CLIC Detector R&D @ CERN
Status + plans

• 2004 CLIC Study group report: "Physics at the CLIC Multi-TeV Linear Collider“

• 2006-2009 EUDET R&D

• Oct 2007, CLIC07@CERN, first Workshop on CLIC accelerator and
physics aspects → goal: feasibility prove by mid 2010 (CDR)

• Feb 2008 CLIC/ILC Collaboration meeting

Dieter Schlatter 14/04/08

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.

Basic Parameters

- CLIC aims to achieve a luminosity similar to the ILC level at much higher energy

		CLIC	ILC	NLC
E_{cms}	$[TeV]$	3.0	0.5	0.5
f_{rep}	$[\mathrm{Hz}]$	50	5	120
N	$[10^9]$	3.7	20	7.5
ϵ_y	$[nm]$	20	40	40
L_{total}	$10^{34}cm^{-2}s^{-1}$	5.9	2.0	2.0
$L_{0.01}$	$10^{34}cm^{-2}s^{-1}$	2.0	1.45	1.28
n_γ		2.2	1.30	1.26
$\Delta E/E$		0.29	0.024	0.046

- Luminosity is delivered in 50 pulses per second
- Each pulse lasts about $150\,\mathrm{ns}$, contains 312 bunches spaced by $0.5\,\mathrm{ns}$

- In ILC luminosity is delivery by pulses with 5 Hz
- Each pulse is about $1\,\mathrm{ms}$ long 2800 bunches spaced by 350 ns

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$\Rightarrow$ Very different regime

- event reconstruction
- background conditions

- High energy also affect background level

Luminosity and Background Values

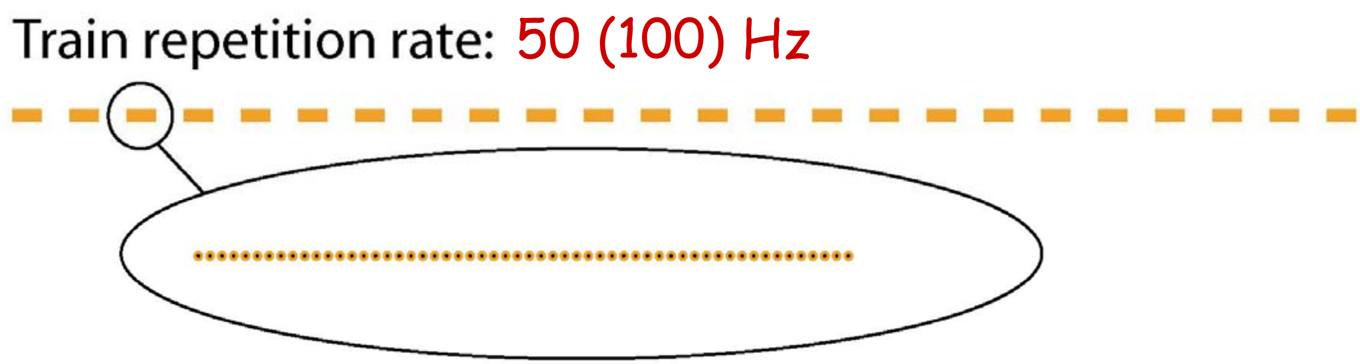
		CLIC	CLIC	CLIC	ILC	NLC
E_{cms}	$[TeV]$	0.5	1.0	3.0	0.5	0.5
f_{rep}	[Hz]	100	50	50	5	120
N	$[10^9]$	3.7	3.7	3.7	20	7.5
ϵ_y	$[nm]$	20	20	20	40	40
L_{total}	$10^{34}cm^{-2}s^{-1}$	2.2	2.2	5.9	2.0	2.0
$L_{0.01}$	$10^{34}cm^{-2}s^{-1}$	1.4	1.1	2.0	1.45	1.28
n_γ		1.2	1.5	2.2	1.30	1.26
$\Delta E/E$		0.08	0.15	0.29	0.024	0.046
N_{coh}	10^5	0.03	37.0	3.8×10^3	—	—
E_{coh}	$10^3 TeV$	0.5	1080	2.6×10^5	—	—
n_{incoh}	10^6	0.05	0.12	0.3	0.1	n.a.
E_{incoh}	$[10^6 GeV]$	0.28	2.0	22.4	0.2	n.a.
$n_\perp$		12.5	17.1	45	28	12
n_{had}		0.14	0.56	2.7	0.12	0.1

- Target is to have about one beamstrahlung photon per beam particle
  - similar effect to initial state radiation

  ⇒ average energy loss is larger in CLIC than ILC
- Note: shorter bunches increase the photon energy but not the number

Time Structure of the Beams

CLIC



1 train = 312 bunches 0.5 nsec apart

ILC

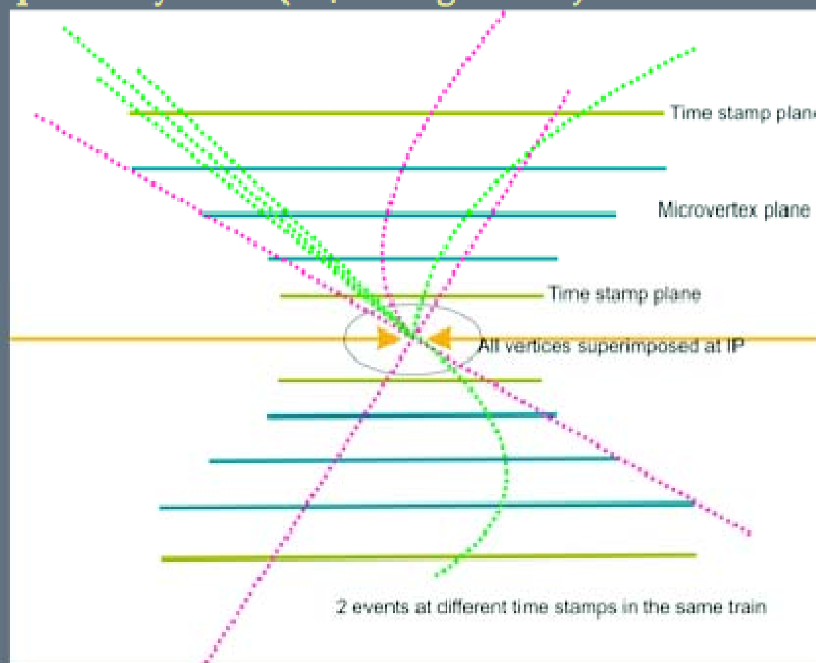
⇒ 5 Hz 1 train 2625 bunches 369 ns apart

Experimenting at CLIC similar to the "NLC"

Time stamping!

Timing Issue at CLIC

- Time tagging of vertices
  - 331 BX's piled up in detector/electronics
- Issue of track reconstruction ambiguities
  - No longitudinal spread of BX interactions
  - Bunch identification by time stamp
    - Ideal time stamp precision 1/6 of bunch separation, 100 ps rms
    - Interaction point very stable (10 μm longitudinal)

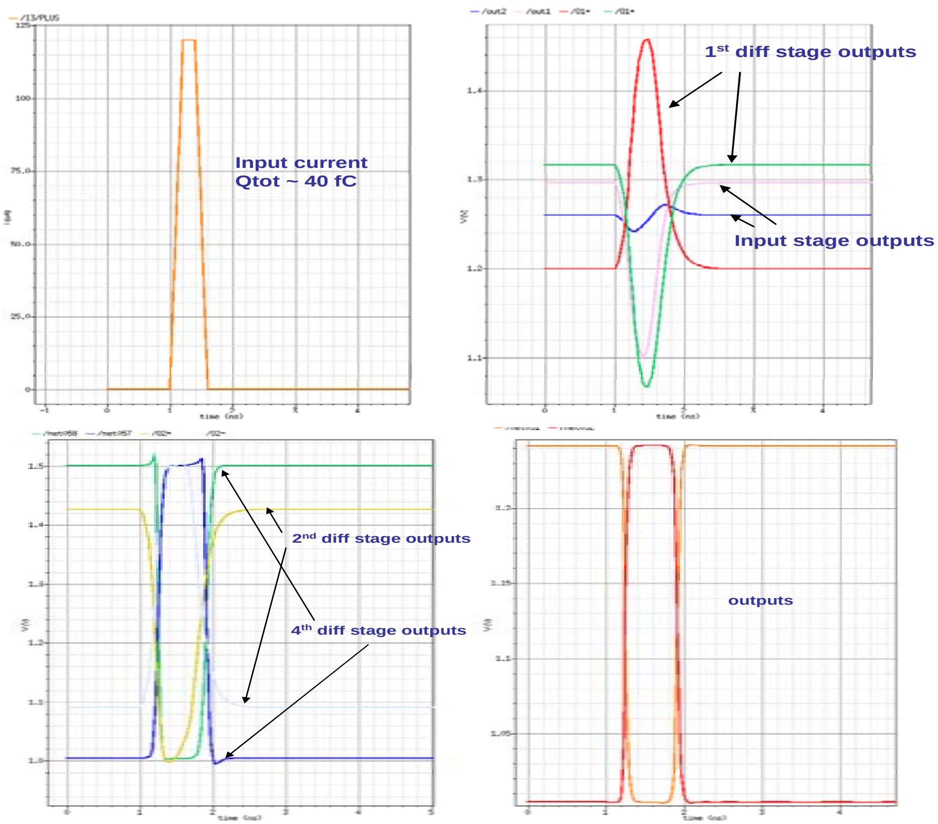


Pierre Jarron CLIC07

Electronics, NA62 Gigatracker or even faster

NA62@SPS: rare decay $K^{\pm} \rightarrow \pi^{\pm} \nu\bar{\nu}$

- Ultra fast amplifier NINO
  - Done in 250 nm preliminary simulation in 130 nm



- NINO 130
  - Rise time amplifier 150 ps
  - Time stamping better than 20 ps
- NA62 electronics
  - Time stamping 250 ps

Detector Specifications

Detector	CLIC
Vertexing	$15\mu m \oplus \frac{35\mu m GeV/c}{p \sin^{3/2}\theta}$ $15\mu m \oplus \frac{35\mu m GeV/c}{p \sin^{5/2}\theta}$
Solenoidal Field	$B = 4\ T$
Tracking	$\frac{\delta p_t}{{p_t}^2} = 5. \times 10^{-5}$
E.m. Calorimeter	$\frac{\delta E}{E(GeV)} = 0.10\frac{1}{\sqrt{E}} \oplus 0.01$
Had. Calorimeter	$\frac{\delta E}{E\ (GeV)} = 0.40\frac{1}{\sqrt{E}} \oplus 0.04$
μ Detector	Instrumented Fe yoke $\frac{\delta p}{p} \simeq 30\%$ at $100\ GeV/c$
Energy Flow	$\frac{\delta E}{E\ (GeV)} \simeq 0.3\frac{1}{\sqrt{E}}$
Acceptance mask beampipe small angle tagger	$\lvert\cos\theta\rvert < 0.98$ 120 mrad 3 cm $\theta_{min} = 40$ mrad

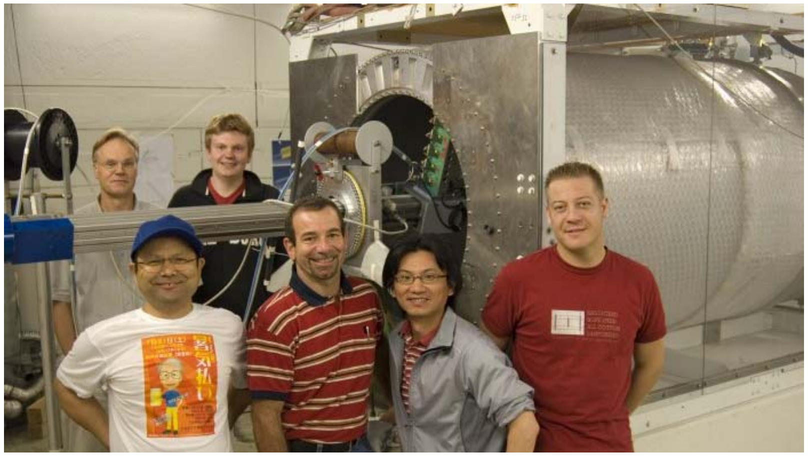
CLIC Report 2004:
Starting point: the TESLA TDR detector adapted to CLIC environment

- Detailed studies performed for previous CLIC parameters
- Update with new CLIC parameters is underway
- Greater need for time-stamping of events
- No significant physics difference found previously between NLC and TESLA at sub-TeV energies
- None expected between old and new multi-TeV parameters

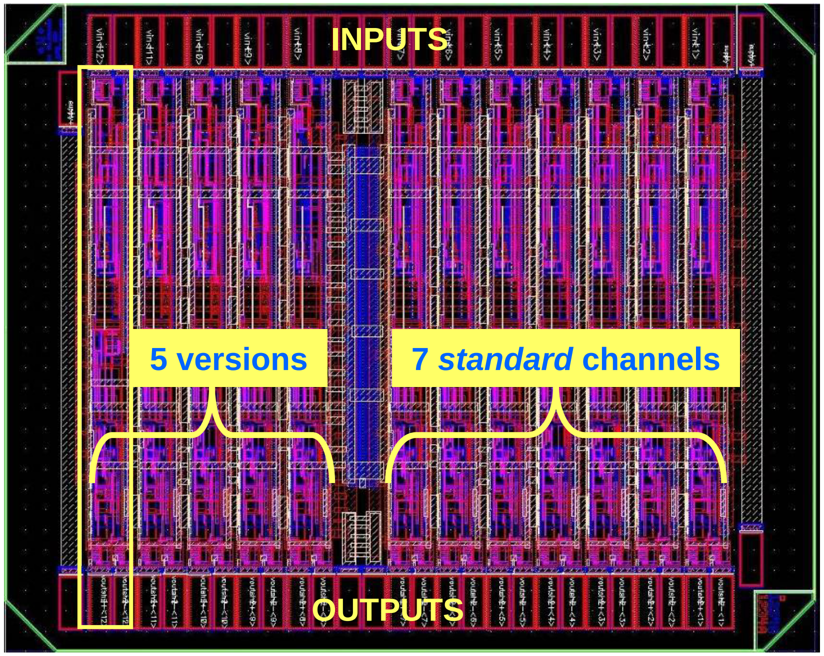
CERN participation in EUDET

2006-2009

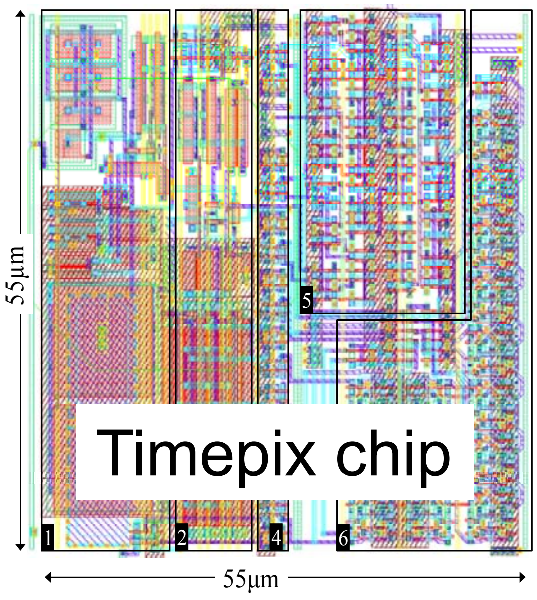
- MICELEC: microelectronics user support
- VALSIM: optimisation of hadronization process in GEANT4
- Magnet: magnetic field map of PCMAG magnet at DESY test beam
- Timepix: development of pixel chip for TPC pixelised readout
- TPC electronics: development of TPC pad readout (aiming for combined analog/digital readout fitting behind 1×4 mm^2 pads)



PCMAG field map campaign at DESY 2007



TPC pad readout, programmable amplifier 130 nm technology



Lucie Linssen

CERN contribution to LC tasks in recent FP7 proposal

http://project-fp7-detectors.web.cern.ch/project-FP7-detectors/Default.htm

- Test beam for combined linear collider slice tests (providing beam, large magnet, general infrastructures etc.)

- Continued support for TPC electronics

- Participation in Project office for linear collider detectors (engineering tools for project office; design support for test beam set-up)

- Test-case of LC project tools on CLIC forward region example (together with DESY and ILC forward study teams)

- Software tools (geometry and reconstruction tools)
- Microelectronics user support

CLIC-ILC Collaboration?

- **Following visit of Barry @ CERN (Nov 07)**

  http://www.linearcollider.org/newsline/archive/2007/20071213.html

Independently of US/UK financial crisis,

but even more desirable now

- **CLIC-ILC Collaboration meeting (Feb 08)**

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

- **GDE/ACFA Meeting at Sendai/Japan (March 08)**

  http://www.awa.tohoku.ac.jp/TILC08/

Subjects with strong synergy

1. **Civil Engineering and Conventional Facilities**
2. **Beam Delivery Systems & Machine Detectors Interface**
3. **Detectors**
4. **Cost and Schedule**
5. **Beam Dynamics & Beam Simulations including Low Emittance Transport**

Topics for CLIC-ILC Detector R&D

(summary: Detectors from meeting 8 Feb 08)

1) Define a CLIC detector concept at 3 TeV.

(update of 2004 CLIC Study) based on ILC detector concepts.

2) Detector simulations

- Simulation tools to be used by ILC and CLIC (WWS software panel)
- Validation ILC detector options for CLIC at high energy, different time structure and different backgrounds
- 1 TeV benchmark studies to provide overlap
- compare performance using defined benchmark processes (e.g. WW/ZZ separation)

Lucie Linssen 08/02/08

Continue Summary…

3) EUDET /DEVDET (infrastructure for LC detector R&D, with associated non-EU groups)

- microelectronic tools
- 3D interconnect technologies (for integrated solid state detectors)
- simulation and reconstruction tools
- combined test with magnet and LC sub-detectors

4) TPC

- TPC performance at high energies (>500 GeV).
- TPC read out electronics

5) Calorimetry

- Dual Readout Calorimetry (feasible at LC?)

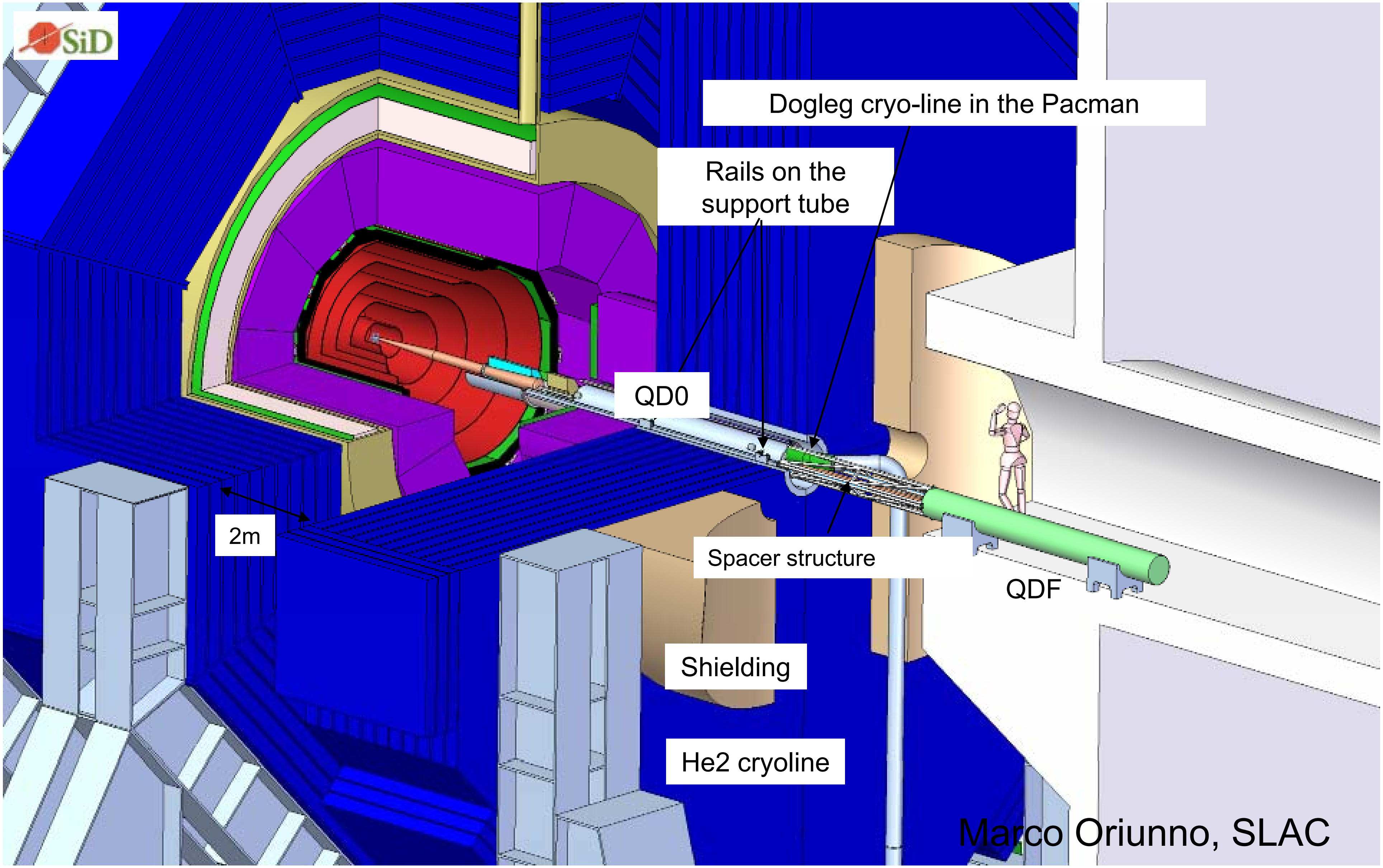
6) General

- increased CLIC participation in future ECFA workshops (2008 Warsaw) on LC detectors

Machine Detector Interface

- General layout and integration
  - Common meeting/review required
  - Common engineering tools for detector design in preparation (DESY, CERN, IN2P3, FP7)
- Background and luminosity studies
  - Strengthen support
- Masking system
  - Constraints on vertex detector
- Detector field
  - Need a field for CLIC
- Magnet design
- Common simulation tools for detector studies
  - Need to review what is available
- Low angle calorimeters
- Beam pipe design (LHC)
- Vacuum etc. (LHC)

IR integration, SiD example



Background and Luminosity Studies

- Common simulation tools
  - BDSIM ()
    - Integration into GEANT?
  - FLUKA (CERN)
  - Halo and tail generation (CERN)
  - Common formats etc
- Study of machine induced background
  - In particular, neutrons, muons and synchrotron radiation
  - Mitigation strategies
    - e.g. tunnel fillers against muons
- Study of beam-beam background and luminosity spectrum

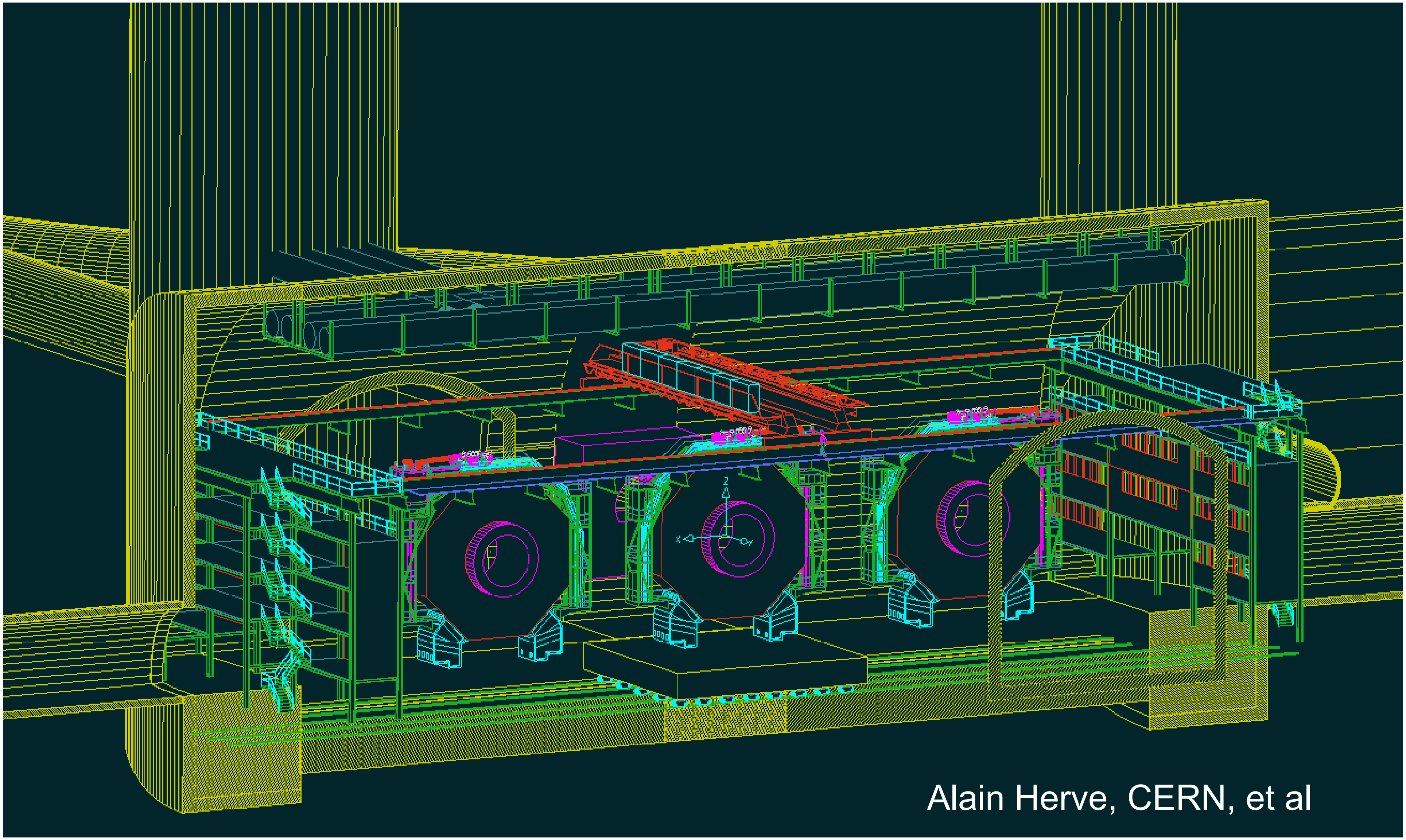
Support, Stabilization and Alignment

- LAPP, Oxford, CERN, FP7, BNL, SLAC, …
  - Other please join
- Low-noise design
  - Noise level measurements (DESY, CERN)
    - Among others, measurements at LHC
  - Component design
- Mechanical design of quadrupole support
- Final quadrupole design
- Stabilization feedback design
  - Sensors
  - Actuators
  - Interferometers

Experimental Area Integration

- Common definitions
- Infra-structure
  - Work is quite generic
    - No large differences expected for CLIC detector to some ILC detector
  - Collaboration has started
  - LHC expertise
- Push-pull
  - Is an option for both projects
  - A collaboration has started
  - Brings ILC/CLIC/LHC expertise
- Crossing angle
  - Investigate requirements
  - Then study benefits to find a common crossing angle

Push-Pull studies for two detectors



Conclusion
(from CLIC07)

- Good exchange with ILC experts, possible basis for future collaborations?
  - There are certainly communalities with the ILC detectors
  - ILC detector studies: R&D and discussions/optimization still ongoing

- Work is needed for CLIC on detector studies
  - Some benchmark channels started (taking SiD)
  - Need to discuss MDI with machine group (e.g.Mask upgrade/forward region instrumentation)
  - How well does particle flow (Energy flow) work at CLIC?

- R&D detector proposals being prepared
  - Good prospects for adequate time stamping at CLIC
  - Novel calorimeter concepts

- Specific detector R&D in FP7 (DevDet)?