CLIC: Ideas for Machine Protection and Interlock systems *15'*

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With ideas from (and for !) others

CLIC

CLiC = **C**ompact **Li**near **C**ollider:

A machine to study new phenomena with high precision:

- Higgs, Susy, other exotic phenomena
  (to be discovered at LHC
- LHC: P-P collisions (non elementary quark bags)
- CLIC: e+ e- (elementary particle / anti-particle)
  - All beam energy available to produce new stuff (LHC: $E_{quark} \approx 1/6\ E_{proton} \approx 1$ TeV)
  - Well defined centre of mass
  - No spectator quarks
  - Clean process
  - Prerequisite for precision measurements

CLIC Energy required to cover LHC energy reach

- ~ 7 TeV/6 +50% ≈ 1.5 TeV x 2 beams

Linear ?

Circular machines:

– Relative energy loss/turn = 88.5 E^3/ρ TeV^{-3} km turn^{-1} (ρ = arc radius)

LEP @ E=104.5 GeV, ρ=3.6 km, E-loss/turn = 2.8 %

@CLIC energies 1.5 TeV

- For similar losses as in LEP we need
  $\rho = 15^3$ x 4 km = 13500km (about twice the radius of the earth).
- For 100% loss @ 1.5 TeV ρ = 300 km

LEP was the last circular e^+ e^- machine.

Compact ?

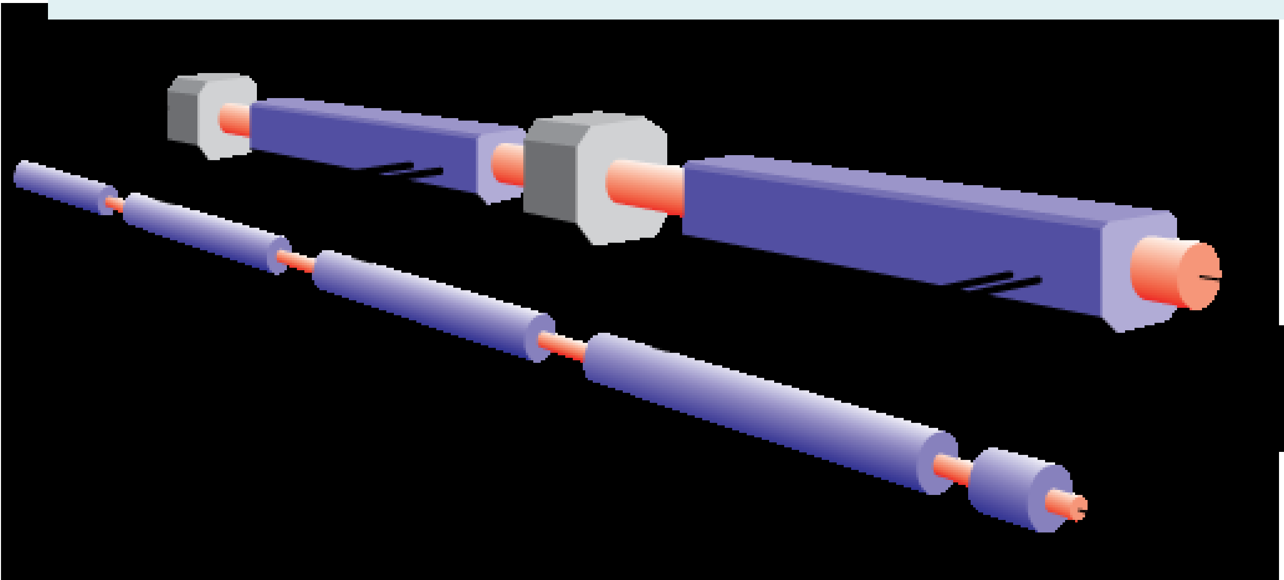
- With an accelerating gradient of 100 MV/m 1.5 TeV needs 15 km
- Need space for quadrupoles, BI, etc. (5 km)
- Need space for beam delivery (4 km: cleaning, diagnostics, final focus)
- Total span : 2x24 km = **48 km**

Compact?

Not a table top accelerator, but with conventional accelerating gradients 30 MV/M we would need 140 km

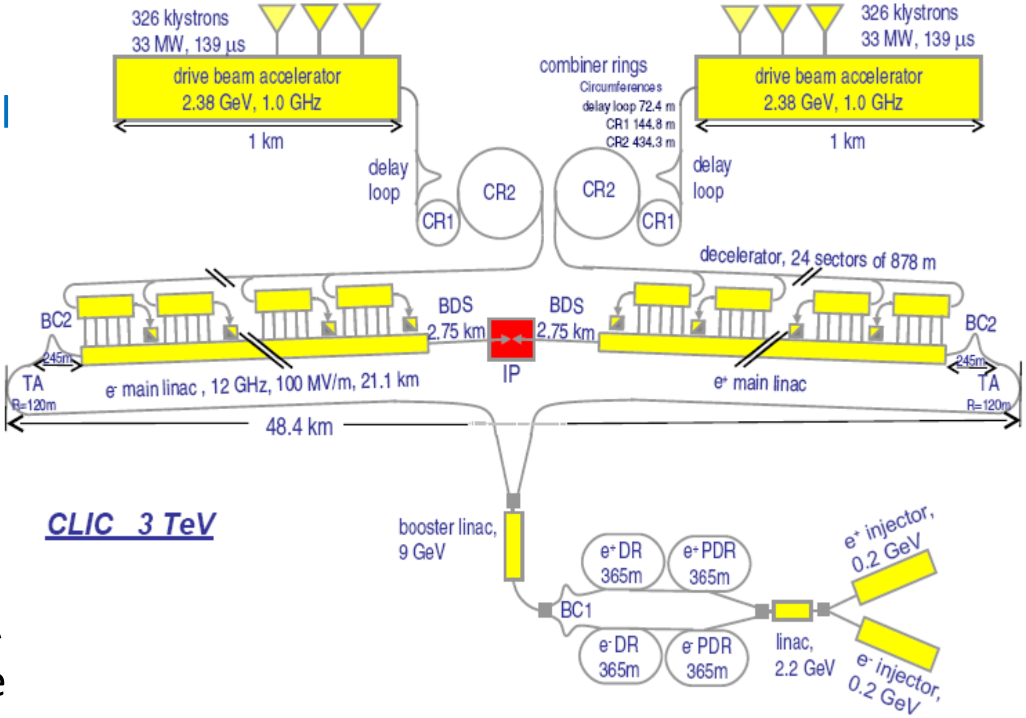
The tricks

- High acceleration gradient: ~ 100 MV/m
  - `Compact' – total length < 50 km at 3 TeV
  - Normal conducting acceleration structures at high frequency 12 GHz
- Novel Two-Beam Acceleration Scheme
  - The energy of a high intensity low energy beam is extracted to accelerate a low intensity beam to high energy
  - Frequency multiplication of low energy beam to produce high frequency
  - Cost effective, reliable, efficient
  - Simple tunnel, no active elements, modular, easy energy upgrade in stages



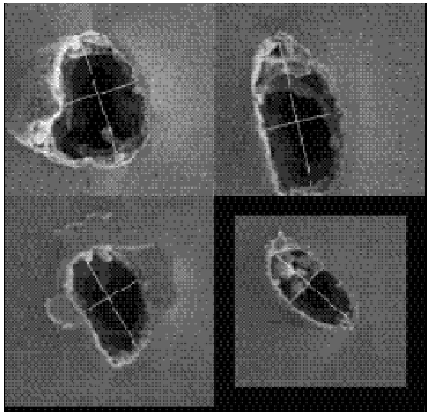
CLIC

- **A complex and extensive machine**
  ~ 60 Km of beam tunnel, numerous accelerators equivalent to ~2x the actual full CERN accelerator complex.
- **High beam power**
  - Drive beam 2 x 70 MW,
  - main beam: 2 x 14 MW
- **Microscopic beam spots**
  Size matters: at 3 GeV main beam is 4 orders above damage threshold in the extraction channel of a damping ring. (A single bunch is 1ne order above damage threshold)
  Picture: single pulse damage in 1.4 mm of cupper (holes size 10 x 20 um)



CLIC study program:

- Conceptual design report end of 2010.
- Technical design phase and proposal 2011-2016



Topics with potential MPE implications

- Machine Protection
  - Conceptual design of CLIC MP system and operational scenario
  - Failure simulation and risk analysis
  - Interlocks and post pulse analysis
  - Static protection
  - Quench protection system
  - RT protection (Emergency dumps)

- Electronics
  - Rad hard electronic developments
  - 200 000 electronic cards to build (cost reduction is an issue)

Not detailed in this presentation, will be addressed in the future.

Failure simulation

Study beam failure modes in the CLIC complex

- Estimate potential damage
- Estimate frequency

Revise protective measures if the risk is too high

Resources: Fellow since Nov. 2010 (Carlos Maidana)

Tools: Simulation tools (Placet, others)

Deliverables:

- maximum tolerances on main beam kicks/displacements to stay clear of collimators
- then failure in decelerators
- etc...

Interlocks and post pulse analysis

Failure types and mitigation

- Slow machine drifts
  - Post pulse analysis to detect correct behaviour for next pulse.
  - Like LHC PM analysis, but: 18 ms for data collection + decision on 6 10^6 channels

    Automated analysis, embedded systems, certified software modules
- Equipment failures:
  - Interlock system: 20 ms - 2 ms before next pulse permit
  - 185 stations, 1800 user channels.

Concepts to be demonstrated by a prototype implementation in CTF3

- Interlock system (BIC HW based)
- Post pulse analysis
- RT protection for drivebeam linac

Resources: Doctoral student starting in January (Patrice Nouvelle)

Failure types and mitigation (continued)

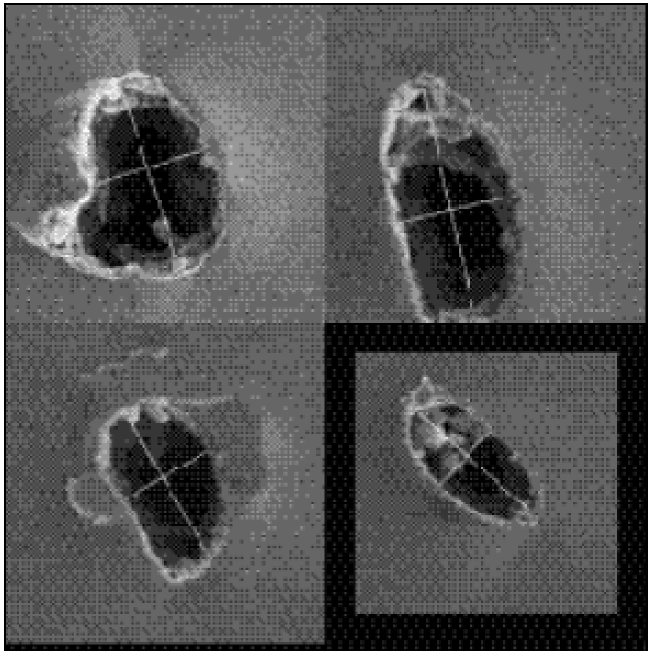
- Fast Equipment failures (< 2ms)
  - safe by design (i.e. slow magnet current circuits with τ=L/R >> 2 ms)
  - **Resources:** Responsibility of equipment groups
- In flight errors (RT failures after next pulse permit was delivered)
  - Failures types:
    - Kicker misfiring
    - RF breakdowns
    - Drivebeam production errors
  - Studies:
    - Failure simulations
    - Design of masks (Material studies)
    - RT protection
  - **Resources:** next slides

6.2.1 Masks

Required to protect against kicker failures in all extraction channels:

- Combiner rings
- Turn arounds
- Damping rings

Specification yet unknown TE/BT



Possible new project:

Study effects of high brilliance electron beams in matter.

i.e. find a material that can survive a CLIC beam impact.

In collaboration with EN/STI

6.2.2 Emergency Dumps

Intermediate emergency dumps (Kicker + internal dumps)

RT protection in case of rt error in DR or DB linac

Locations:

- Drive beam linac (up to 5 locations)
- Damping rings (0-2 dumps)

Unknown:

- Number of required emergency dumps
- Alternatives
- Cost of emergency dumps

To be studied for TDR phase

6.2.3 Quench protection system

Scaling parameters:

– Detection channels	8 x 13
– Energy extraction systems	8
– Cabling	6 km

Total estimated cost 220KCHF

Developments and studies

- Based on LHC quench protection system
- New development energy extraction system: (semiconductor switch as used in HIE-Isolde project)

- Simulations quench heat dissipation / propogation (Emmanuele Ravaioli)

6.1.1 Frond End Acquisition and Controls

Scaling parameters:

- **Channel count** 7 10^6 1.7 10^6 (CLIC .5 TeV)

1 control chassis per module (250 channels)

- Chassis + controller + power supply = 5000€
- N carriers + mezzanines. First guess n=8

25000 chassis, 200000 boards

Cost knowledge:

- ~~(VME) LHC control system~~
- New developments

Uncertainties: (Large)

- New developments
- New concepts
- Rad-hard electronics
- Cost reduction through mass industrialization

Status:

Work in progress

- Collaborate with Mick Drapper, Marc Vanden Eynden, Lars Soby, Javier Cerano for detailed cost estimate.
- Proposed cost boundary between (sub-)components and 6.1.1

The end

Thanks for your attention

- Some spare slides…