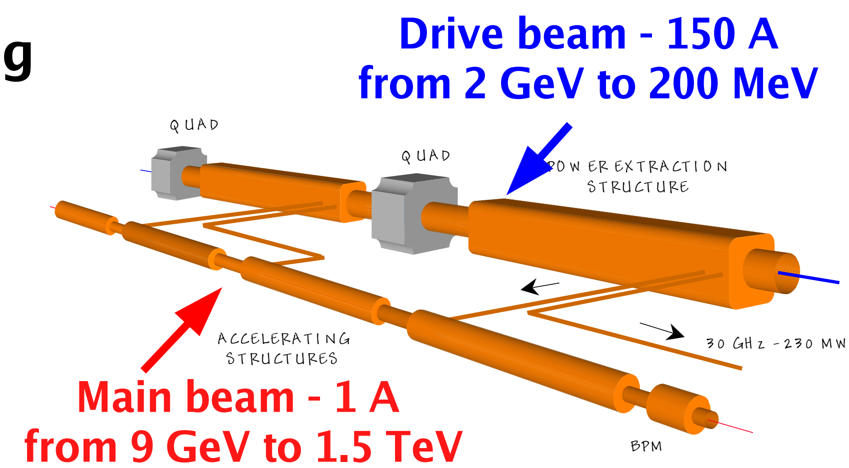
CLIC – ILC R&D

- **New CLIC parameters**
  - revised in 2007
- **CLIC detector R&D**
  - specific to CLIC needs
- **CLIC07 Workshop, October 2007**
  - accelerator, physics & detectors
- **CLIC – ILC Collaboration**
  - first collaboration meeting February 2008

CLIC

- **Major revision of CLIC parameters made in summer 2007**
  - final parameter optimization still ongoing
    - preparations for detailed report ongoing
- **Basic changes**
  - 30 GHz -> 12 GHz RF frequency
    - close to old NLC frequency (11.424 GHz)
      - easier to adapt NLC work and experience
    - lower frequency allows more relaxed alignment tolerances
  - 150 MV/m -> 100 MV/m
    - reduces breakdown rate and surface damages in RF accelerating structures
    - 50 km long LINAC allows 2 x 1.5 TeV = 3 TeV CM energy (was 5 TeV)
  - 0.5 ns bunch spacing, 312 bunches (= 156 ns bunch trains), 50 Hz (3 TeV)
    - optimized for maximum luminosity
    - was subject of various changes in the past: 0.667 ns -> 0.267 ns -> 0.667 ns -> 0.5 ns
- **Aim for feasibility and conceptional design report in 2010 (CDR)**



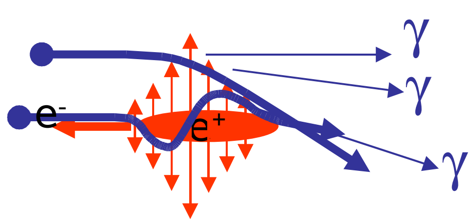
CLIC Parameters I

Luminosity at 500 GeV similar to ILC/NLC

Parameter	Symbol	CLIC 3 TeV	CLIC 1 TeV	CLIC 0.5 TeV	ILC 0.5 TeV	NLC 0.5 TeV	Unit
Center of mass energy	E_{cm}	3000	1000	500	500	500	GeV
Main Linac RF Frequency	f_{RF}	12	12	12	1.3	12	GHz
Luminosity	**L**	**5.9**	**2.25**	**2.24**	**2**	**2**	$\mathbf{10^{34}\ cm^{-2}\ s^{-1}}$
Luminosity (in 1% of energy)	$L_{99\%}$	2	1.08	1.36			$10^{34}\ cm^{-2}\ s^{-1}$
Linac repetition rate	f_{rep}	50	50	100	5	120	Hz
No. of particles / bunch	N_b	3.72	3.72	3.72	20	7.5	10^9
No. of bunches / pulse	k_b	312	312	312	2670	192	
No. of drive beam sectors / linac	N_{unit}	24	8	4	-	-	-
Overall two linac length	l_{linac}	41.7	13.9	6.9	22	14	km
Proposed site length	$\mathbf{l_{tot}}$	**47.9**	**20.1**	**13.2**	**31**	**32**	**km**
DB Pulse length (total train)	t_t	139	46	23	-	-	μs
Beam power / beam	P_b	14	4.6	4.6	10.8	6.9	MW
Wall-plug power to beam efficiency	η_{wp-rf}	8.7	6.1	6.1	9.4	7.1	%
Total site AC power	$\mathbf{P_{tot}}$	**322**	**~150**	**~150**	**230**	**195**	**MW**

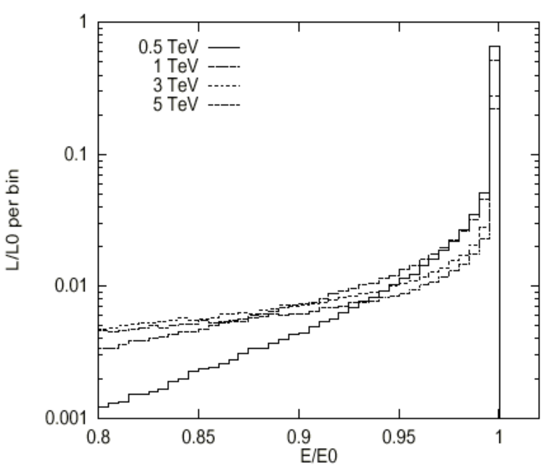
CLIC Parameters II

3x more energy loss due to beamstrahlung at CLIC w.r.t. ILC at 500 GeV



unavoidable at Linear Colliders in general: small beam sizes -> large beamstrahlung

Parameter	Symbol	CLIC 3 TeV	CLIC 1 TeV	CLIC 0.5 TeV	ILC 0.5 TeV	NLC 0.5 TeV	Unit
Transverse horizontal emittance	$\gamma\varepsilon_x$	660	660	660	8000	3600	nm rad
Transverse vertical emittance	$\gamma\varepsilon_y$	20	20	20	40	40	nm rad
Nominal horizontal IP beta function	β^*_x	4	20	15	20	8	mm
Nominal vertical IP beta function	β^*_y	0.09	0.1	0.1	0.4	0.11	mm
Horizontal IP beam size before pinch	σ^*_x	40		142	640	243	nm
Vertical IP beam size before pinch	σ^*_y	1		2	5.7	3	nm
Beamstrahlung energy loss	δ_B	29	11	7	2.4	5.4	%
No. of photons / electron	n_γ	2.2	1.2	1.1	1.32	1.3	-
No. of pairs (p_T^{min}=20MeV/c, Î¸$_{min}$=0.2)	N_{pairs}	45	17.1	11.5			-
No. of coherent pairs	N_{coh}	38	0.07	0.0001			10^7
No. of incoherent pairs	N_{incoh}	0.44	0.09	0.05			10^5
Hadronic events / crossing	N_{hadron}	3.23	0.29	0.1			-



CLIC luminosity spectrum

similar number of photons / electron at 500 GeV but higher energy per photon at shorter bunches (CLIC)

Physics and Detectors WG @ CLIC07

- 2 sessions
  - physics landscape and new studies
  - detectors
    - part 1: invited speakers from the ILC community
      - overviews on status of ILC detector R&D
    - part 2: CLIC specific detector studies
      - new detector ideas
      - engineering studies
      - detector simulation study

~25 participants

Physics & Detectors Wkg (09:00 ->11:55)		Chairperson: Michael Hauschild (*CERN*) , Ron Settles (*Max-Planck-Institut fuer Physik*) Location: 40-S2-B01
09:00	Detailed discussion on backgrounds etc. (20') (Slides)	Daniel Schulte (*CERN*)
09:25	New ideas on EWSB (20') (Slides)	Christophe Grojean (*CERN*)
09:50	The road from LHC->SLHC->LC (20')	Michelangelo Mangano (*CERN*)
10:15	Heavy Higgs study (15') (Slides)	Arnaud Ferarri (*Univ. of Uppsala*)
10:35	Coffee Break (20')	
10:55	Stau searches at CLIC (15') (Slides)	Ilkay Turk Cakir (*TAEA*)
11:15	Excited leptons at CLIC (15') (Slides)	Orhan Cakir (*University of Ankara*)
11:35	4th generation at CLIC (15') (Slides)	Saleh Sultansoy (Sultanov) (*TOBB Univ of Eco & Tech*)

Physics and Detectors WG @ CLIC07

the ILC/DESY part...

~35 participants

Physics & Detectors Wkg (Location: Main Auditorium) (13:40 ->18:40)		Chairperson: Michael Hauschild (*CERN*) , Ron Settles (*Max-Planck-Institut fuer Physik*)
13:40	MDI Experience from the ILC (20') (Slides ; video; video download)	Karsten Buesser (*DESY*)
14:05	ILC Pixel/microvertexing (20') (Slides)	Marc Winter (*Institut de Recherches Subatomiques (IReS)*)
14:30	ILC Tracking (20') (Slides)	Klaus Dehmelt (*DESY*)
14:55	ILC Calorimetry (20') (Slides)	Erika Garutti (*DESY*)
15:20	EUDET (15') (Slides)	Joachim Mnich (*DESY*)
15:40	Coffee Break (20')	
16:00	Calorimetry (crystals) (15') (Slides)	Paul Lecoq (*CERN*)
16:20	Time stamping (15') (Slides)	Pierre Jarron (*CERN*)
16:40	Pixel microvertex technologies (15') (Slides)	Michael Campbell (*CERN*)
17:00	3D silicon (15') (Slides)	Cinzia Da Via (*Brunel University*)
17:20	TOF (15') (presentation)	Crispin Williams (*Universita & INFN, Bologna*)
17:40	Interaction Region Engineering at ILC: Push-Pull option (15') (Slides)	Alain Herve (*CERN*)
18:00	Detector Services Design for push-pull option (15') (Slides)	Andrea Gaddi (*CERN*)
18:20	SID detector at 3 TeV (15') (Slides)	Marco Battaglia (*UC, Berkeley & LBL, Berkeley*)

the CLIC/CERN part...

CLIC Detector

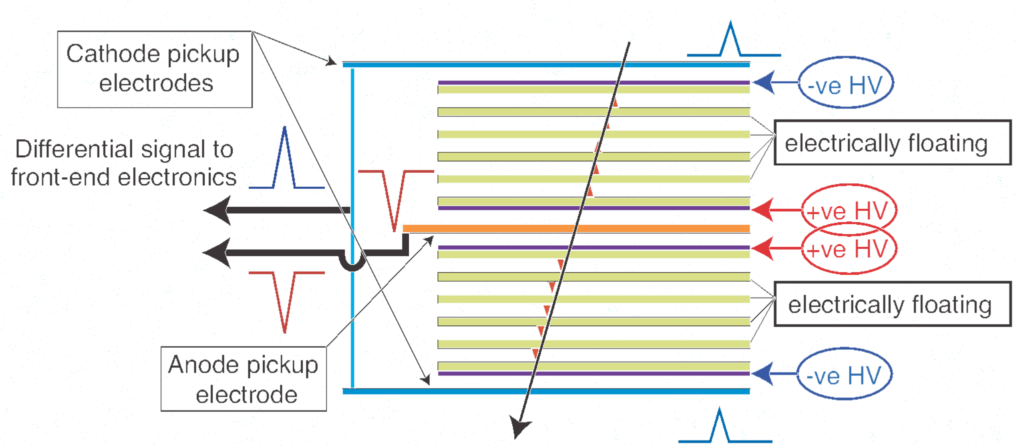
- **CLIC detector = 90% ILC detector + 10% CLIC specifics**
  - CLIC is profiting a lot from ILC detector R&D
    - (= ILC community are also working for a CLIC detector...)
- **Major CLIC – ILC differences (the 10% CLIC specifics)**
  - higher energy -> particle jets become more dense
    - need tracker with better double track resolution
      - TPC was disfavoured some years ago (double hit resolution of classic TPC ~1 cm)
      - thanks to ILC R&D now ~2 mm TPC double hit resolution (GEMs or MicroMegas)
      - TPC could be reconsidered again as CLIC main tracker as alternative to full Si tracker
    - need calorimeters with higher granularity
      - Particle Flow concept (favoured by most ILC detector concepts) requires to identify individual calorimeter EM and hadronic clusters
      - alternatively: forget particle flow, build calorimeter with (hardware) compensation = DREAM concept
  - much shorter bunch spacing: 0.5 ns (CLIC) vs 337 ns (ILC)
    - need "time-stamping": identification of tracks from individual bunch crossings
      - if no time-stamping -> overlay of physics events with hadronic background from beamstrahlung
      - what resolution is needed? what is the degradation in physics?

Time Stamping

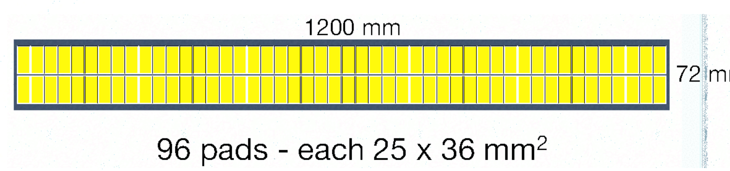
- **Ideal detector would be capable to identify particles from individual bunch crossings in all detector components**
  - → **not realistic, most detectors don't have 0.5 ns resolution or better**
- **Way out**
  - → **add a few dedicated time stamping layers**
    - **Fast silicon pixel layers for tracking**
    - **TOF layer with high granularity in front or inside calorimeters**
      - **ALICE Multigap RPCs have time resolutions of <100 ps**

ALICE-TOF has 10 gas gaps (two stacks of 5 gas gaps) each gap is 250 micron wide

Built in the form of strips, each with an active area of 120 x 7.2 cm^2, readout by 96 pads

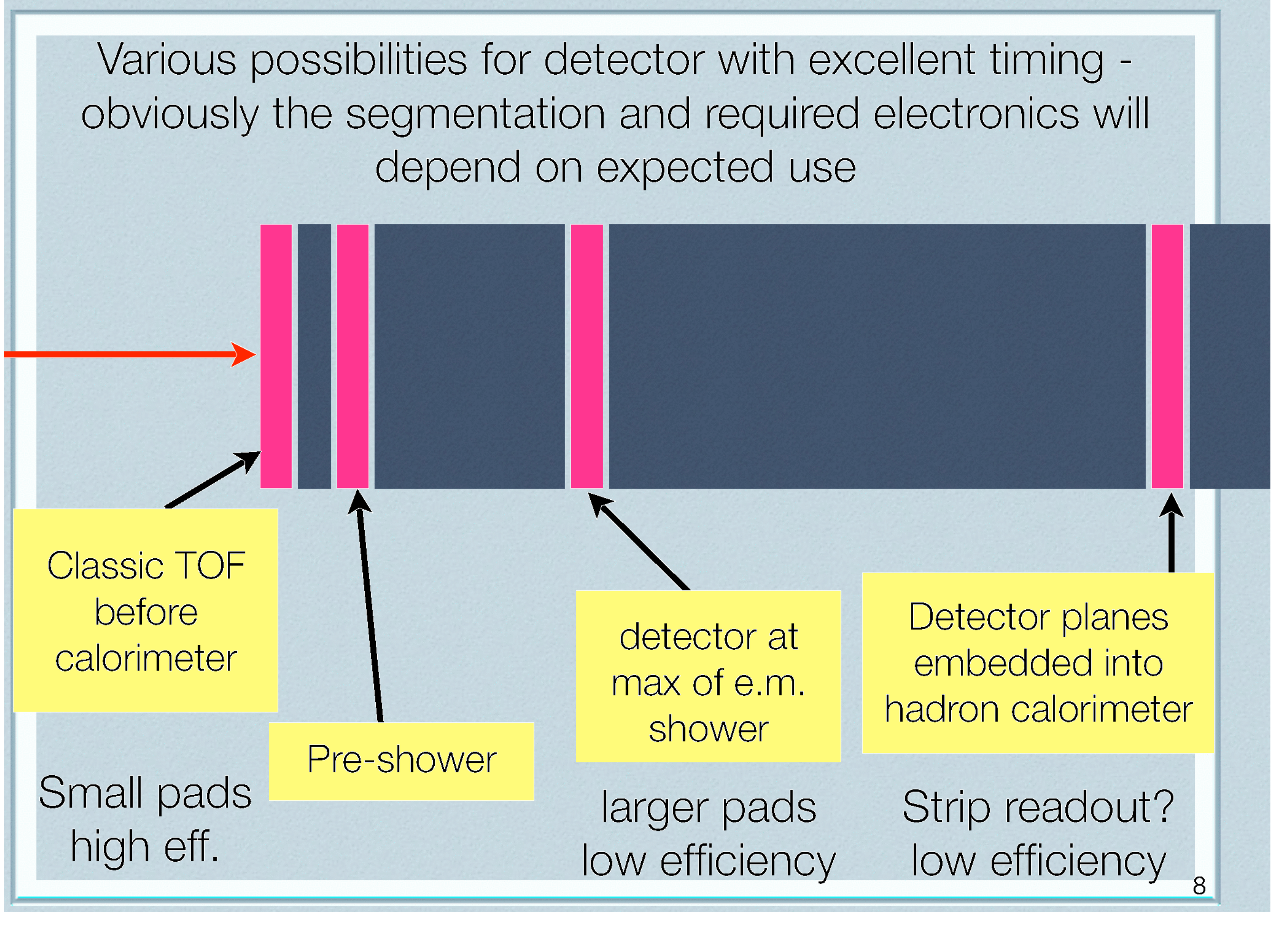


C. Williams



Time Stamping - Calorimeters

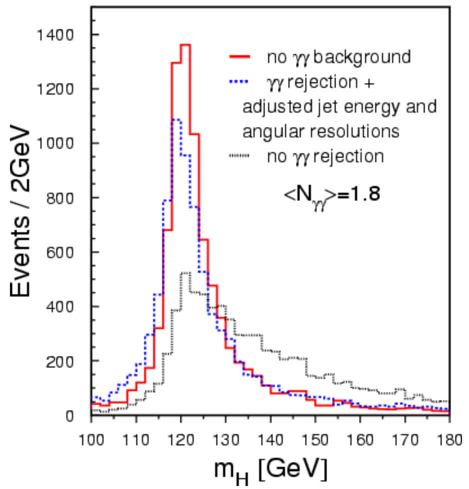
C. Williams



- **Fast TOF available already today**
  - **need to optimize for CLIC**
    - **granularity, segmentation, material, electronics (type/power)**
    - **how fast do we really need? faster electronics -> higher power consumption**

Why Time Stamping?

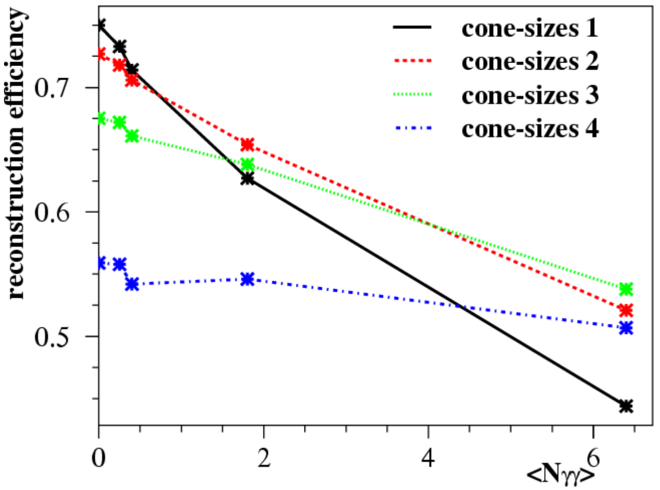
- **Overlay of physics events with background events from several bunch crossings**
  - ➔ **degradation of physics performance**
- **Main background sources from beamstrahlung**
  - ➔ **e^+e^- pairs from beamstrahlung photons**
    - **low p_T, can be kept inside beam pipe with high magnetic field, B > 3 T**
  - ➔ **hadrons from 2-photon collisions (beamstrahlung photons)**
    - **can have high p_T, reach main tracker and confuses jet reconstruction**
    - **typically ~O(1) hadronic background event per BX with p_T > 5 GeV tracks**



Higgs mass reconstruction from HZ ➔ $b\bar{b}q\bar{q}$

reconstruction of H ➔ $\tau^+\tau^-$

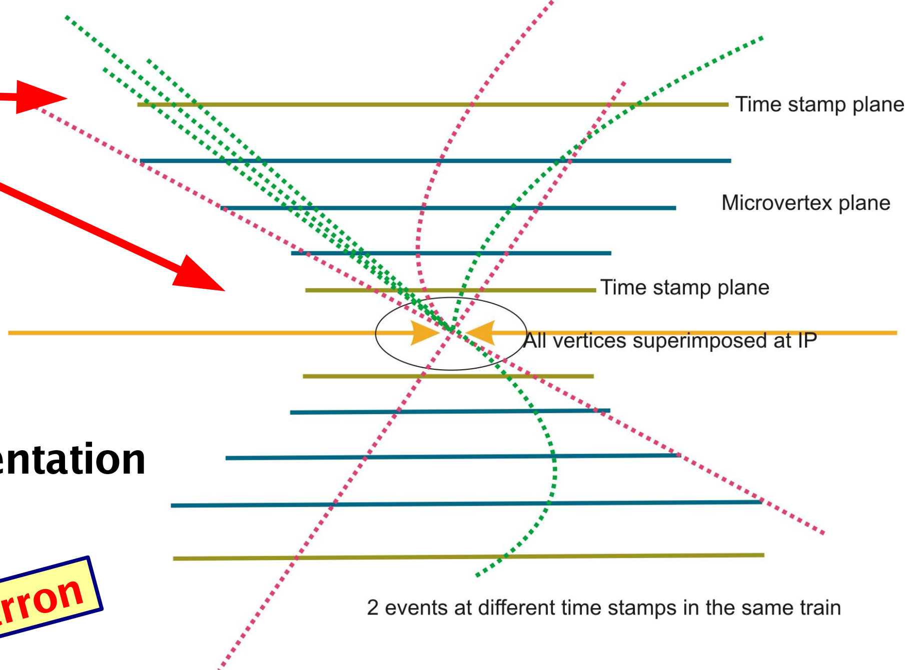
K. Desch et al., TESLA-NLC study from 2004



Time Stamping - Tracking

- **Longitudinal bunch length ~ 10 μm**
  - no way to identify different events/tracks due to different vertex positions
    - at LHC: much longer bunches, collisions distributed along z-axis + can be identified
  - only way at CLIC: need precise time measurement (< 0.5 ns) in tracker
  - limitations
    - time stamping requires fast detector/electronics
    - but cannot affort too many channels/pixels (high power consumption)
- **Basic idea**
  - have few time stamping layers
    - fast, larger pixels, not so many channels
    - Hybrid pixel, 0.3 x 0.3 mm^2
  - + “standard” tracker layers
    - “slow”, small pixels, many channels, precise
    - Monolithic sensor pixel, 0.02-0.05 mm segmentation
    - integrate of full bunch train (156 ns)

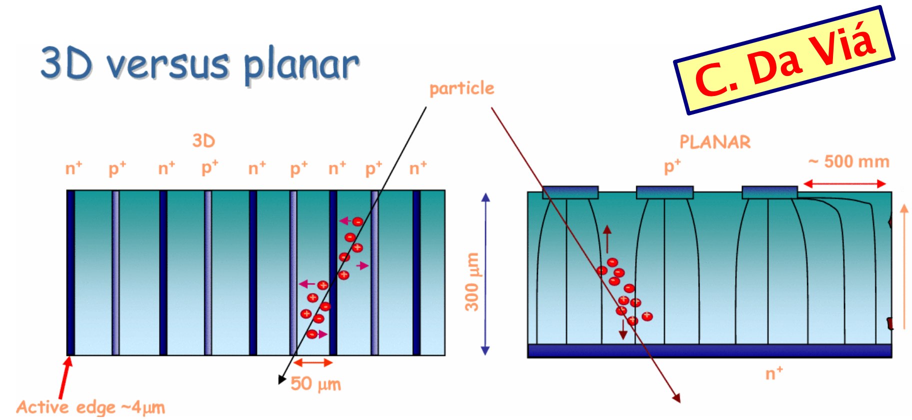
2 vertices in 2 different BX’s in one train

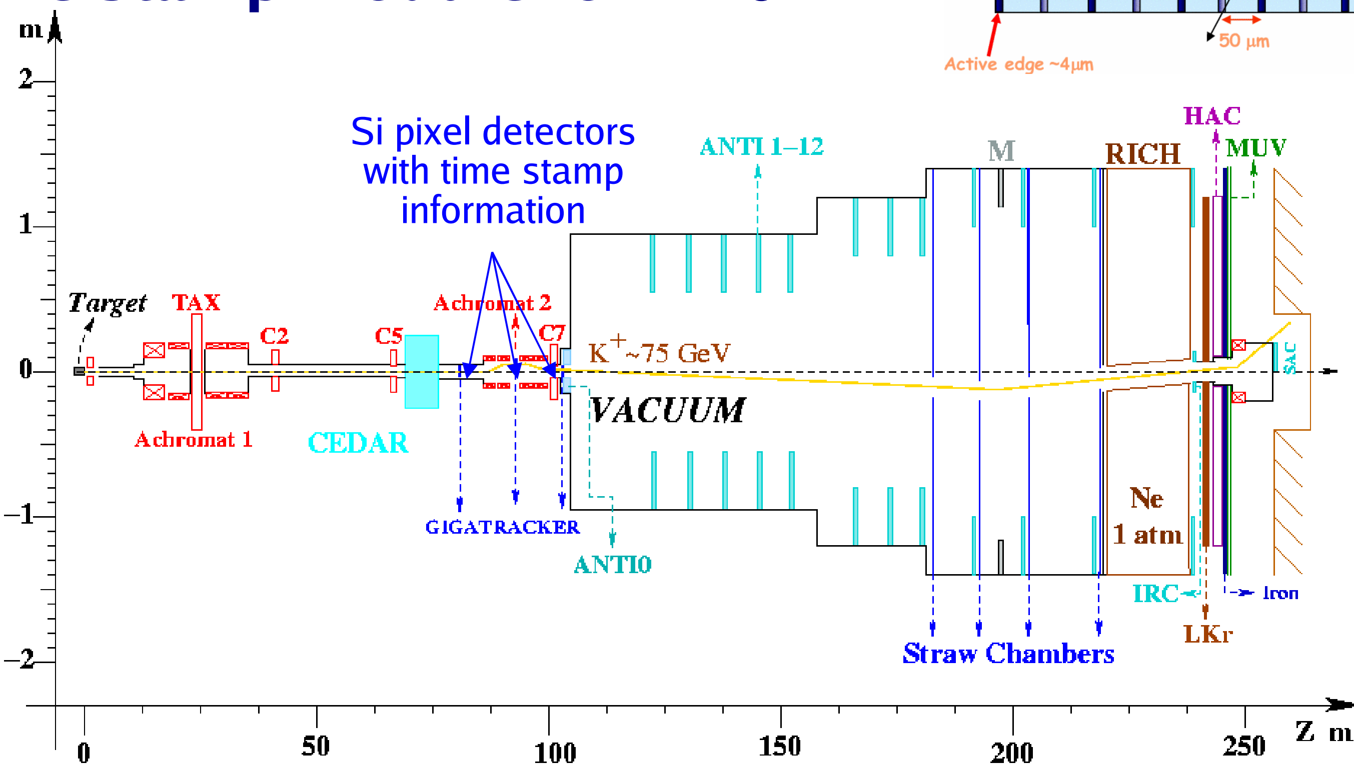


P. Jarron

Time Stamping - Prospects

- **Preliminary results on 130 nm Front End circuits encouraging**
  - time resolution < 100 ps for 300 μW power on 0.3 x 0.3 mm^2 pixel
- **Fast sensors also encouraging**
  - can reach 1 or 2 ns in 3-D silicon
- **Proposal to build demonstrator time stamp module for NA62**



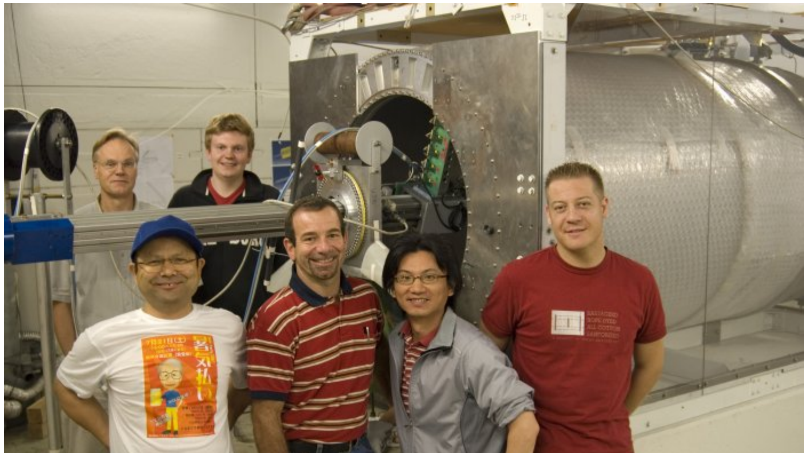


measurement of rare Kaon decays:
$K^+ \rightarrow \pi^+ \nu \nu$

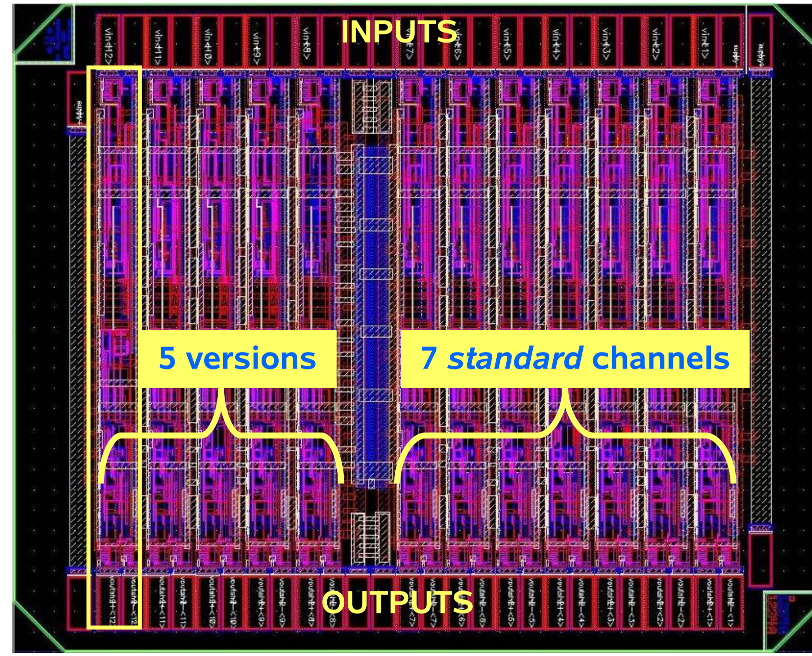
CERN participation in EUDET

- **EUDET FP6 Programme to provide infrastructure for ILC detector R&D**
  - **small CERN participation, ~1.2 FTE CERN staff**
- **Work packages with CERN involvement**
  - **MICELEC**
    - **microelectronics user support**
  - **VALSIM**
    - **optimisation of hadronisation process in GEANT4**
  - **PCMAG**
    - **magnetic field map for magnet in 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 1x4 mm^2 pads**

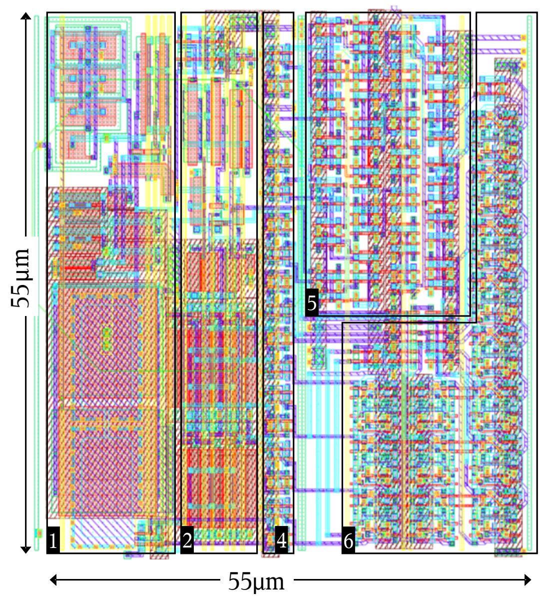
EUDET highlights



PCMAG field map campaign at DESY 2007



TPC pad readout, programmable amplifier 130 nm technology



Timepix chip, 256 x 256 pixels, 55 μm^2 per pixel, individually programmable: time or charge

CERN Contribution to FP7 LC tasks

L. Linssen

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

CLIC – ILC Collaboration?

J-P Delahaye

- **First discussions following a visit of Barry Barrish at CERN in November 2007**

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

  - **independent of UK/US financial crisis but even more disirable now**

- **Subjects with strong synergies**
  - **civil engineering and conventional faclities**
  - **beam delivery systems & machine detector interface**
  - **detectors**
  - **cost and schedule**
  - **beam dynamics & beam simulations including low emittance transport**

CLIC – ILC Collaboration

J-P Delahaye

- **First CLIC – ILC Collaboration meeting, 8th Feb @ CERN**

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

  - about 35 participants from accelerators and detectors
- **Prepared by**
  - Marc Ross, Nick Walker, Akira Yamamoto (ILC-GDE project managers), Jean-Pierre Delahaye (CLIC study leader and ILC-GDE member)
- **Objectives**
  - review selected subjects + define tasks of common interests
  - once defined, nominate contact persons for each subject (convenors)
    - prepare plan af actions including schedule
- **General remarks**
  - large number of common issues on each of the five selected subjects
  - possible common studies limited by available resources
  - LHC experinece extremely useful

How to collaborate?

J-P Delahaye

- **Presently (for each sub-system)**
  - ILC team working on ILC system with ILC beam at 500 GeV
  - CLIC team working on CLIC system with CLIC beam at 3 TeV and scaling down to 1 TeV and 500 GeV
  - Fruitful excahnegs between technical experts
  - different designs of sub-systems for (not always) good reasons
- **Possible future**
  - CLIC & ILC teams working together on CLIC and ILC systems at 500 GeV
  - identify together if same design/technology can be used
  - understand why and what necessary differences
  - define together necessary modifications of the sub-system for the upgrade in energy to 1 TeV for ILC and 3 teV for CLIC
- **Connect the 2 communities such their projects are comparable**

CLIC – ILC Detector R&D

L. Linssen

- **Define a CLIC detector concept at 3 TeV (based on ILC concepts)**
- **Detector simulations**
  - simulation tools to be used by ILC and CLIC (WWS software panel)
  - validation of ILC detector options for CLIC at high energy, differen time structure and different backgrounds
  - 1 TeV benchmark studies to provide overlap
  - compare performance using defined benchmarks (e.g. WW/ZZ separation)
- **EUDET/DEVDET (infrastructure for LC detector R&D)**
  - microelectronic tools
  - 3D interconnect technologies (for integrated solid-state detectors)
  - simulation and reconstruction tools
  - combined test with magnet LC sub-detectors
- **TPC**
  - TPC performance at high energies (>500 GeV)
  - TPC read-out electronics
- **Calorimeters**
  - dual read-out calorimetry (feasible at LC?)

Machine Detector Interface

D. Schulte

- **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 field for CLIC
- **Magnet design**
- **Common simulation tools for detector studies**
  - need to review what is available
- **Low angle calorimeters**
- **Beam pipe design (LHC)**
- **Vaccum etc. (LHC)**

Background and Luminosity Studies

D. Schulte

- Common simulation tools
  - BDSIM 0
    - 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
  - mitigaton strategies
    - e.g. tunnel fillers aginst muons
- Study of beam-beam background and luminosity spectrum

Support, Stabilization and Alignment

D. Schulte

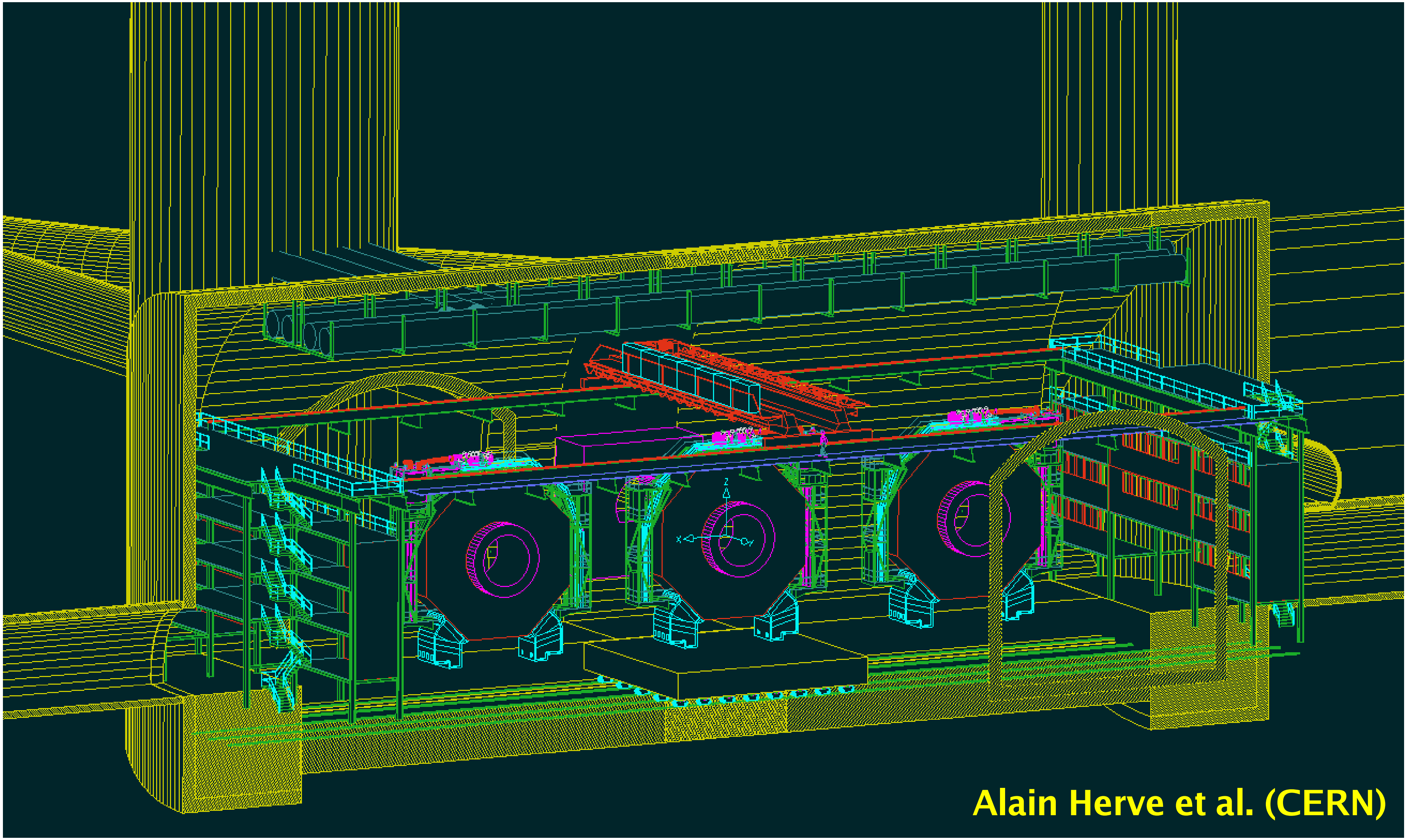
- LAPP, Oxford, CERN,FP7, BNL, SLAC, ...
  - others please join!
- Low-noise design
  - noise level measurements (DESY, CERN)
    - among others, measurements at LHC
  - component design
- Mechanical design of quadrupole support
- Final quadrupole design
- Stabilisation feedback design
  - sensors
  - actuators
  - interferometers

Experimental Area Integration

D. Schulte

- **Common definitions**
- **Infrastructure**
  - work is quite generic
    - no large differences expected for CLIC detector w.r.t. ILC detector
  - collaboration has started
  - LHC expertise
- **Push-Pull**
  - option for both projects
  - 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



Conclusions

J-P Delahaye @ Sendai, March 2008

- CLIC – ILC collaboration on subjects with strong synergy
- Win-Win situation for both studies and for HEP in general
- Ambitious but realistic and practical approach
  - starting on limited number of projects
  - convenors to define plan of (limited) actions
- Most efficient use of limited resources
- Overlap in each others meetings
  - CLIC members -> ILC meetings, ILC members -> CLIC meetings
- Provide credibility to Linear Collider community
  - mutual understanding of status, issues, advantages of both technologies
  - responsible preparation of the future comparison of possible options for HEP with agreed pros and cons and criteria
- Collaborative Competition and/or Competitive Collaboration