CLIC technology developments

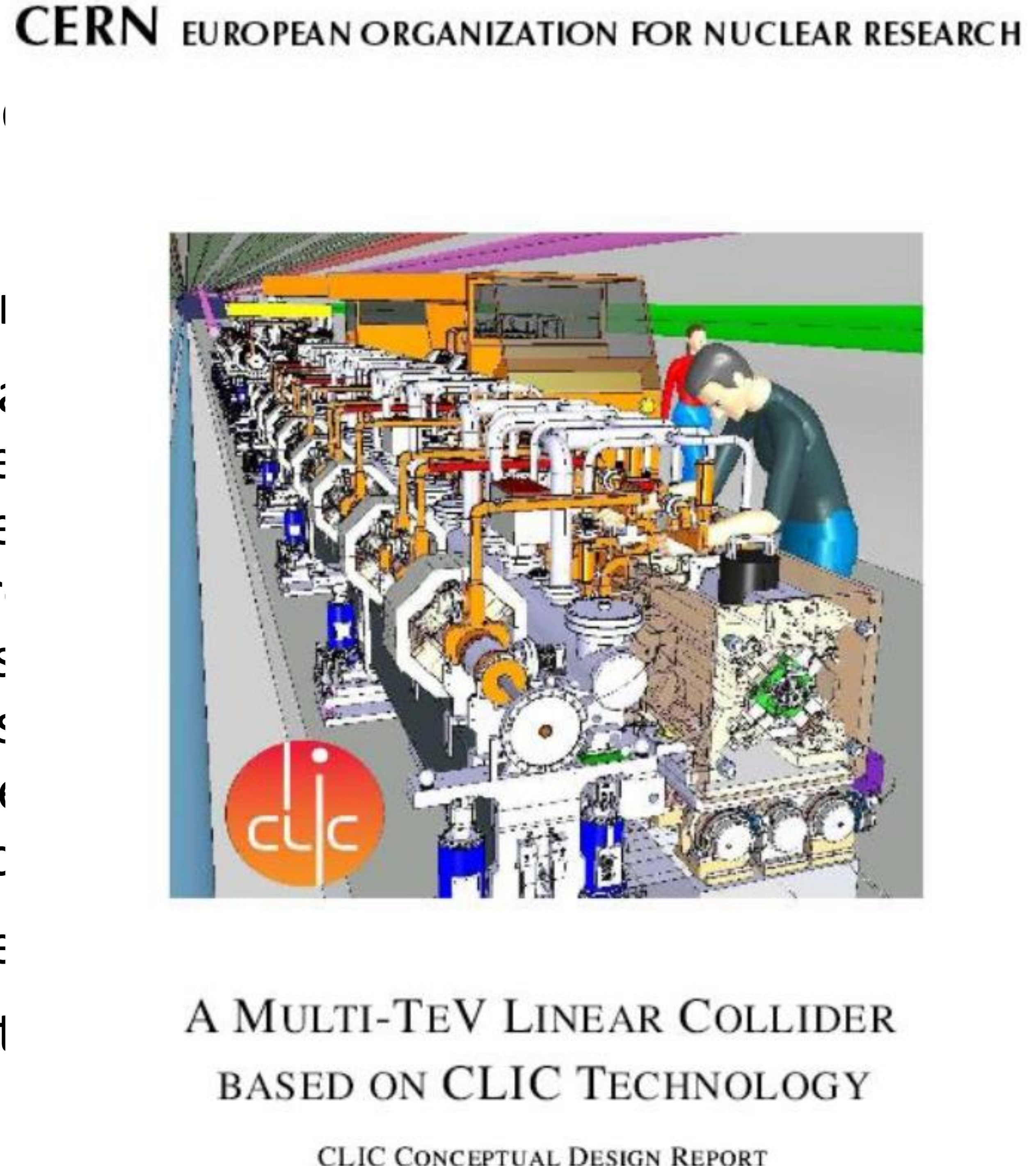
- Scope of “CLIC technology Developments” =: TD

- Present situation; some flashy positive results (short)
- Outlook for 2018
- Summary

CLIC review 1-3-2016; H.Schmickler, BE-BI-QP on behalf of the CLIC-TD team

Scop… …:=TD) (1/2)

- Activity c…
- Mandate …
  - collect te… …e so far
  - collect re…
  - classify r…
    - a) ess… …ility of the project
    - b) ess… …eters
    - c) nee… …uction
    - d) nic…
- Define the… …) and follow-up
- Document… …2012



Scope of CLIC Technology Developments (:=TD) (2/2)

- “Thousands” of important subjects to chose from…

- Need to make a choice depending on:

- answers needed for PIP in 2018
- available resources
- potential synergy with collaborating institutes
- overlap with externally funded R&D initiatives
(ex: damping ring R&D = synchrotron light sources R&D)
- overlap with ILC R&D
- potential for being useful in other accelerators

Overview of TD activities

- beam instrumentation
- warm magnets development
- superconducting wiggler
- mechanical pre-alignment
- quadrupole active stabilization
- R&D on new alignment concepts: PACMAN program
- vacuum technology
- fast pulsed kickers
- module R&D
- main dump design
- Control system approach for main linac
- modulators for the drive beam klystrons → now under EV
- RF system prototype (extreme beam loading) for damping rings

= on track

= needs more or refined effort

= activity stopped due to lack of resources or low priority

…so far not covered in TD, but considered "must" in original analysis:

- measurements of the time dependence of the earth magnetic field AND correlations of fluctuations over distances up to 1 km
→ very important for the modelling of the BDS of CLIC

→recently new initiative by D.Schulte

- extension of the present state of the art timing and synchronization systems from distances of ~km to distances of ~10 km

→ need to rely on developments in the FEL sector

A few flashy slides as part of the full program:

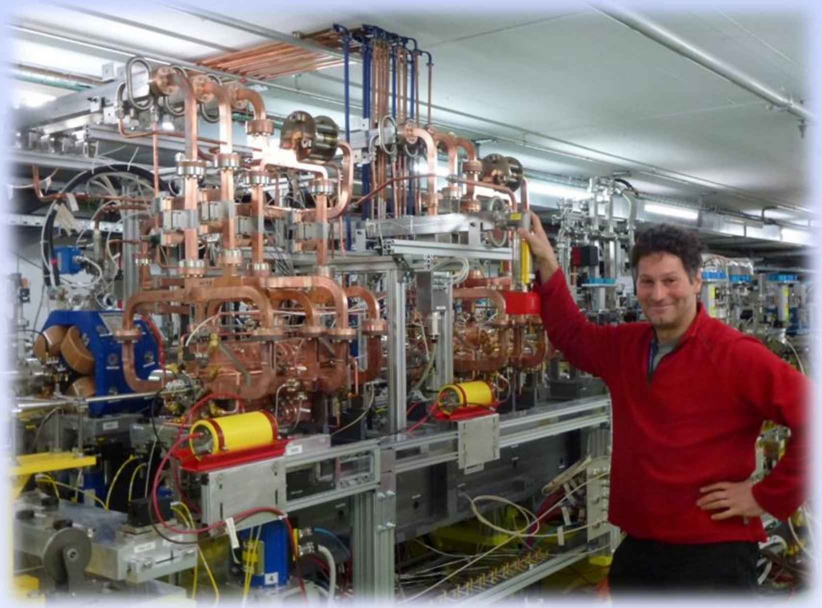
1) CLIC module prototypes in building 18 and in CLEX
2) CLIC magnet program
3) CLIC Beam instrumentation
4) PACMAN
5) Objectives for Quadrupole Stabilization

…sorry for those activities not covered

CLIC Module R&D

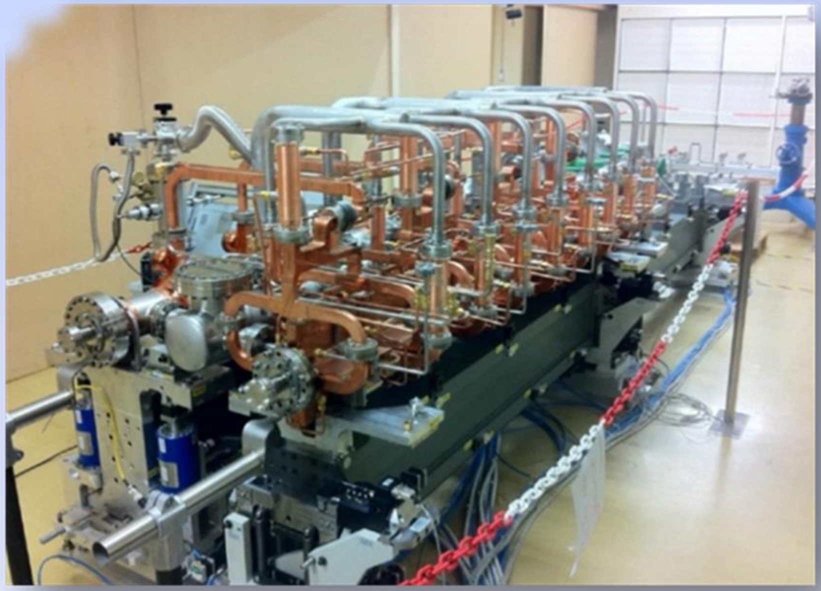
CLIC prototype Module with real RF components installed in CTF3 and tested with drive and probe beam

A



CLIC mechanical test modules with mock up components in a dedicated Lab for thermo-mechanical, alignment and integration testing.

B



CLIC Warm Magnet Catalogue

A wide magnets population in the different parts of the CLIC complex → CLIC Magnet Catalogue:

1) CLIC Drive Beam complex (turnaround, delay line, combiners rings, TL, etc.) :
- **12096** magnets in total; divided in **14** types with population from **32** to **1872** units.

2) CLIC Main Beams Transport :
- **2291** magnets in total; divided in **17** types with population from **1** to **250** units.

3) CLIC Damping Rings :
- **4076** magnets in total; divided in **11** types with population from **76** to **1004** units.

4) CLIC Post-Collision line :
- **18** magnets in total; divided in **5** types with population from **2** to **8** units.

QD0 prototype

5) CLIC Beam Delivery System :
- about **400** magnets in total; divided in **70** types with population from **1** to **96** units.

Electro- and PM prototypes

6) CLIC DBQ (EM or PM design): - **41848** magnets in total.

7) CLIC MBQ: - **4274** magnets in total; divided in **4** types with population from **368** to **1490** units

Prototypes – optimized for stabilization

All that give **more than 65000 magnets (!**) …number approximated since injector systems not included)

- We have unified similar magnets design (to get larger series for more convenient procurement) where possible.
- The total **procurement cost**, the **powering** and **cooling** needs for all the CLIC magnets Catalogue was evaluated by use of proved estimation formulas (CERN MSC-MNC sources), and including production learning curves estimation (*ref. CERN doc. EDMS:100426 by P. Lebrun).*

Main Beam Quadrupole (MBQ)

In Total: 4142 MBQ needed.

308 of TYPE1

TYPE1	
Aperture (Ø)	10 mm
Length	420 mm
Gradient	200 T/m
Current density	6.1 A/mm2
Current	126 A
Voltage	8 V
Power	990W
Weight	85 kg

1276 of TYPE2

TYPE2	
Aperture (Ø)	10 mm
Length	920 mm
Gradient	200 T/m
Current density	6.1 A/mm2
Current	126 A
Voltage	16 V
Power	1980 W
Weight	170 kg

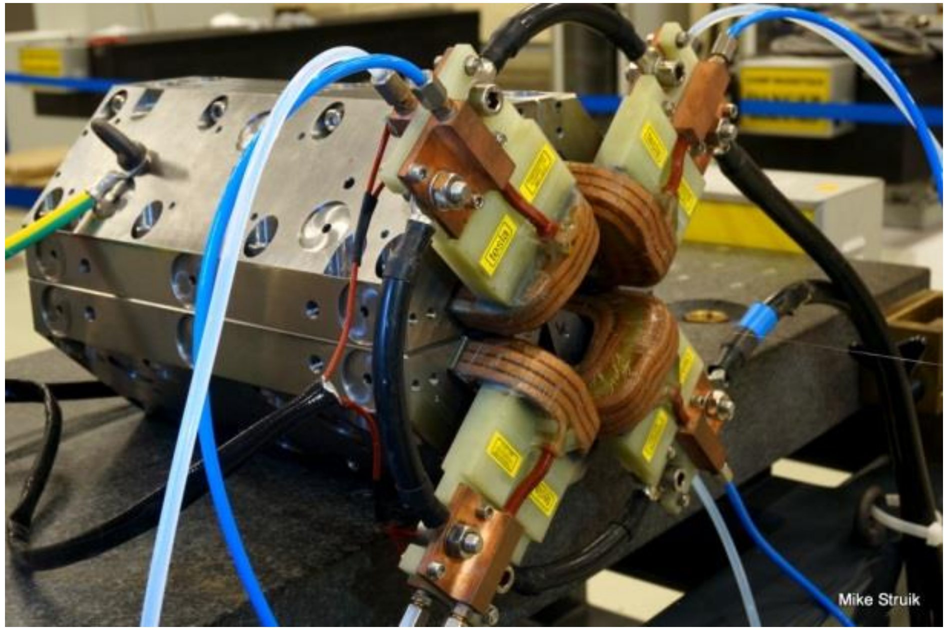
964 of TYPE3

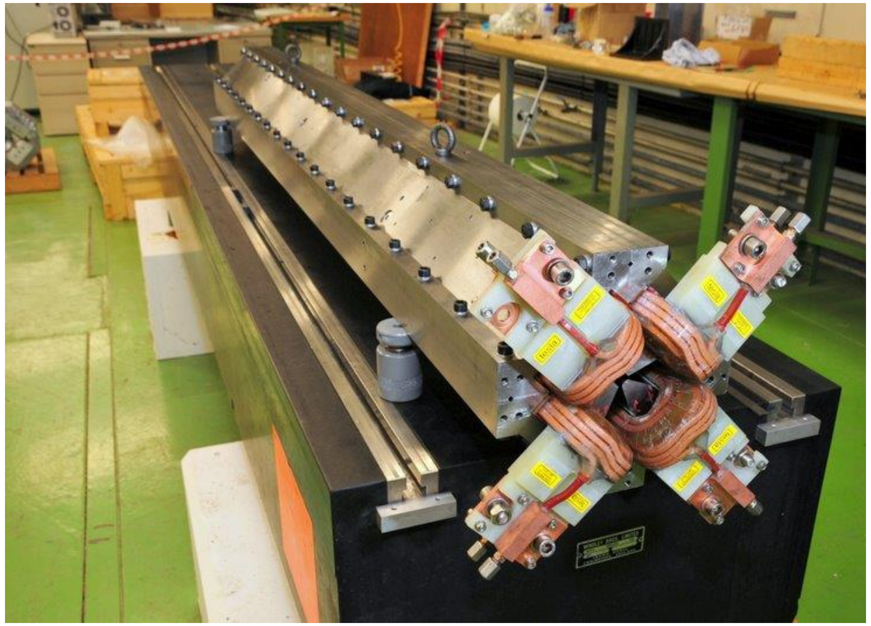
TYPE3	
Aperture (Ø)	10 mm
Length	1420 mm
Gradient	200 T/m
Current density	6.1 A/mm2
Current	126 A
Voltage	24 V
Power	2970 W
Weight	280 kg

1594 of TYPE4

TYPE4	
Aperture (Ø)	10 mm
Length	1920 mm
Gradient	200 T/m
Current density	6.1 A/mm2
Current	126 A
Voltage	30.4 V
Power	3831 W
Weight	370 kg

3 Prototypes of TYPE1 and 1 of TYPE4 procured (for investigation on quadrants machining, achievable field quality, stabilization study and “2-Beam” Modules technical mock-up)



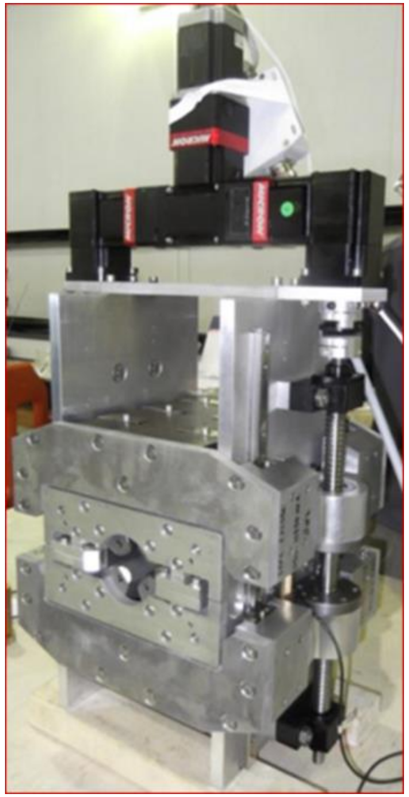


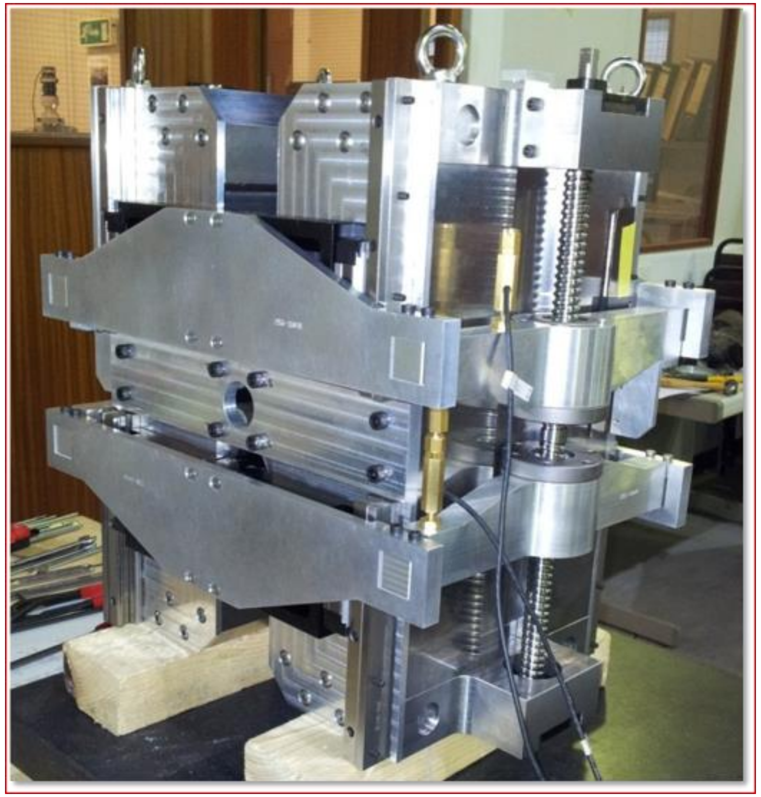
Drive Beam Quadrupole (DBQ) – PM Version

2 designs to cover the needed gradient range of the Decelerator (integrated gradient from 1.2 to12.2 T) were developed at:

ASTeC (Daresbury Laboratory within the CERN-UK collaboration)

- the 1st prototype (High Gradient) was delivered at CERN and measured (Magnetic Meaurements and Metrology) in 2012.
- the 2nd prototype (Low Gradient) delivered and measured at CERN in 2014



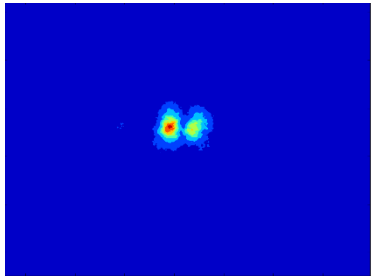


BI workpackages – 2011-16

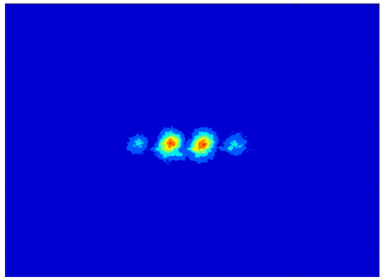
- R&D on Beam position monitor (IFIC and RHUL)
  - Design and validation of CLIC Cavity BPM resolution – *On-going at Califes*
  - Cavity BPM impedance budget – *100% CLIC-UK activity – On-going at KEK*
  - DB stripline BPM working in the vicinity of PETS – *On-going at CLEX*
- R&D on Emittance monitoring (RHUL, U. Liverpool)
  - Validation of Laser Wire Scanner performance at ATF2 - *100% CLIC-UK RHUL - Completed*
  - R&D on 'cheaper and simpler' non-interceptive method (i.e. Diffraction radiation)
  - R&D on ultra high-resolution Optical Transition Radiation monitor for single bunch operation
  - R&D on gas profile monitor / gas jet scanner for DB emittance monitoring
- R&D on short bunch length monitoring (Dundee/Daresbury)
  - Development of 1ps bunch length monitor on Califes (Marie-Curie) - Completed
  - Prototyping of E-O bunch length monitor with 20fs time resolution - 100% CLIC-UK activity – To be completed by April 2017
- R&D on BLM developments (U. Liverpool and Australian Synchrotron)
  - Cost effective Beam loss monitor based on Cherenkov fibres for CLIC module
  - Development of Beam loss monitor only sensitive to charged particle for Damping rings

One slide on ODR (measurements at Cornell)

Beam size measurement : Angular distribution @600nm



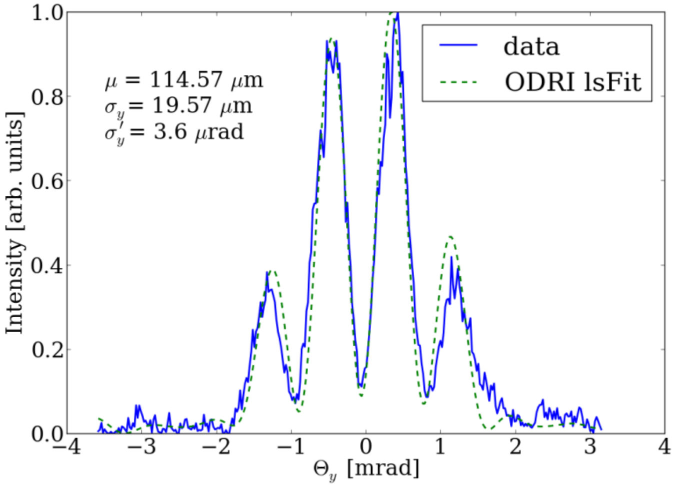
2mm mask aperture
ODR



1mm mask aperture
ODRI

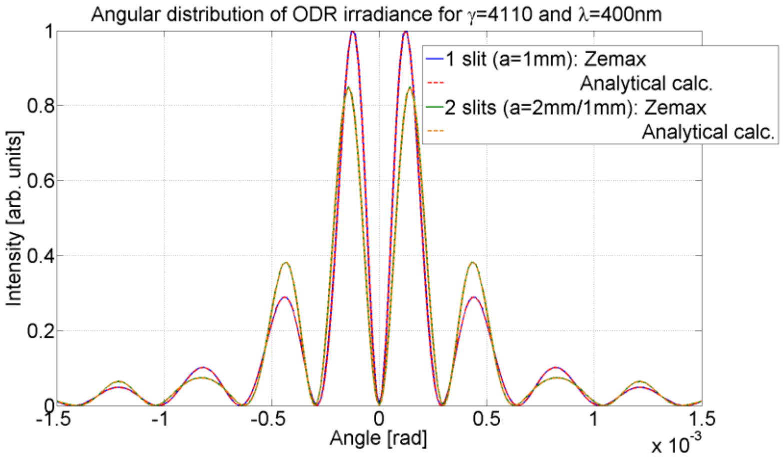
Least Square Fit Analysis

- Taking into account the coplanarity of the target of 40nm
- Fitting 3 parameters/ position, size and divergence



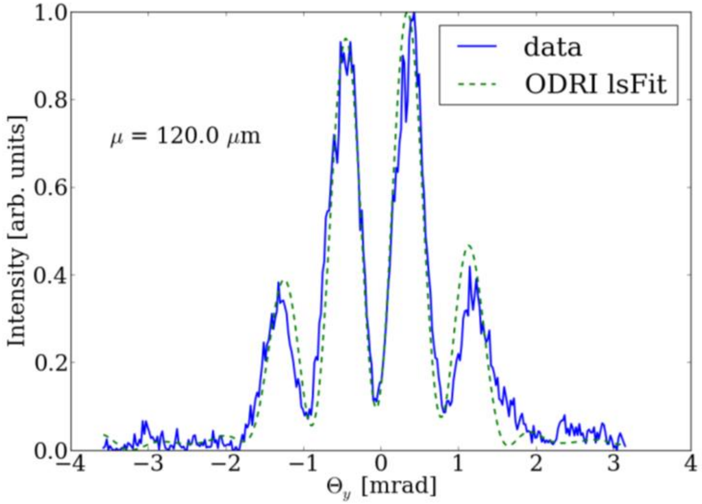
Difficult to measure smaller due to lifetime limitations if using smaller slit size

ZEMAX simulations ODR/ODRI



CESR measured beam parameters

ε_y [m]	σ_y(ODR) [um]	σ_y' (ODR) [urad]
3.96e-11	17.6	4.08



Particle Accelerator Components Metrology & Alignment to the Nanometer scale

PACMAN

- Metrology
- Survey & alignment
- Beam instrumentation
- Radio Frequency
- Nano-positioning
- Magnetic measurements

Propose a combined method of fiducialisation and initial alignment for the CLIC components to gain time & accuracy

Prove the feasibility of the high accuracy metrology & alignment tools developed by a validation bench

Extrapolate the tools & methods to other projects

PACMAN structure (WP)

Supervisory Board
CERN,
HEXAGON METROLOGY, ETALON, ELTOS, METROLAB, DMP, SIGMAPHI, NI
PISA univ., CRANFIELD, SANNIO univ., LAPP, ETHZ, IFIC, SYMME

Management team

WP0 Management
H. Mainaud Durand

WP5 Training
N. Catalan Lasheras

WP6 Diss & Outreach
M. Modena

WP1 Metrology & Alignment
H. Mainaud Durand

WP2 Magnetic Measurements
S. Russenschuck

WP3 Precision mech. & stabilization
M. Modena

WP4 Beam Instrumentation
M. Wendt

CTC-003 Quadrupole stability

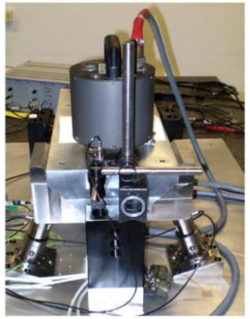
Task1: Stabilisation technologies

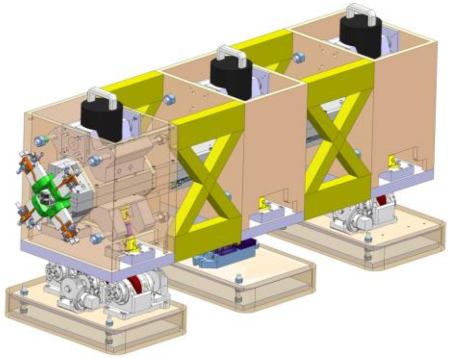
Actuators and sensors with sub nano metre resolution, use in accelerator environment, systematic studies of vibrations sources, Controller design

Task 2: Implementation MB Quadrupoles

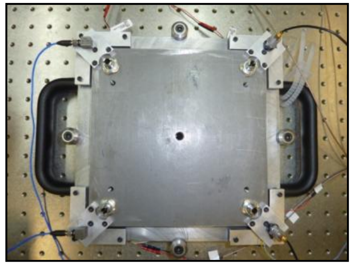
Task 3: Implementation FF quadrupoles

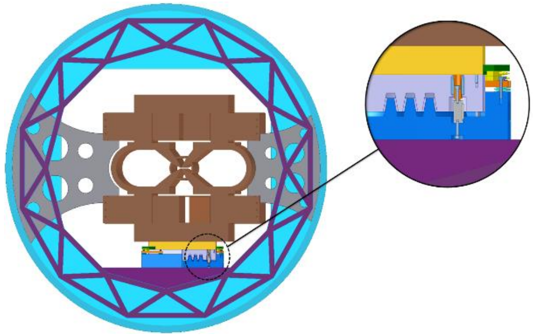
Task4 Integration, simulation, physics





Stabilised Type 4 Deliverable EUCARD	Stabilised MD0 proto Deliverable EUCARD
Type 1 and 4 Test modules/CLEX	Tests with beam Demonstration
Type 2 and Type 3 implementation	
Test with beam Demonstration	





Themes for continued R&D

- **<u>Increased performance</u>**: Sensor development and follow up industry, improved electronics, Interaction with BBF, stability and ratio increase RMS displacement
- **<u>COST reduction</u>**: Electronics, Number of actuators and sensors, x-y sensors, Assembly
- **<u>Compatibility components accelerator environment:</u>**
Sensor development, research + qualification
Test campaigns under radiation and magnetic fields
- **<u>Overall system analysis:</u>**, sensitivity to change of requirements, interaction with integrated luminosity simulations, characterisation components
Characterisation vibrations sources,
compliance of components, compatibility with alignment
- **<u>Pre-Industrialised, operational system:</u>**
Reliability, operation, failure analysis, remote distributed control system, series production

Outlook for 2018 – main messages (1/2)

- Beam instrumentation:
  Will meet defined objectives for most critical components (MB and DB BPM prototypes; fibre optics BLMs based on detection of Cherenkov light, long. profile monitor with ~10fs resolution, ODR transverse profile monitor.
  → Not really a good solution for sub-um profile measurements
  → almost no effort on cost mitigation (except BLM).
- Warm magnets prototypes:
  Will meet all defined objectives with good results (QD0 prototype). Possibility to "go green" with PM magnets (based on CERN-UK collaboration)
- Superconducting wiggler: Nb3Sn wiggler prototype performance is marginal and quench behaviour not fully understood (yet).
  → Will **NOT** have full size prototype of NbTi wiggler, but 30 cm short sample.
- Mechanical Prealignment Reference system: Have already a system working to specifications (based on stretched wire). System is complex and expensive.
  → R&D on Cost mitigation ongoing. Radiation hardness of components not fully established.
  → Still working on laser based alternative !
- Main Beam Quadrupole Stabilization. Effort has basically stopped. Principle demonstrated, but not on full scale prototypes. Electronics not radiation hard.
  → Not a satisfying situation.
- PACMAN: Program will conclude in 1.5 years.
  →Very little time to inject results into module design.

Outlook for 2018 – main messages (2/2)

- Vacuum: Vast program. Limited resources will only propose solutions for main beam vacuum system.
  →Damping rings and long transport lines will need to be addressed later.
- Fast pulsed kickers: Two major efforts:
  a) Damping rings extraction kickers: Will conclude with a prototype and tests in ALBA
  b) Drive beam extraction kickers (high rep-rate): Will not be done as prototype…but have a paper study by SLAC.
- Module R&D: future program will have two components:
  1) New design of MB and DB module ready for construction of prototype in 2019
  2) Contribution to CLIC cost model and feasibility study of industrial production and RF commissioning
  → details in presentation of Steffen
- Main dump design: Design of water dump refined, some simulation work on entrance window (beryllium) done.
  → needs to be taken up again after PIP
- Control system for main linac: Case study finished; will need a new approach to controls, i.e. all equipment from various groups controlled by same electronics (space and heat constraints; rad hard linked for this developed by BE_CO based on components of CERN-PH.)
- Modulators: →see presentation of Steffen
- Damping Ring RF system: Huge beam loading to be handled with tight specifications on resulting spread in longitudinal and transverse beam emittance.
  → Will have paper study for high bandwidth cavity system with specific LLRF and beam measurements at ALBA.

Summary

- The TD program has been downsized/re-scoped a few times: Only “MOSCOW-must” studies and developments are remaining.
- Program is matched to the defined objectives of the CLIC PIP write-up in the years 2018/2019.
- We will have good results in most cases, except:

1) main beam quadrupole stabilization: Program reduced too early to an insignificant effort due to resources limitations in the EN department. Two residual important things need to be demonstrated:
a) working prototype for a 400 kg heavy and 2m long load (type 4 quadrupole)
b) radiation hardness of local electronics (ultra low noise preamplifiers, sensors, actuators)

Can a new effort be relaunched in conjunction with a stabilization of the HL-LHC insertions?

2) fs timing system and equipment synchronization:

3) ??? cost effective alignment reference system???: (my hope: laser based)

4) Measurements and development of a model for space and time correlations of earth magnetic field. → (what if new initiative of Daniel fails?)