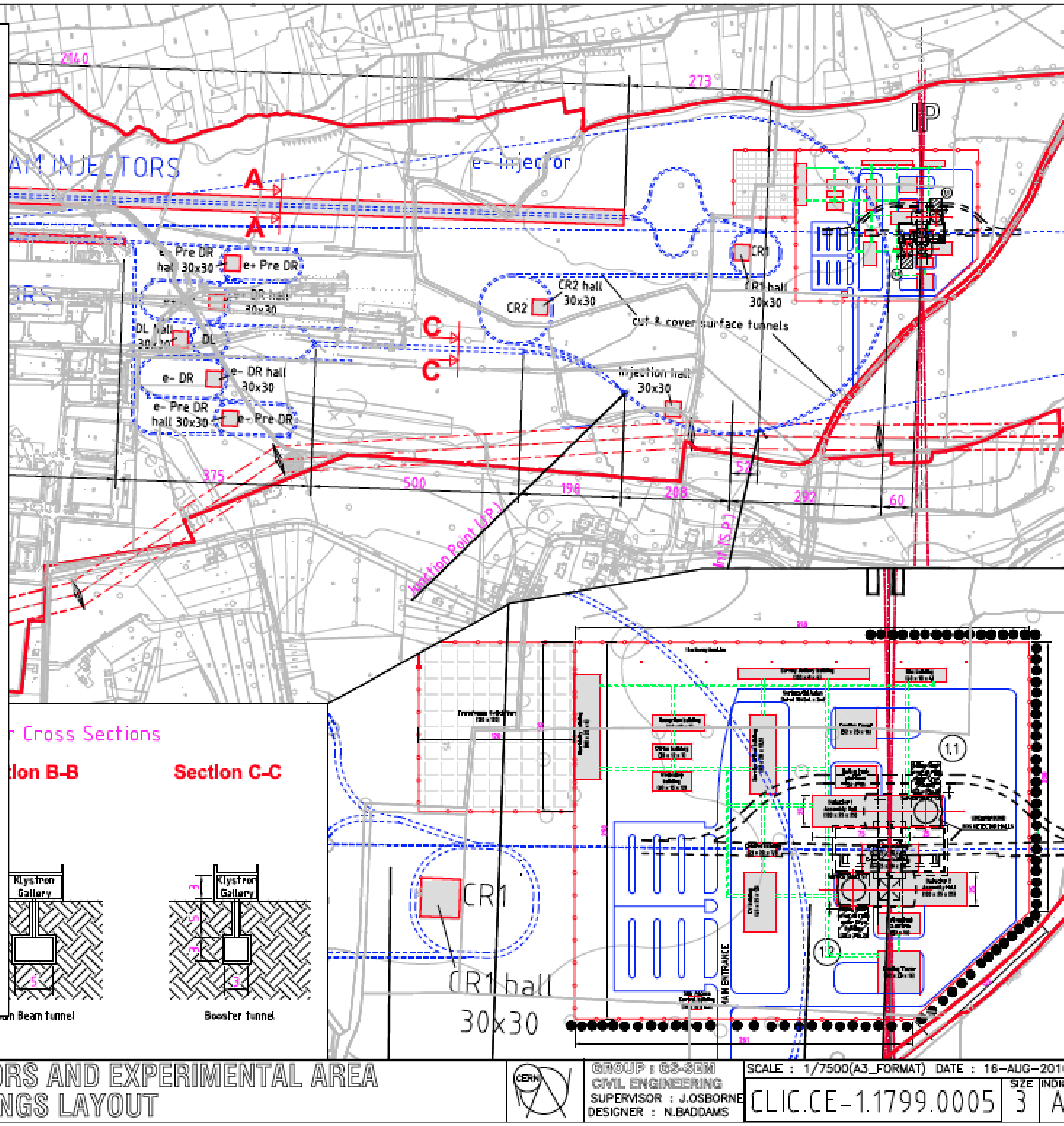
- Machine interface systems and machine background simulations, beam dump
- TC issues: Engineering, assembly, installation, services, magnets, cooling and powering, safety …
- Push-pull …. time, risk, resources, the real gain



The figure:
The interaction region, caverns and surface installation in the CERN Prevessin area, as foreseen in the CLIC CDR.

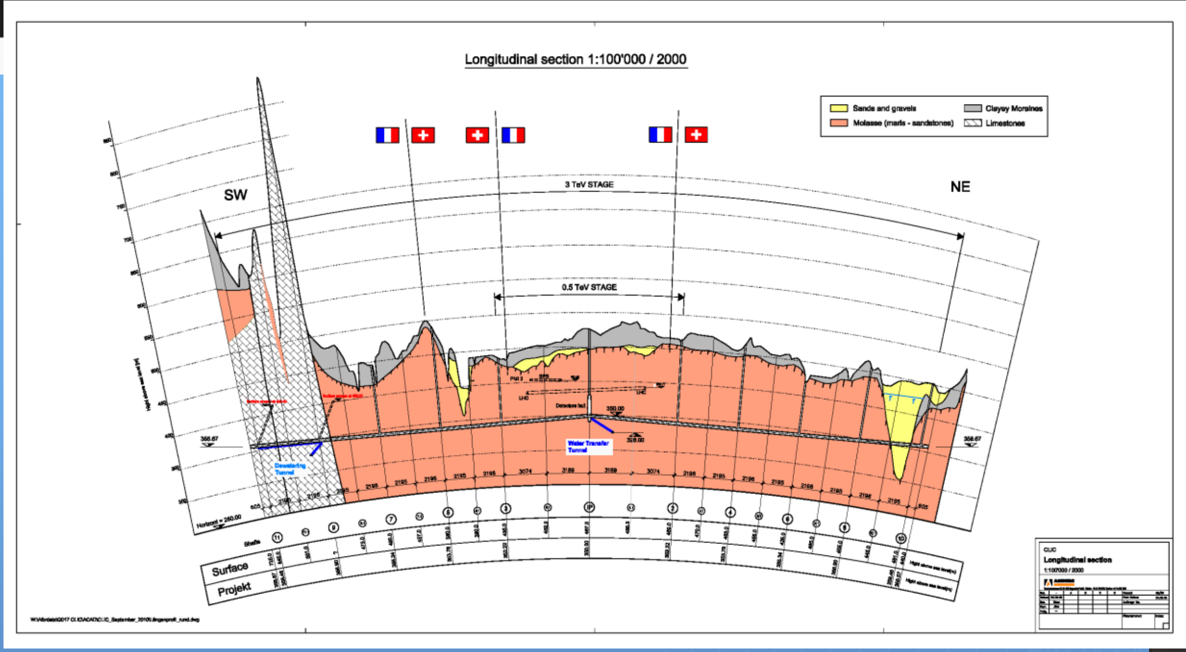
Generally:
The entire logistics of dealing with assembly, test-areas infrastructures, a large user community – all these issues need to be considered (for CLIC or ILC)

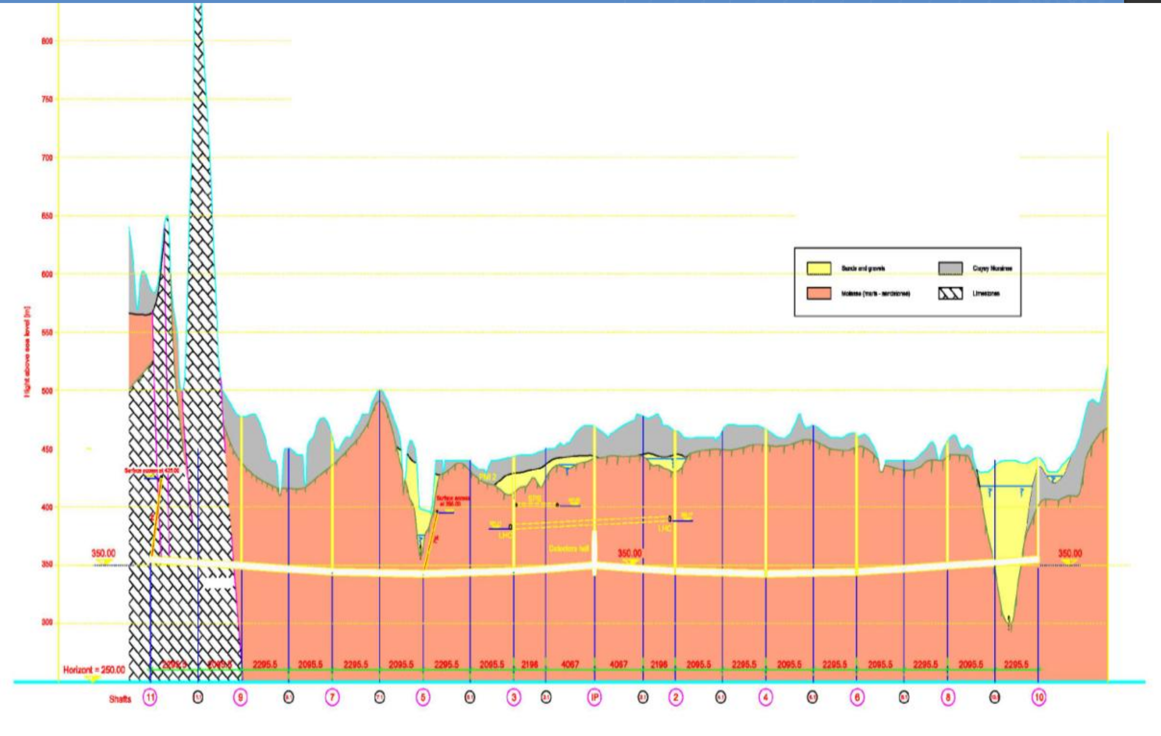
The next years:
The north areas testbeams are already, and will increasingly host LC detector parts and community.



# CERN Site

- A proper site study is needed
- Impact: environmental, socio-economic
- Will link to interaction region study (obviously)
- Include Swiss and French partners (host states in this case)
- Guidance from the European Strategy update in 2012
- Could be implemented as a European Community project (2013-2016)



# Collaboration and Governance

- Our overall guidelines currently when considered the plans for 2011-16:
  Cover CLIC specific work, CERN specific work for a LC including the possibility of hosting it, and participate very actively in the global preparations for a LC (e.g GDE)
- Make effort to define work-packages for all partners for next phase and increase external activities and responsibilities
- Consider a Governance Board for the CLIC collaboration (to be discussed)

# Summary

- First: Most results that I have shown today will be improved by the end of this week - there is a lot of very impressive and detailed work going on
- Second: A very important time ahead for a future LC, physics guidance is within reach (we hope), prototyping and technical development are moving ahead, but there are many challenges still in the future
- Third:  Any future LC project is a global endeavour, and workshops of this type (starting today) will remain very important to share information and discuss the next steps across technological differences and preferences