Progress of the technical studies

- CDR: Present layout and schedule
- Organization of Technical Work
  Creation of CTC (2008)
  → Working groups organization
  → prioritization/classification of work

  → Lots of examples

Basics of CDR

Vol1: Executive Summary: target 20 pages
Vol2: The CLIC accelerator and site facilities
Vol3: The CLIC physics and detectors (resp: PH-LCD team)

- 3 TeV option for CLIC as baseline for the optimization of the parameters.
- Construction staging starting from the lowest demanded energy (let us say 500 GeV) as indicated by LHC results up to the full 3 TeV machine.
- Parameter changes and optimization for the "500 GeV" machine plus additional consequences for later energy upgrades in a separate chapter

- Volume 2:
  - Detailed description of the CLIC specific important subjects
  - Description of the physics and beam dynamics of all machine components following the order in the CLIC PBS.
  - Technology chapters grouped together by disciplines.

Vol2: 1) CLIC specific important subjects

- CLIC layout, Parameter optimization in order to achieve high luminosity/energy
- Explanation of the CLIC 2-beam acceleration scheme
- Drive beam generation
- RF structures (accelerating and PETS)
- Creation and Emittance-Preservation of ultra low emittance beams
- Operational scenario (highest luminosity through various RT feedbacks and active stabilization, DB setup, MB setup, up-time, machine protection)

Vol2: 2) Main Beam CDR chapters

- Injectors
  e- source and linac
  e- polarization
  e+ source and linac
  options for polarized e+ beams
- Damping Rings
  Pre-damping Rings
  Damping Rings
  Bunch compressors #1
- Booster Linac
- Beam transport
  Transfer to tunnel
  Long Transfer Line
  Turnaround

  Bunch compressor #2
- Linac Accelerators
- Beam Delivery Systems
- Preservation of Polarization up to IP
- Machine Detector Interface
  Beam Induced Background
  Energy Spectrum
  Mask design
  push - pull implications
- Post-collision line
- Dumps

Vol 2: 3) Drive Beam CDR chapters

- Injectors overall requirements
  e- source
  Linacs
- Frequency multiplication
  Delay loops
  Combiner rings
- Beam transport
  Transfer to Tunnel
  Long Transfer Lines
  Turnaround and bunch compressor
- Decelerator Linac
- Dumps

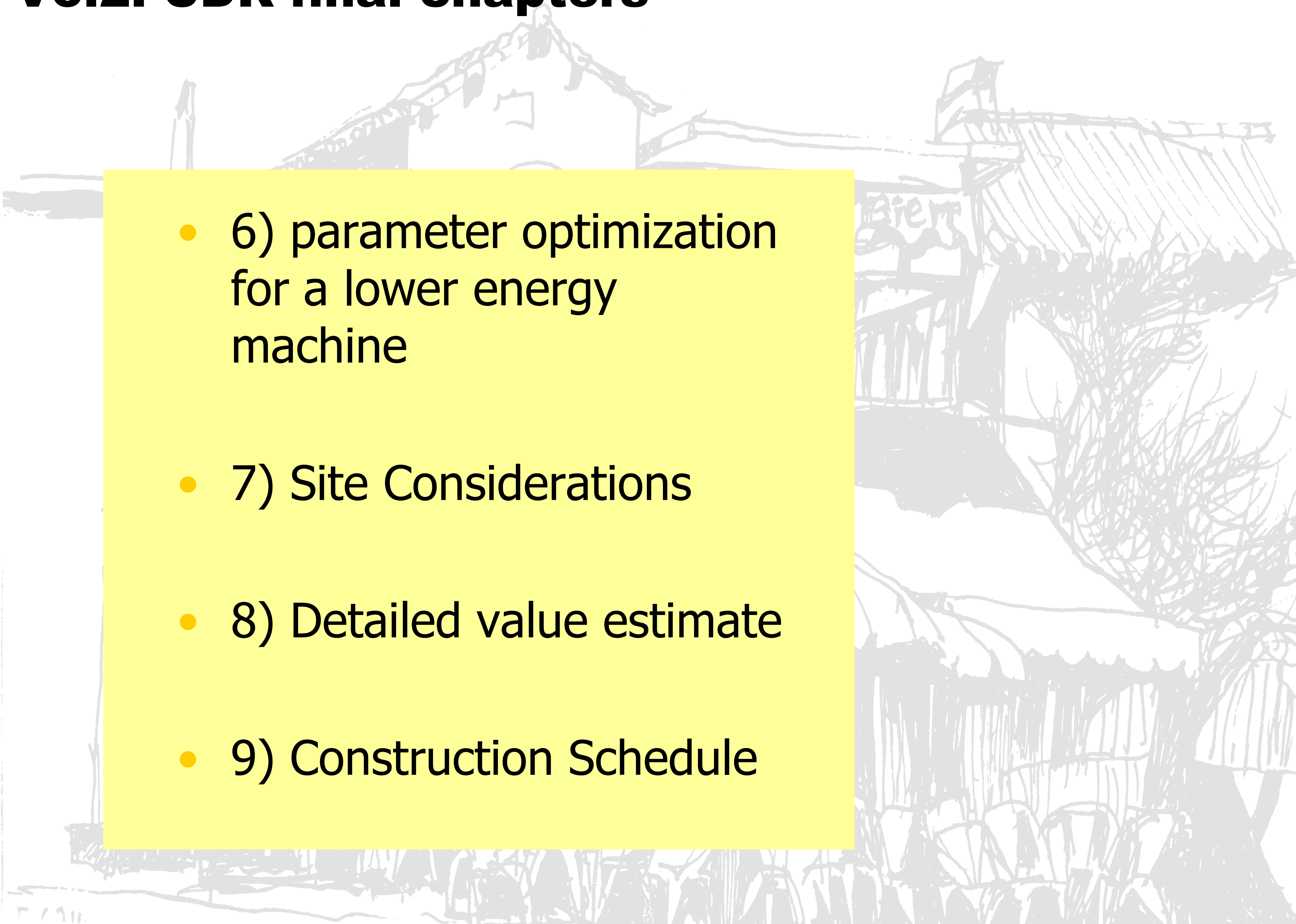
Vol 2: 4) CDR technology chapters

- e- source
- e+ source
- e+ polarization
- Magnet systems
- Vaccum Systems
- RF systems
  Accelerating Structures
  Decelerating Structures
  Two Beam Module
  Modulators
  Klystrons
  Low Level Rf systems
  Beam Synchronous Timing
  Wakefield Monitors
- Dumps, Collimators and Beam Stoppers
- Machine Protection
- Beam Instrumentation
- Beam Transport equipment
- RT feedback equipment
- Control System, general timing system
- Active mechanical pre-alignment
- Stabilization equipment
- Power Converters and DC network

Vol2: 5) CDR conventional facilities chapters

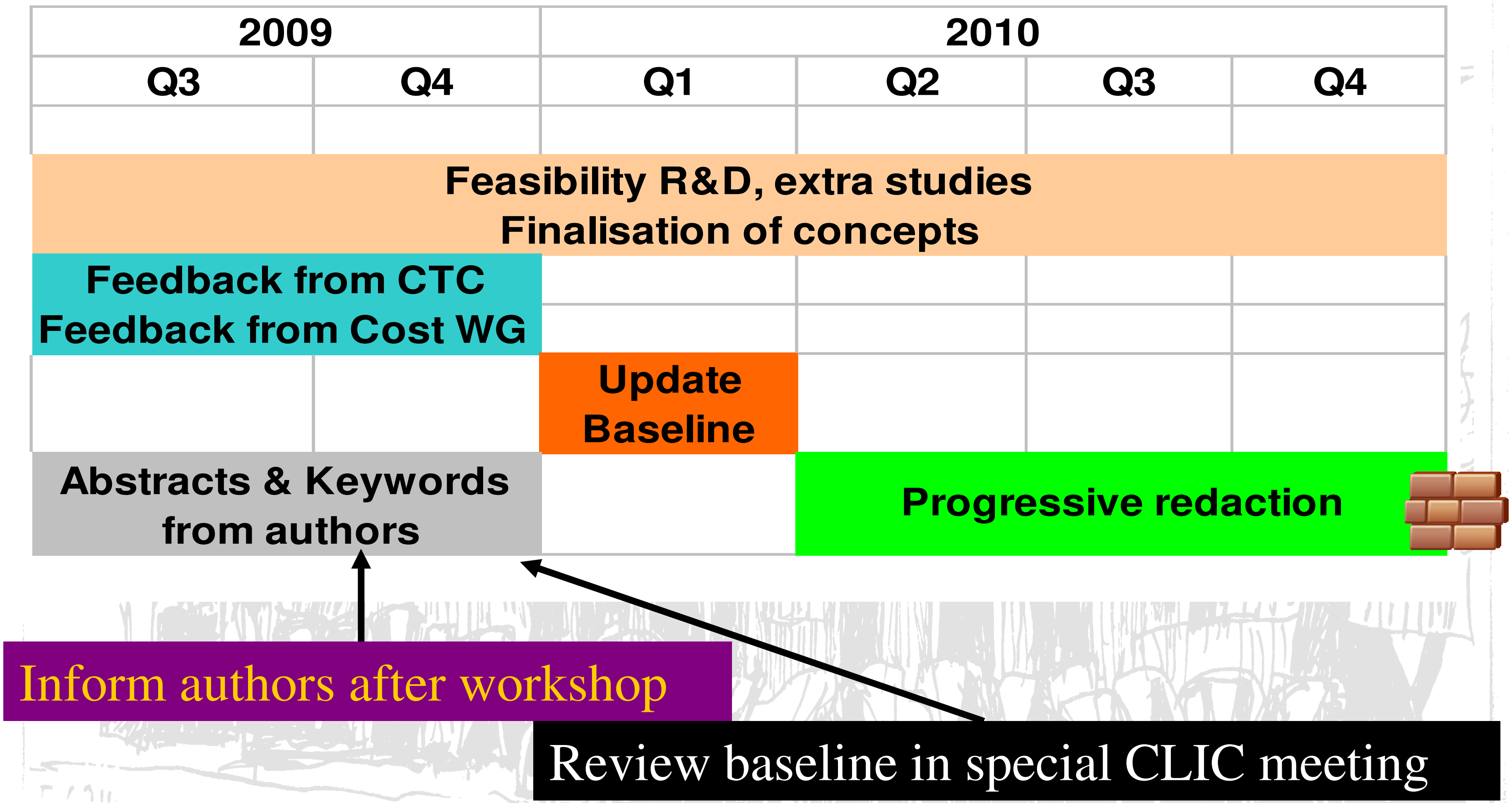
- Civil Engineering
  - Underground Facilities
  - Tunnel Cross-Section
  - Surface Structures
  - Site Development
- Electricity
- Access Control Systems and rel. communications
- Cooling and Ventilation
  - Water cooling
  - Ventilation
  - Gas
- Cryogenics
- Handling
  - Horizontal
  - Vertical
- Safety
  - Radiation Safety
  - Fire Safety
- Survey
  - Geodesy and Networks
- Machine Installation

Vol2: CDR final chapters



- 6) parameter optimization for a lower energy machine
- 7) Site Considerations
- 8) Detailed value estimate
- 9) Construction Schedule

CDR schedule



CDR team (for volume 2: CLIC accelerators)

- Not yet organized
  (probably in complete ignorance of the effort needed)
- 2 people part time "volunteered" for editorial help
- CDR will be based on articles (4 … 10 pages) to be written by members of the collaboration.
  A preliminary list of authors exists, will be distributed/negotiated shortly after this workshop.
- 2 sample contributions exist (one more than last year!)
  → did not invest time yet to streamline them.

→ The main focus of the past year was to organize the technical work for the individual chapters.

CDR technical preparation

- Project wide:
  Spring 2009: Classification of technical items into:
  - feasibility items
  - performance items
  - cost items
- For feasibility items:
  - justification of choice
  - detailed R&D plan, resource estimate
  - feasibility demonstration benchmarks
  → endorsed in ACE meeting in June 2009
- Other items:
  treated in corresponding working teams:
  - Beam Dynamics WG, CTF3, Rf Structures WG
  + CTC and the associated WGs and activities

CTC Working Groups/activities

- Civil Engineering and Services
- Two Beam Module integration
- Machine Detector Interface
- Machine Protection & Operation
- Stabilization of machine Components
- Pre-alignment
- Instrumentation
- Beam Based feedbacks
- Various studies on accelerator technologies

- ***Work for 3 "feasibility items" is followed by the CTC:***
  ★*- Active nm-level stabilization*
  ★*- CLIC machine protection*
  - MB and DB phase synchronism
- ***Work on preparing and documenting the hardware baseline**:*
  examples:
  - CLIC PBS in EDMS
  ★*- tunnel cross section, CLIC cooling and ventilation*
  - 2 beam module design, hardware integration, module instrumentation
  → *G.Riddone talk this afternoon*
  - technical choices for active pre-alignment system → *also in talk of G.Riddone*
  - beam based feedback systems
  - MDI, choice of FF magnet technology, sub nm-stability
  → *L.Gatignon talk this morning*
  → *A.Jeremie talk just after this one*
  - dump lines and their instrumentation
  ★*- beam instrumentation*
- ***Launching of individual technical studies/optimizations in preparation of the TDR phase:***
  ★*- choice of individual DB klystron power*
  ★*- DR extraction kicker specs and technical solutions*
- ***Cost optimization:***
  ★*- Reduction in number of BPMs in drive beam*

→ *all activities treated in detail in WG5 (and partly in the other WGs)*

Stabilisation Working Group
3rd report to CTC

C. Hauviller/ EN

CLIC stabilization requirements

- Mechanical stabilization requirements:
  Quadrupole magnetic axis vibration tolerances:

	Final Focus quadrupoles	Main beam quadrupoles
Vertical	0.1 nm > 4 Hz	1 nm > 1 Hz
Horizontal	5 nm > 4 Hz	5 nm > 1 Hz

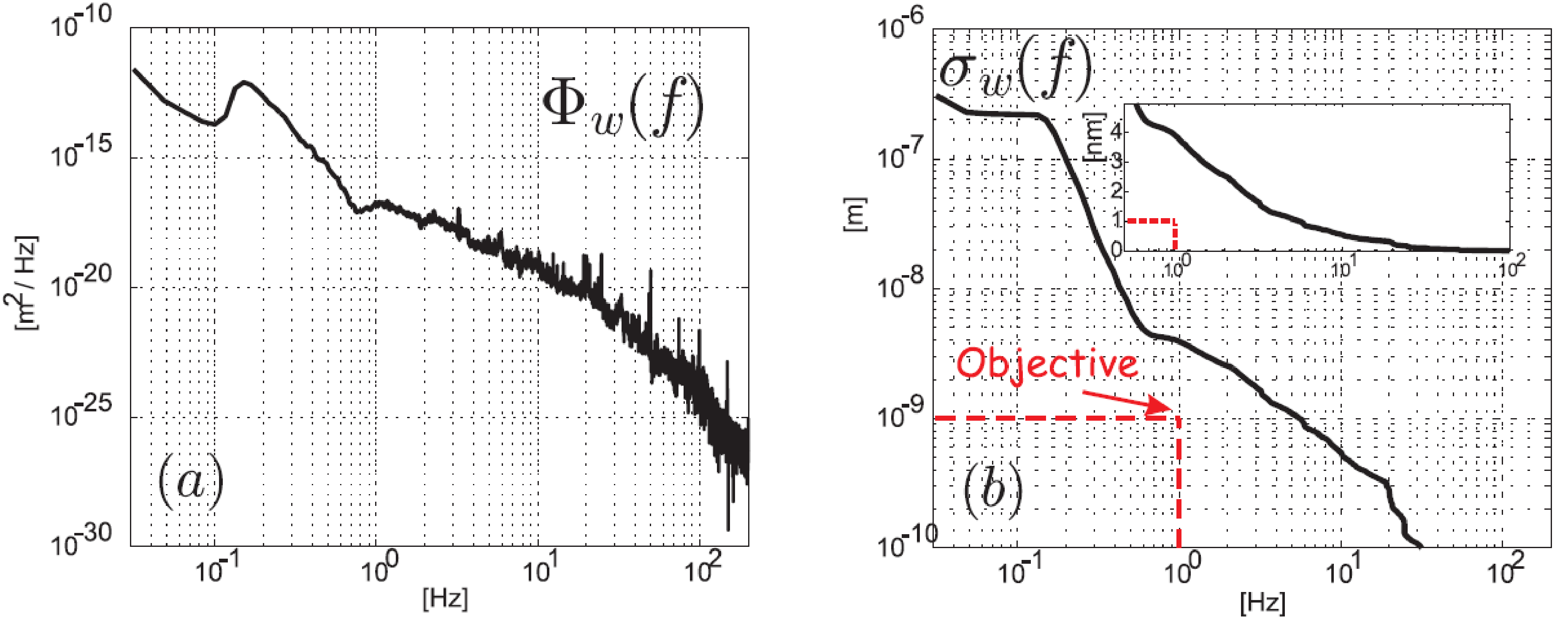
- Main beam quadrupoles to be mechanically stabilized:
  - A total of about 4000 main beam quadrupoles
  - 4 types
  - Magnetic length from 350 mm to 1850 mm
  - Weight from 100 to 400 Kg

Organization of the Stabilization Working Group

- Collaboration: Laboratories participating (to-date):
  - LaViSta (LAPP, Universite de Savoie-SYMME)
  - CERN (EN, TE, BE)
  - JAI- Oxford University
  - CEA-DSM-IRFU-SIS
  - PSI
  - Information from DESY, SLAC,...
  - Contacts with universities
- Extra financing through FP7

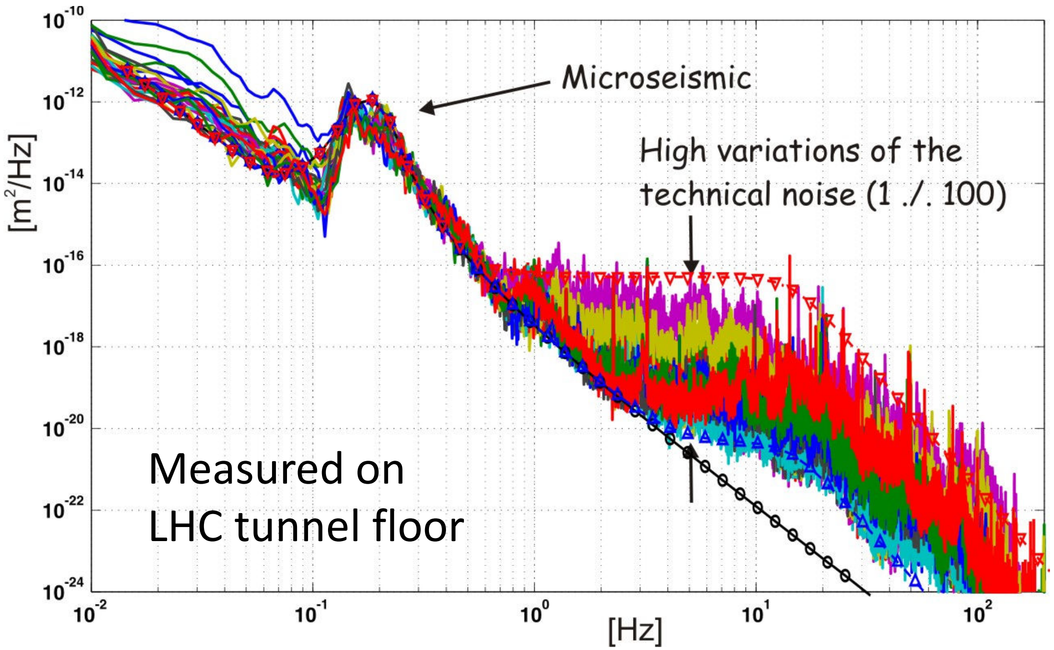
MONALISA IRFU/SIS

Typical ground motion



$$\sigma_x(1) = \sqrt{\int_1^\infty \Phi_x(f)\,df}$$

Mechanical vibration sources



C. Collette, M. Guinchard

Ground motion

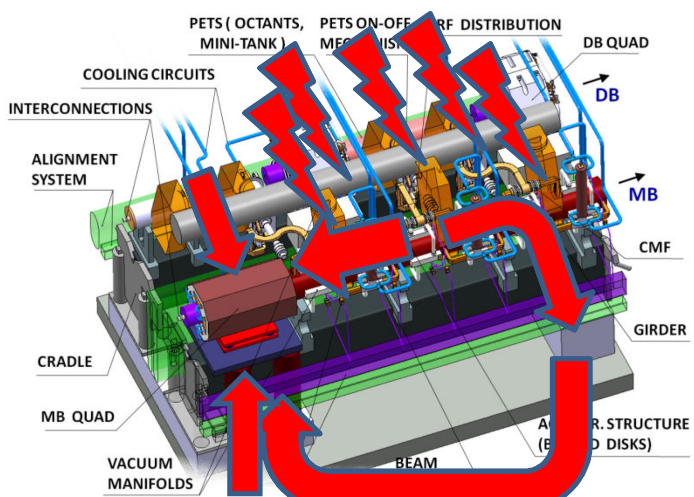
Wind (near surface)

Traffic: trains, trucks, cars

Lifts

Technical noise: cooling water, ventilation, pumps, machinery, electromagnetic induced, ...

Acoustic pressure (above 50 Hz)



Vibrations
Forces

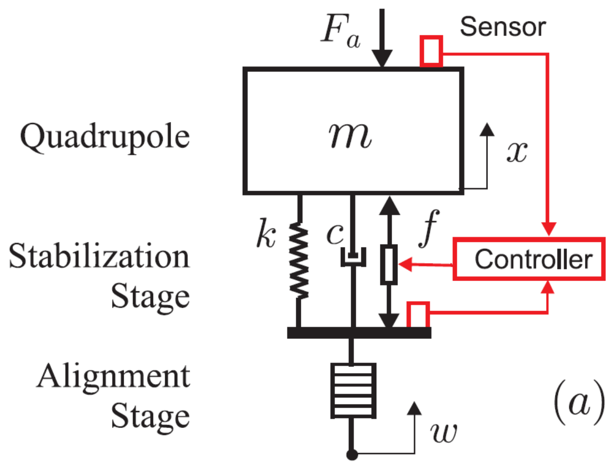
.Schmickler, CLIC workshop09

Transmitted from the ground **through the magnet support**

Transmitted **directly to the magnet** via **beam pipe interconnections, cooling pipes, wind, cables, sound**,...

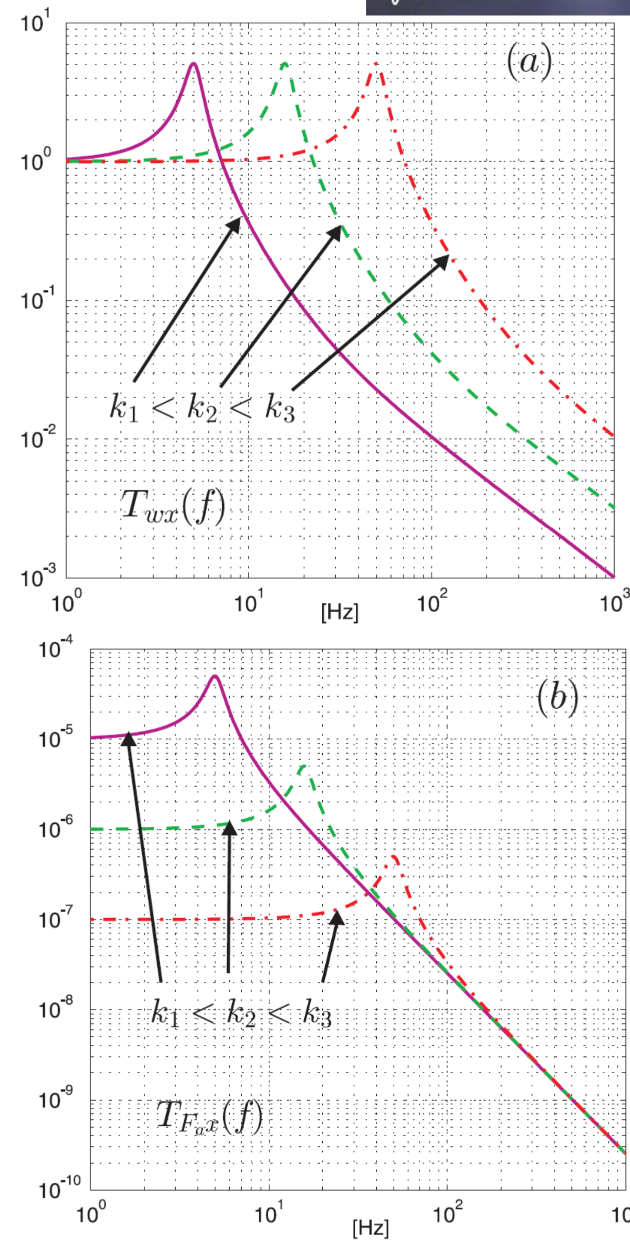
Stabilisation: 2 options

1. Rigid (active)
2. Soft (passive damping)



A soft support improves the isolation but makes the quadrupole more sensitive to external forces Fa

C. Collette

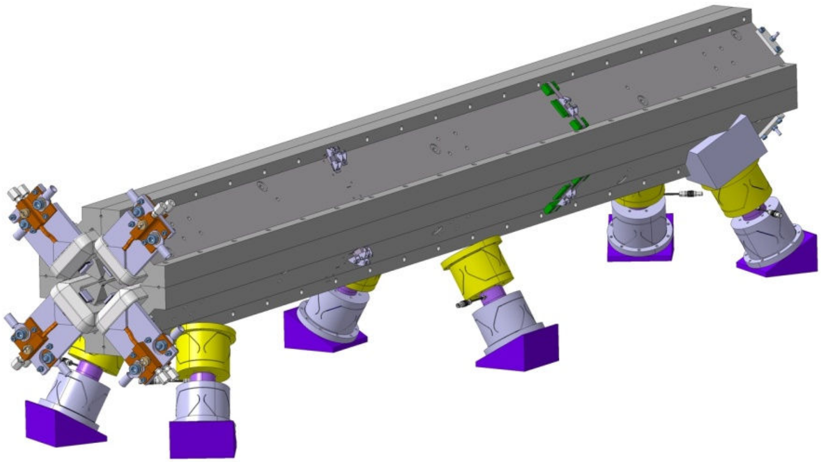


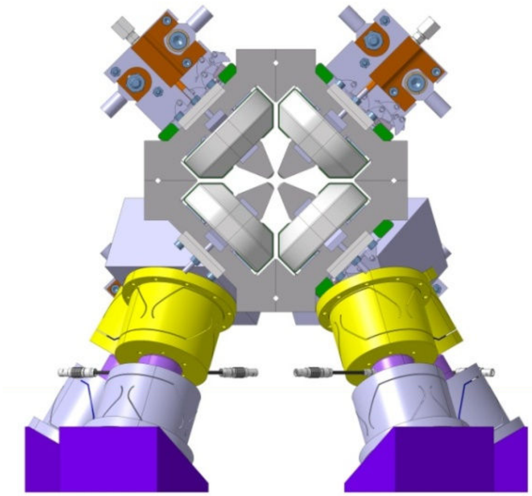
H.Schmickler, CLIC workshop09

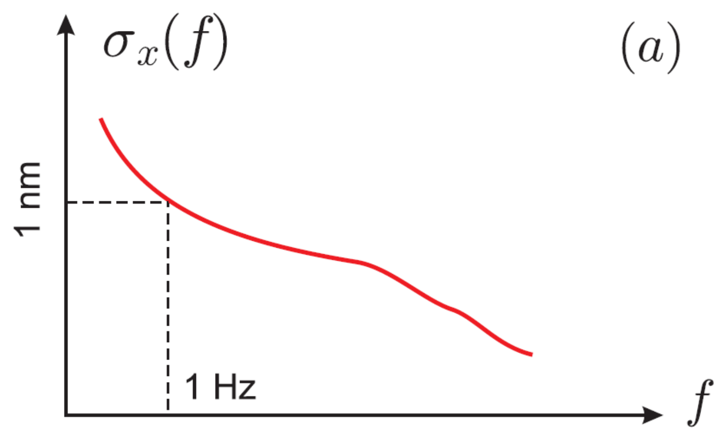
Stabilisation: 2 options

1. CERN option: Rigid

Active stabilisation

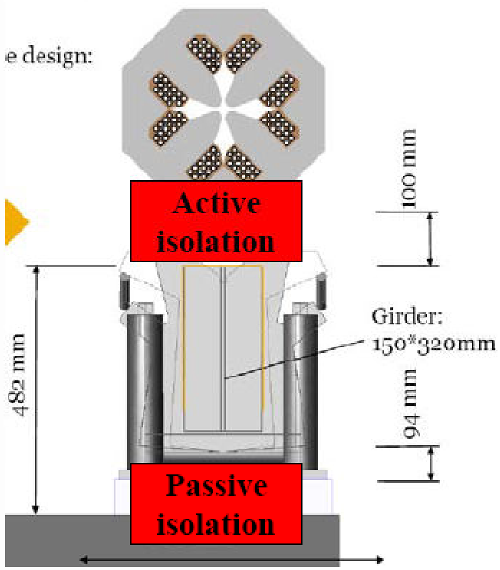


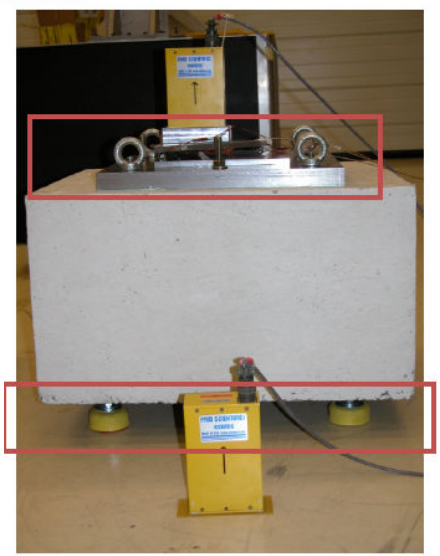


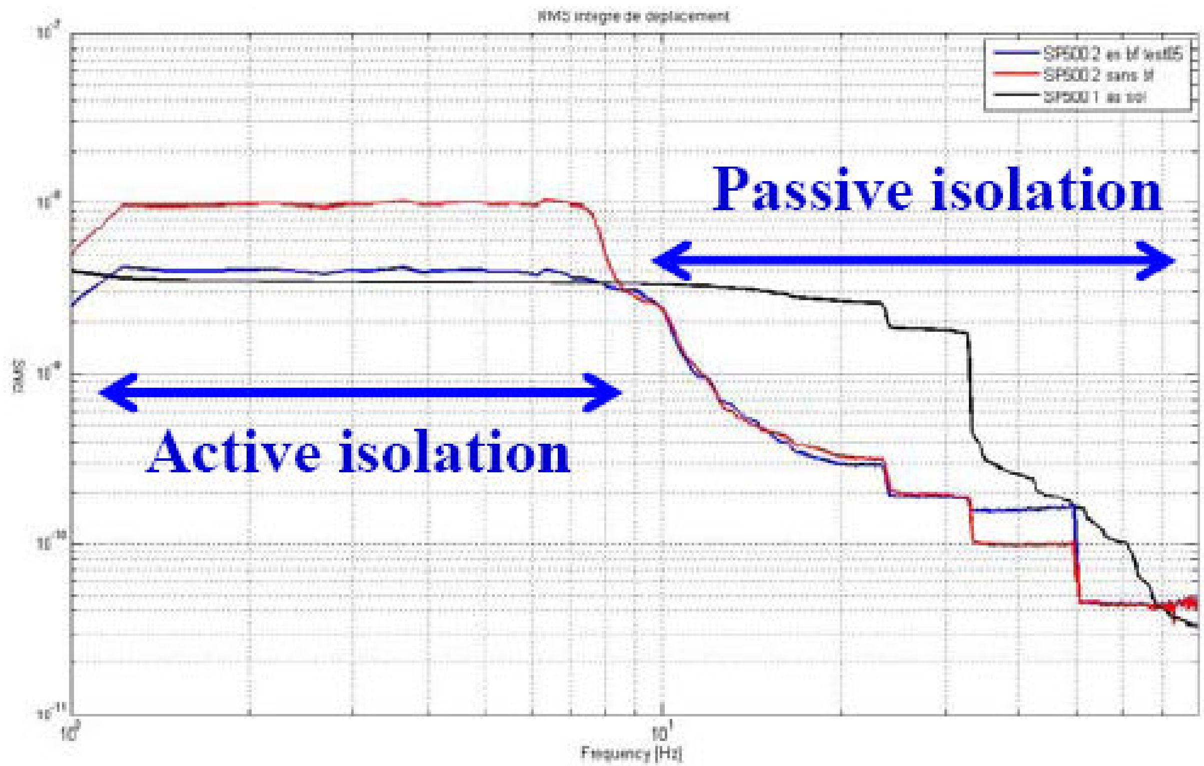


Stabilisation: 2 options

2. Lavista option: Soft support







A.Jeremie, L.Brunetti, G. Deleglise

Foreseen: stronger actuators for higher loads

Conclusion

MONALISA IRFU/SIS

The Stabilization Working Group is up and running.

Actions plan is in place.

A pragmatic approach with a deadline in 2010:
a full scale demonstrator with an MB quadrupole built and qualified.

Input to the FF: measurements, methodology and techniques
Extension of the existing mock-up

Machine Protection and Operational Aspects.

what can be done before the CDR in 2010

M.Jonker ACE 2009 05 27

Beams and beam power

CLIC drive beam (2.4 GeV)	**bunch**	**train**	**pulse**	**second**
Bunches	1	2922	7 0128	3 506 400
Charge [nC]	8.4	**24 544**	58 9075	29 453 760
Time [ns]	0.083	244	140 300	1 s
Current [A]	100	100	4.20	0.029
Beam Energy [kJ]	0.020	**59**	1 413	70 689

CLIC main beam	**bunch**	**pulse**	**second**
Bunches	1	312	15600
Charge [nC]	0.60	**186**	9285
Time [ns]	0.5	156	1 s
Current [A]	1.2	1.2	9.3 10^{-6}
Beam Energy @2.8 GeV [kJ]	0.0014	0.45	22.3
Beam Energy @9 GeV [kJ]	0.0053	1.69	83.6
Beam Energy @1.5 TeV [kJ]	0.89	**278**	13927

LEP (100 GeV)	**bunch**	**beam**	**total**
Bunches	1	8	16
Current [μA]	600	5000	10000
Charge [nC]	53.4	**445**	890
Beam Energy [KJ]	5.4	**45**	90

Type of failures

- Failures causing slow onset of losses
  - Magnet system
  - Vacuum system
  - Slow drifts (alignment, temperature, …)
- Failures causing fast losses
  - RF breakdown
  - Kicker misfiring
  - Klystron trips

Protection against slow losses

Avoid slow losses by choosing magnet current circuits with a large time constant:

- A power converter commit to stay within an acceptable tolerance for 2 ms after failure.
- We have time to abort the next pulse in case of failures of a magnet power converter.

If so, magnet failures should not be a major issue

  – But we still have to evaluate the required reliability (SIL level) for the interlock system.

Similar: A 2 ms closure-inhibit time window for fast sector valves of the vacuum system. (Closure speed ~1 mm / ms)

Protection against fast losses

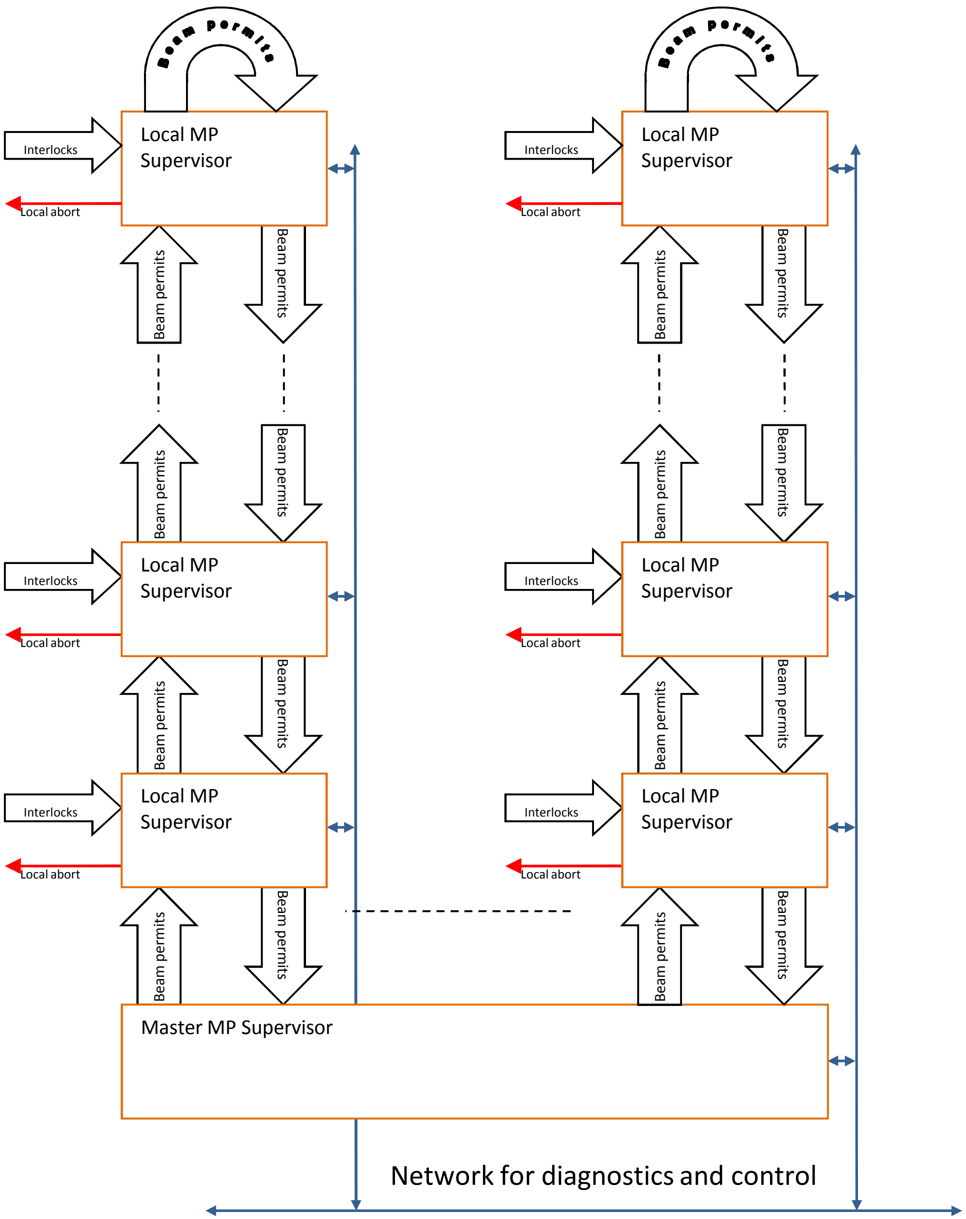
CLIC is essentially a continuous beam line.

- Fast loss detection and fast dump may catch the tail of the pulse.
- For the head of the pulse, we must rely on passive protection.

Can the passive protection also be robust enough such that we do not need a fast dump?

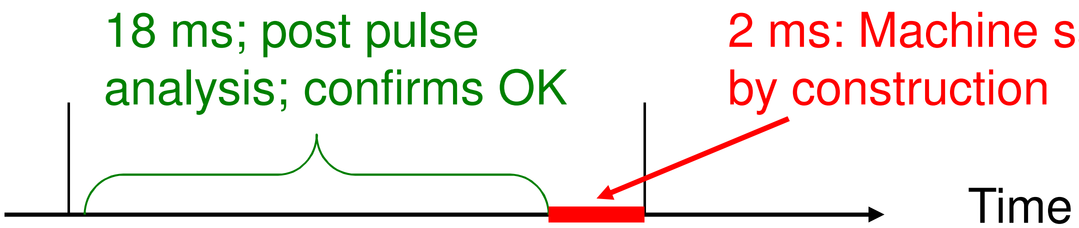
Many studies for collimation system already along these lines.

hw architecture of MP logic



- A central MP supervisor controls 4 parallel Beam-Permit-Chains (BPC) for the two drive and two main beams.
- Each Beam permit chain carries the beam permits for different beam types (pilot, tests, nominal).
- A Beam-Permit-Chain contains n local nodes with user permit inputs that can inhibit the beam permit chain (in both directions).
- In case the beam permit chain is interrupted, the local node will also provide signals that can be used by local beam and equipment abort systems.

Next pulse permit:



The next pulse is only allowed in the presence of the next pulse permit. This pulse permit is delivered if:

- a successful pulse have been delivered previously, (confirmed by post pulse analysis of previous pulse)
- no slow equipment failure (power converter, vacuum, trips) was detected up to 2 ms before next pulse.

In case of absence of the next pulse permit:

successive test beams of lower intensity, and emmittance will have to used to re-establish the readiness of the machine.

(i.e. the permit system is also aware of the beam type)

=> Establishment of operational procedures

For CDR in 2010

- Full inventory of failure modes (slow onsets, fast RT) with
  - estimate incidence rate
  - simulated impact on the accelerator structures and damage incurred by these faults (financial, operational).

    => Frequency x Impact = RISK
  - protection strategies must limit the incidence rate and/or damage to a level where the reduced risk is acceptable (i.e. a few percent of operational time & budget).
  - (effect of combined failure modes
- Detailed requirements for passive machine protection
- Evaluation of the requirements for beam observation systems to detect the onset of instabilities in drive and the main beam (i.e. beam loss, beam intensity loss, position and emittance).
- Provide a list of test beams and establish the procedure to reach nominal CLIC operation starting from a “cold” machine, based on successive beams of increasing intensity and brilliance.

For CDR in 2010 (cont)

- Required tolerance for all magnet circuits for safe operation with nominal beams.
- Proof of feasibility for magnet power circuits with guaranteed tolerance for 2 ms after the onset of failure.
- Evaluation of radiation levels for electronics in the tunnel
- Evaluate the unavailability of the machine for nominal operation due to various interlock conditions and equipment failures.

- ***Work for 3 "feasibility items" is followed by the CTC:***
  ★ *- Active nm-level stabilization*
  ★ *- CLIC machine protection*
  - MB and DB phase synchronism
- ***Work on preparing and documenting the hardware baseline****: examples:*
  - CLIC PBS in EDMS
  ★ *- tunnel cross section, CLIC cooling and ventilation*
  - 2 beam module design, hardware integration, module instrumentation
  → G.Riddone talk this afternoon
  - technical choices for active pre-alignment system
  - beam based feedback systems
  - MDI, choice of FF magnet technology, sub nm-stability
  → L.Gatignon talk this morning
  → A.Jeremie talk just after this one
  - dump lines and their instrumentation
  ★ *- beam instrumentation*
- ***Launching of individual technical studies/optimizations in preparation of the TDR phase:***
  ★ *- choice of individual DB klystron power*
  ★ *- DR extraction kicker specs and technical solutions*
- ***Cost optimization:***
  ★ *- Reduction in number of BPMs in drive beam*

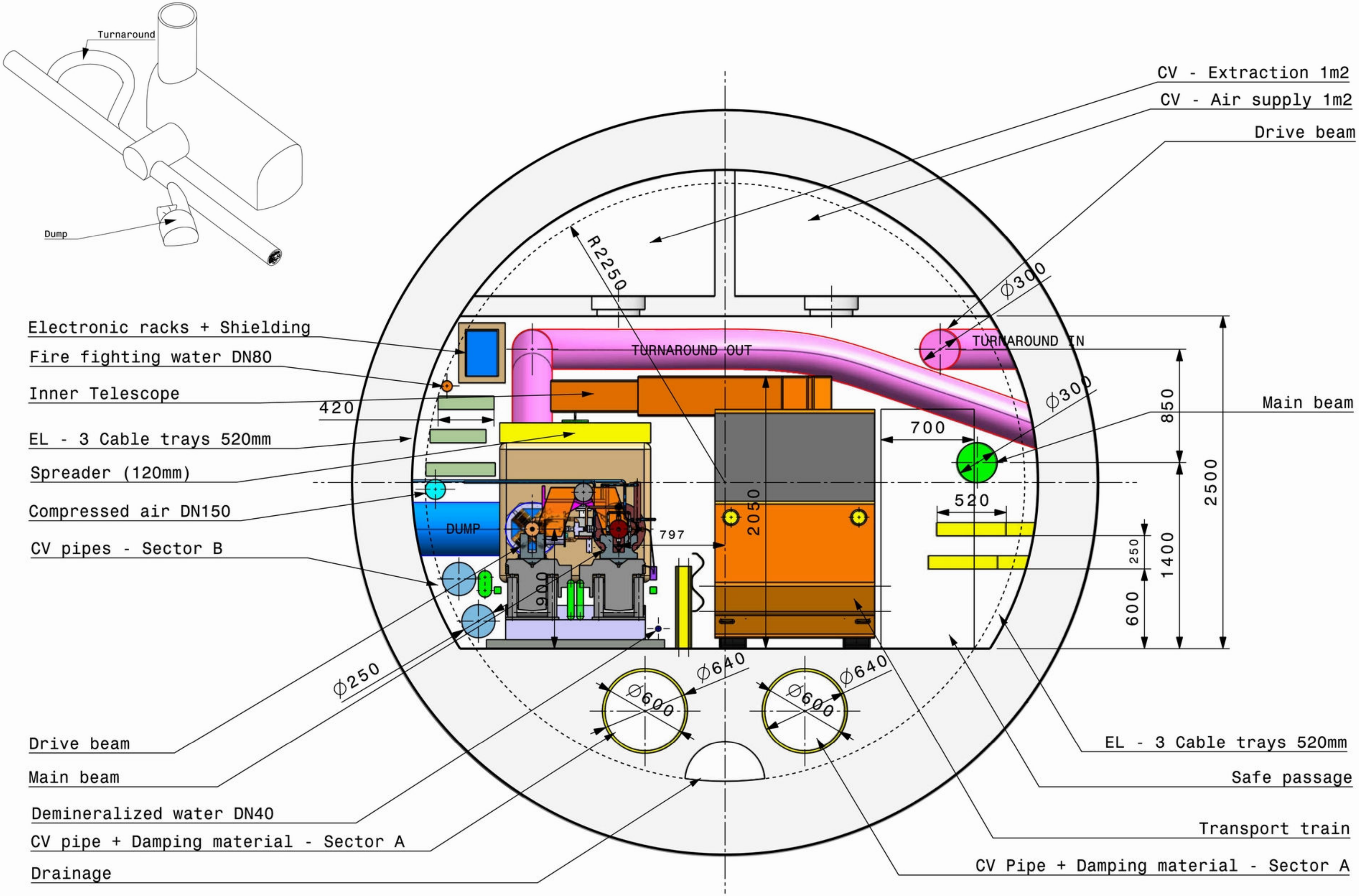
→ all activities treated in detail in WG5 (and partly in the other WGs)

CLIC

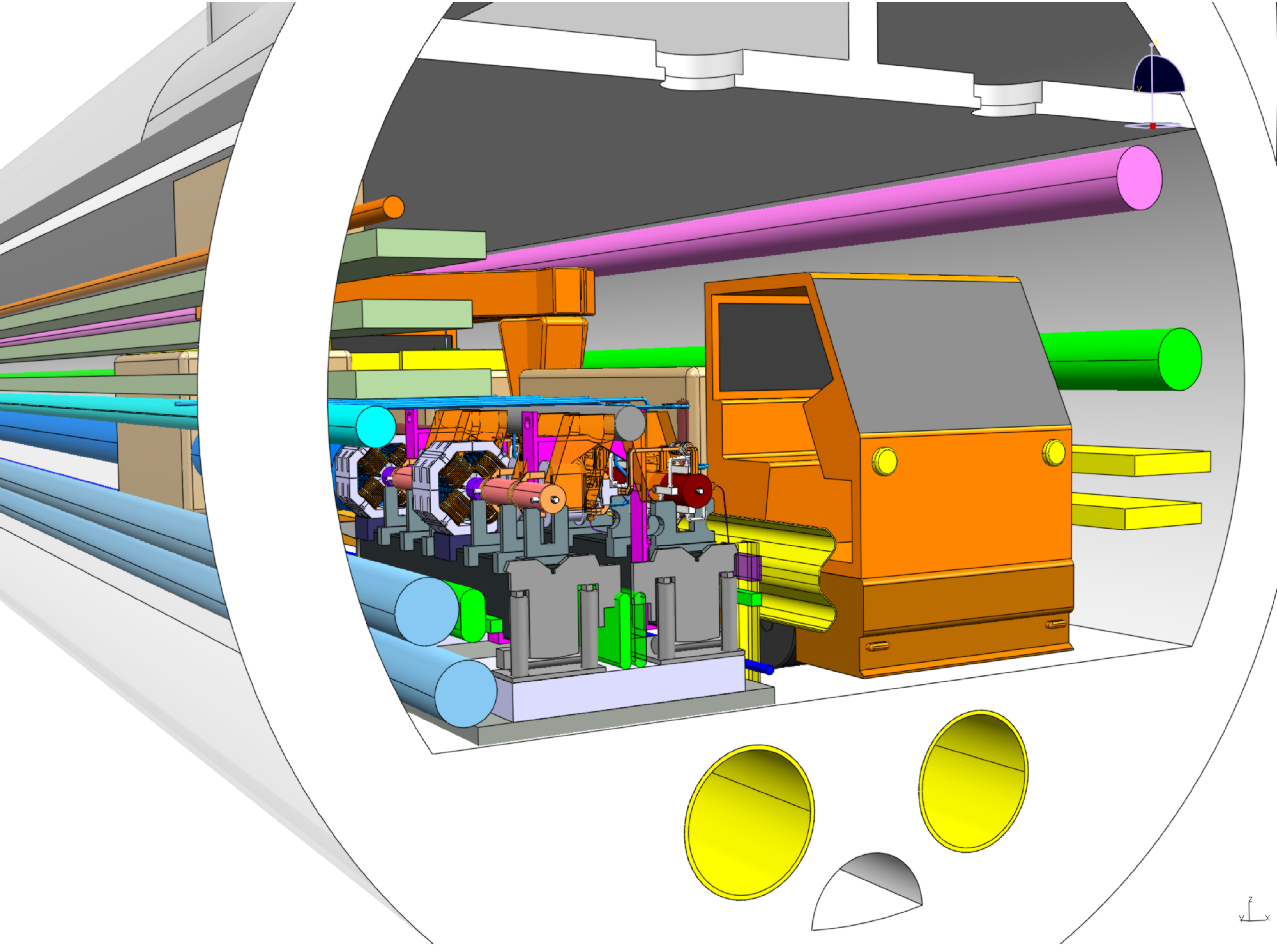
3D STUDIES for the

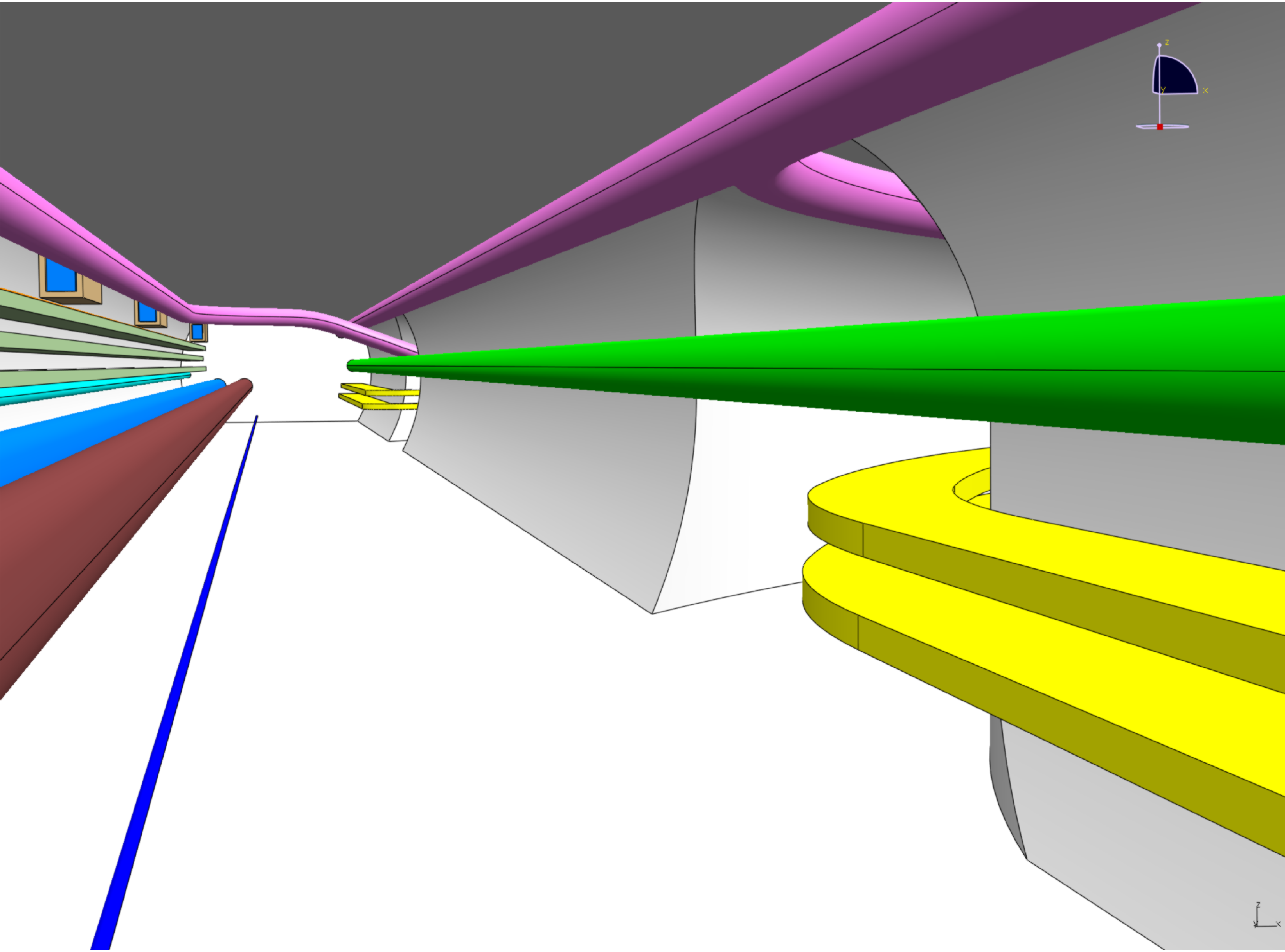
TURNAROUND AREA

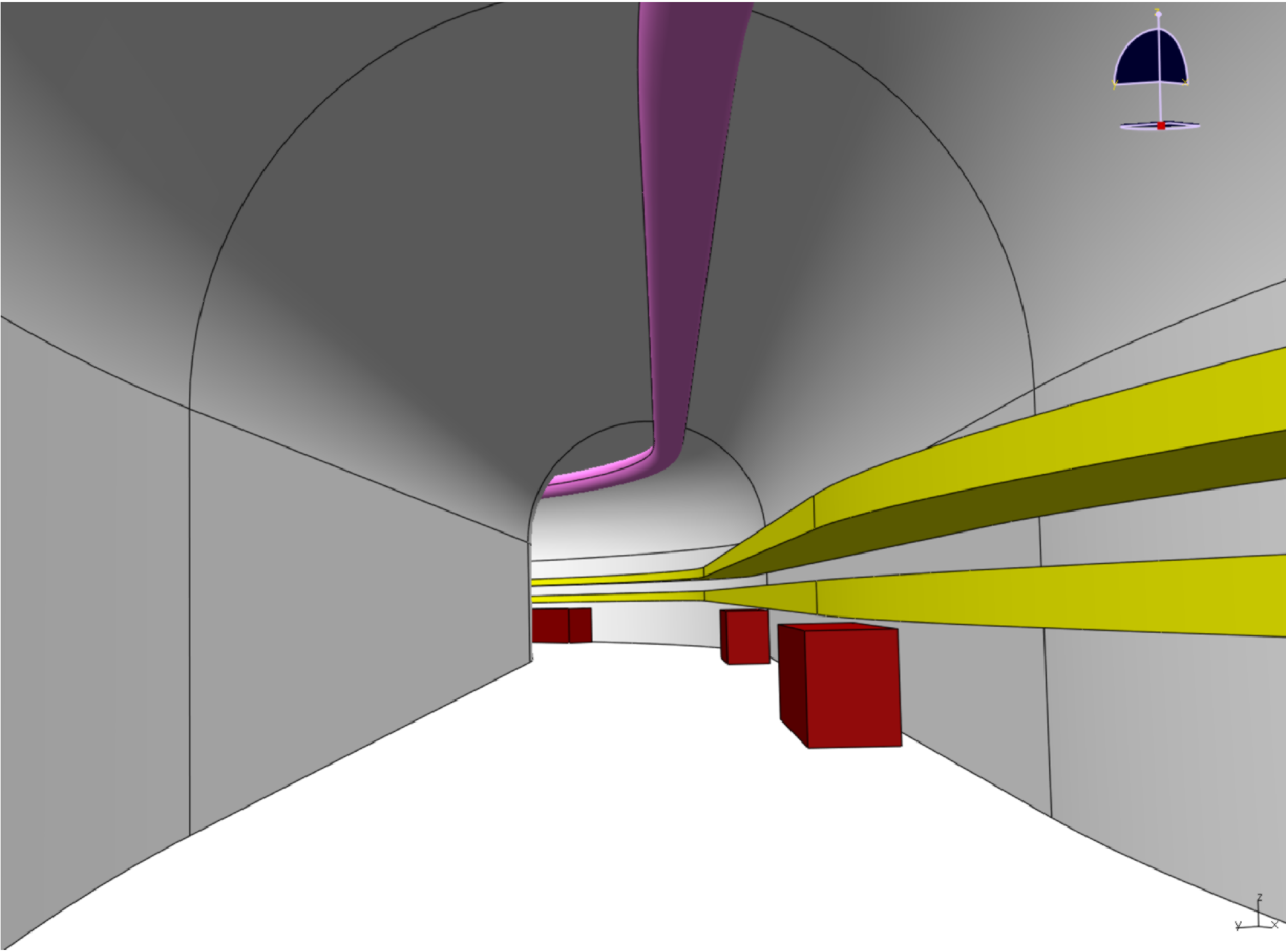
2009 October 9th
John Osborne / A.Kosmicki

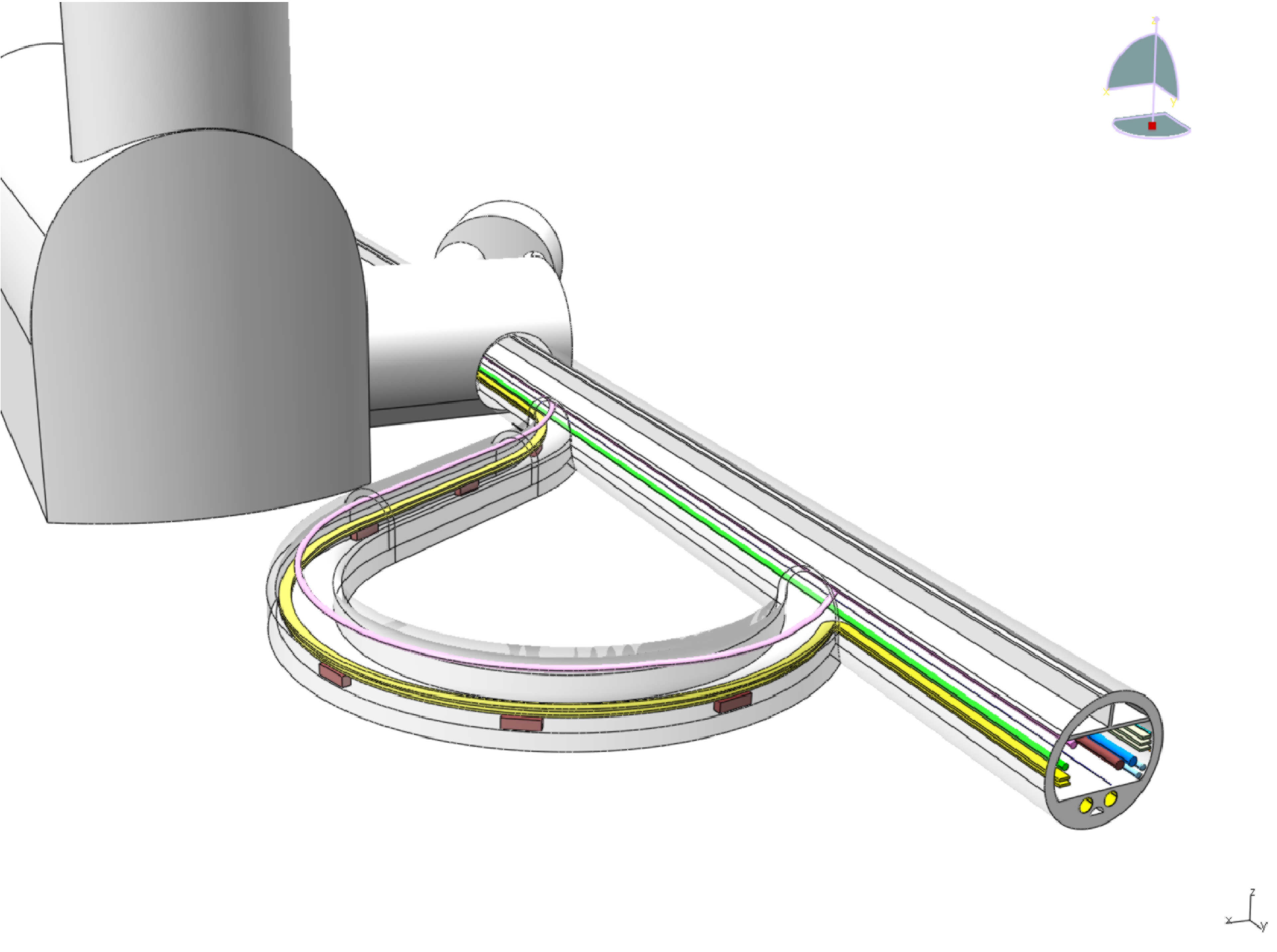


CLIC - Typical Cross Section - Diameter 4500mm - Junction with Turnaround - 1:25
Draft - J.Osborne / A.Kosmicki -October 12th 2009









- ***Work for 3 "feasibility items" is followed by the CTC:***
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  - *- CLIC PBS in EDMS*
  - ★- *tunnel cross section, CLIC cooling and ventilation*
  - *- 2 beam module design, hardware integration, module instrumentation*
  - *→ G.Riddone talk this afternoon*
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  - *- dump lines and their instrumentation*
  - ★- *beam instrumentation*
- ***Launching of individual technical studies/optimizations in preparation of the TDR phase:***
  - ★- *choice of individual DB klystron power*
  - ★- *DR extraction kicker specs and technical solutions*
- ***Cost optimization:***
  - ★- *Reduction in number of BPMs in drive beam*

→ all activities treated in detail in WG5 (and partly in the other WGs)

Summary of CLIC BI workshop

T. Lefevre et al.

1- Collect the beam instrumentation requirements for each CLIC sub-systems and identify Critical Items and the need for new R&D

2- Evaluate the performance of already-existing technologies

- **CLIC specific instruments**
  - Luminosity monitors
  - Beam loss monitor / MPS

- **CTF3 beam diagnostics – importable to CLIC**

- **ILC instruments with similar requirements as for CLIC**
  - Laser Wire Scanner or Cavity BPM
  - Beam Delivery System instrumentation
    Ex: Polarization monitor, Beam Energy measurements
  - Damping ring instrumentation developed at ATF2

- **3rd and 4th generation light sources**
  - Damping ring instrumentation
  - Bunch Compressor instrumentation very similar to XFEL projects
  - Short bunch length and Timing synchronization

CLIC 3TeV – Number of devices

Instrument	N° Devices
Intensity	316
Position	**45242**
Beam Size	**902**
Energy	216
Energy Spread	27
Bunch Length	212
Beam Loss/Halo	0
Beam Phase	240

Drive Beam

47155 devices

No Beam Loss Monitors specified yet

Instrument	N° Devices
Intensity	311
Position	**7579**
Beam Size / Emittance	143
Energy	75
Energy Spread	23
Bunch Length	26
Beam Loss/Halo	4
Beam Polarization	23
Tune	8
Beam Phase	96
Luminosity	4
Wakefield monitor	**2 *142812**

Main Beam

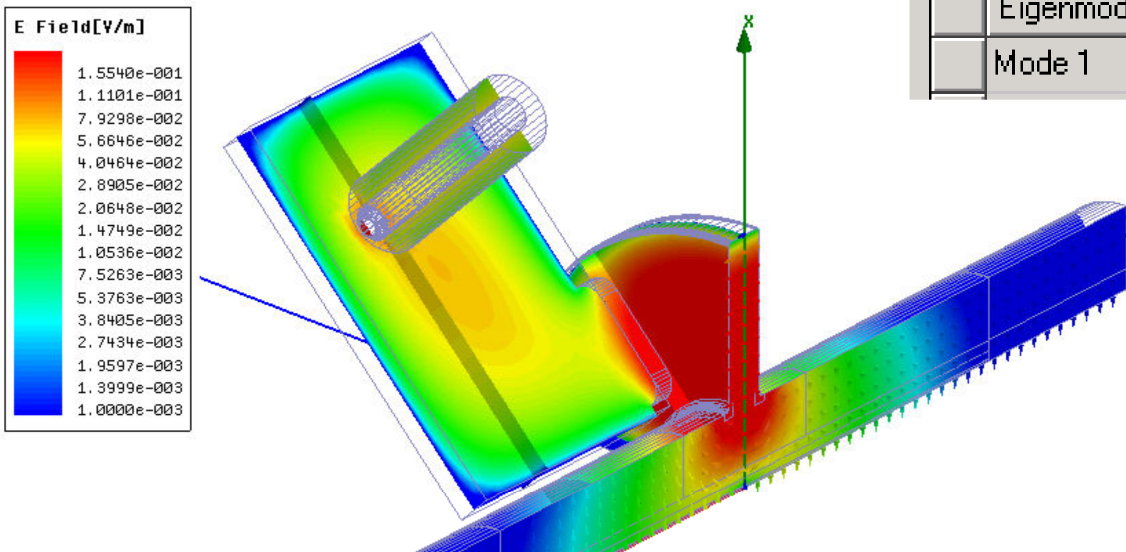
8292 devices

+ 2*142812 wakefield monitors

Beam Position Measurements with a 50nm resolution and adequate time resolution (approx. 4000 units)

Cavity BPM @ FERMILAB

Mode TM_{11}



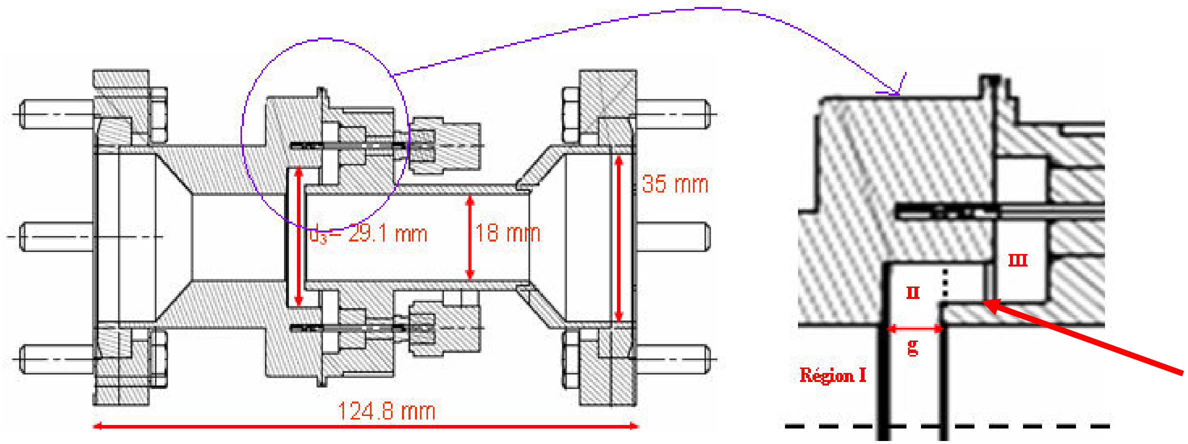
Eigenmode	Frequency (GHz)	Q
Mode 1	13.9855 +j 0.0314875	222.081

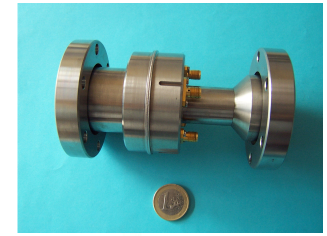
- Work in progress - Design finalized by November 2009 – Prototype 2010

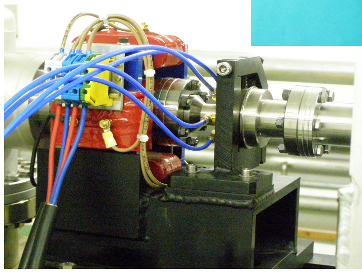
Design of Low-Q low cost cavity BPM (stainless steel)

Reentrant Cavity BPM at CTF3/CALIFES

6 BPMs are installed on the CTF3 probe beam





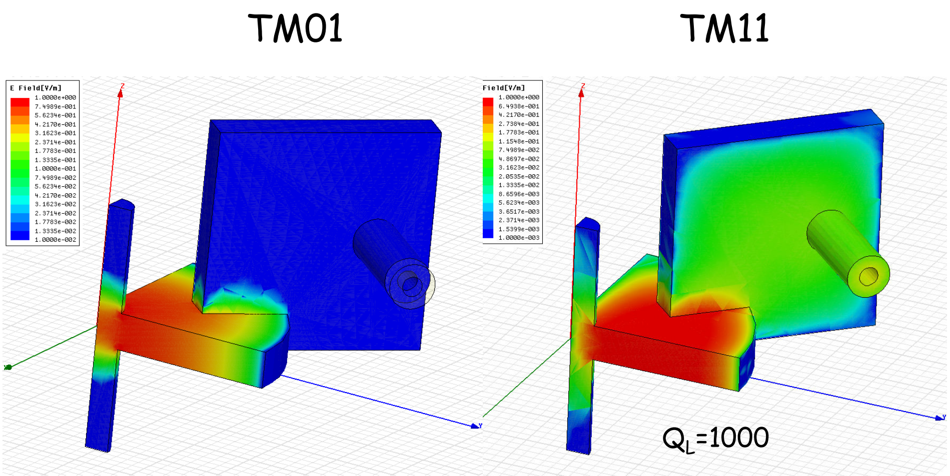


- Design for CLIC parameters and frequency

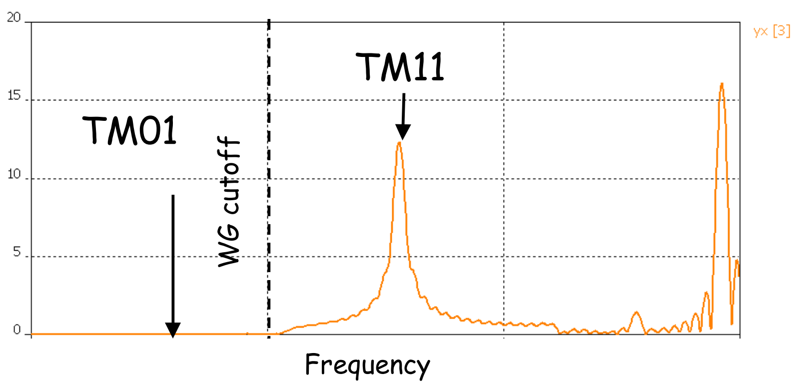
Eigen modes	F (MHz)			
	Measured			d
Monopole mode	3988	29.76	22.3	22.3
Dipole mode	5983	50.21	1.1	7

- nch and multi-
nodes
- Single bunch resolution potential < 1 µm

'yet another high resolution BPM'

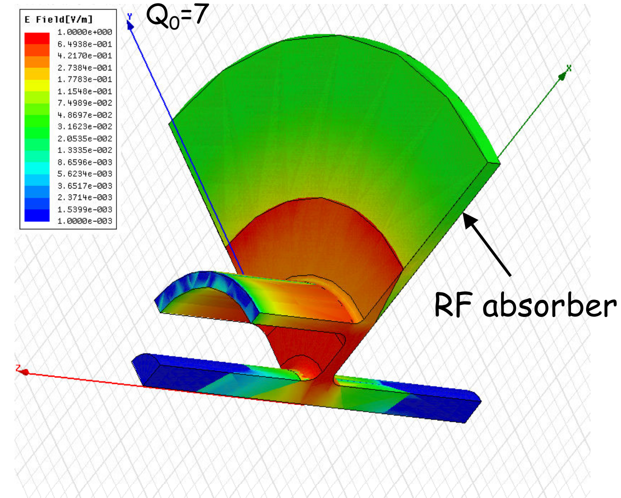


Spectrum of the port signal (single bunch)

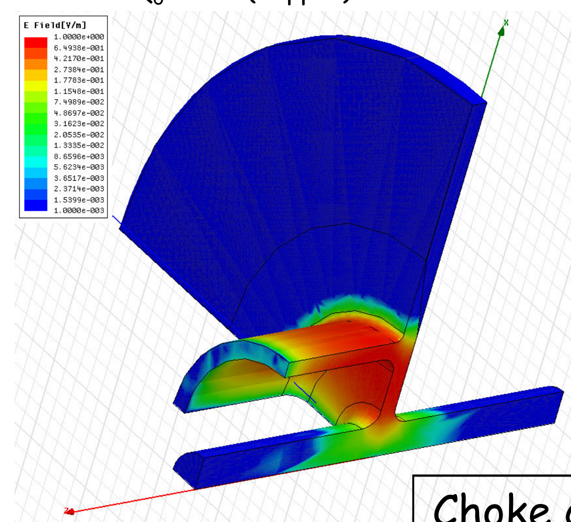


Slotted cavity

Monopole mode TM01
f=7.8GHz
Q_0=7



Dipole mode TM11
f=12GHz
Q_0=1600 (Copper)



Choke cavity

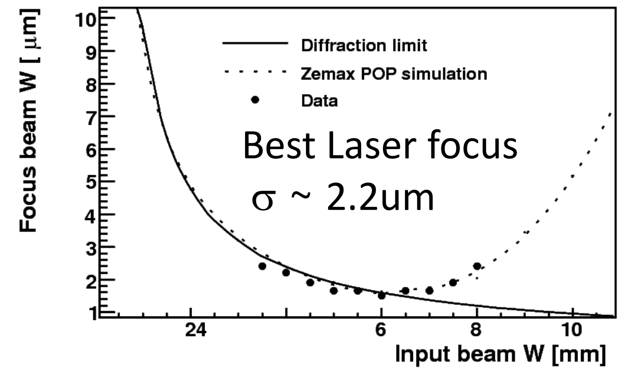
I. Syratchev – R. Fandos

Beam Size Measurement with a micron accuracy

Micron resolution with Laser Wire Scanner

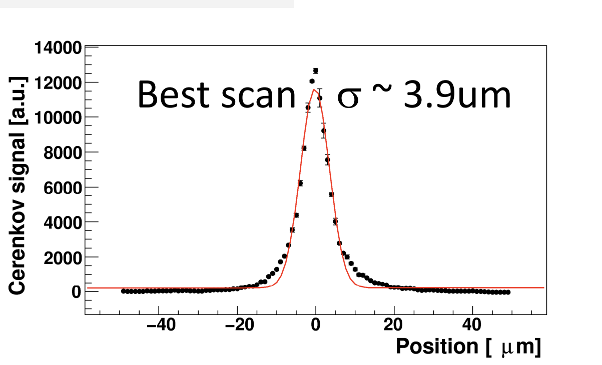
Optimized to measure 20umx1um beam spot size

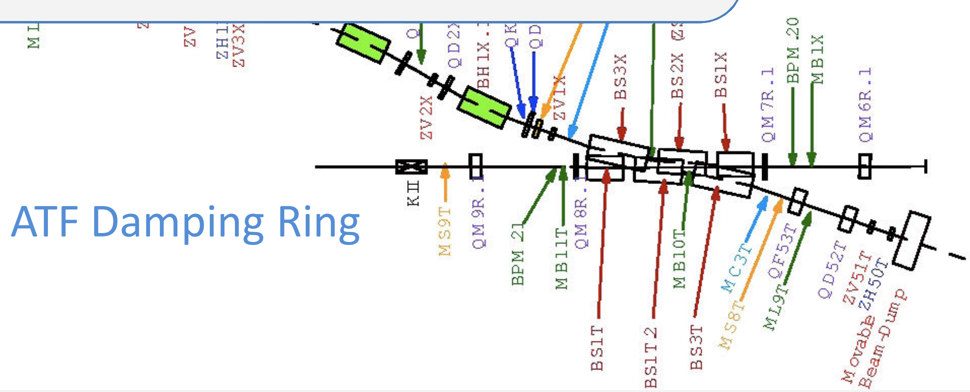
- High energy green (λ=532nm) laser pulses
- Amplify a single pulse from passively mode-locked seed laser
- Frequency locked to ATF RF distribution system at 357MHz
- Pulse duration ~150ps ; Pulse energy ~30mJ
- Laser light is transported collimated to extraction line by series of mirrors and aligned using irises



Dete

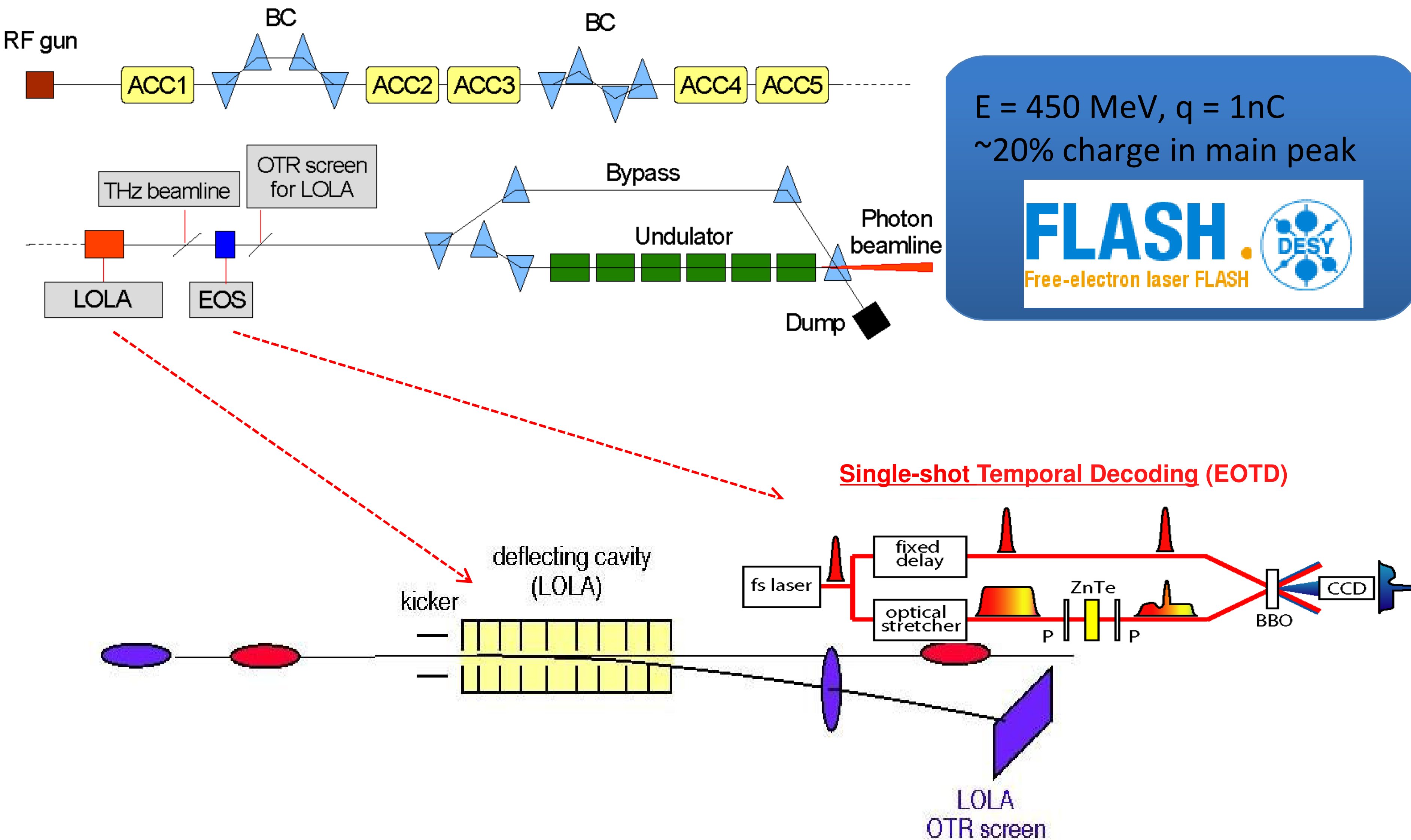
Need to improve the laser spot size by factor 2-3
Improving the optics and laser quality





Bunch length Measurement with a 30 fs resolution

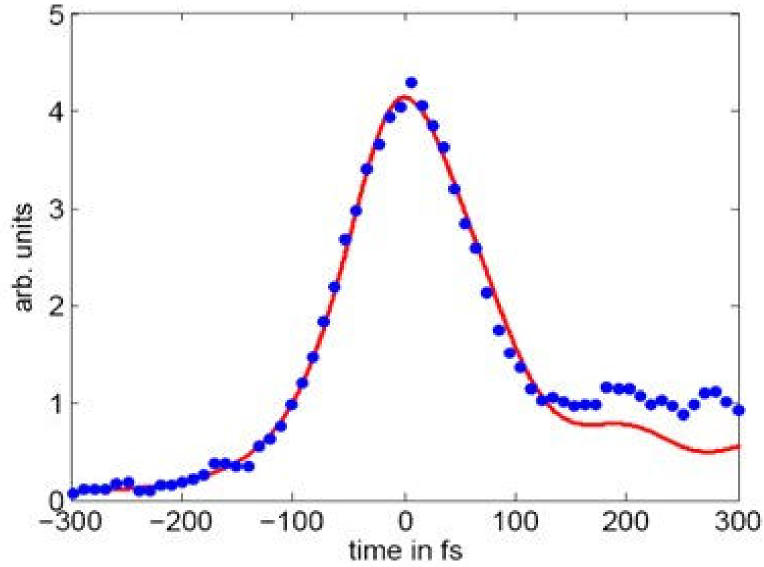
Benchmarking EO at FLASH against LOLA



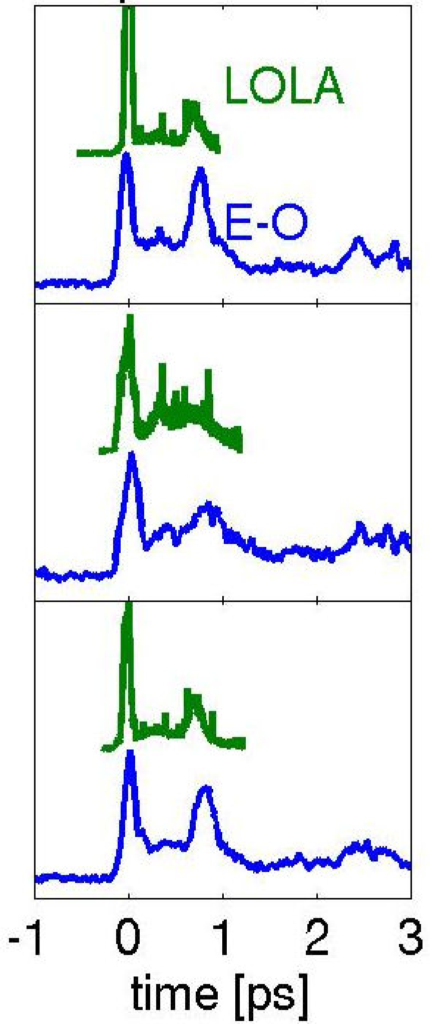
E = 450 MeV, q = 1nC
~20% charge in main peak

Benchmarking EO at FLASH against LOLA

Optimum compression
Fitted Gaussian curve
sigma = 79.3 ± 7.5 fs



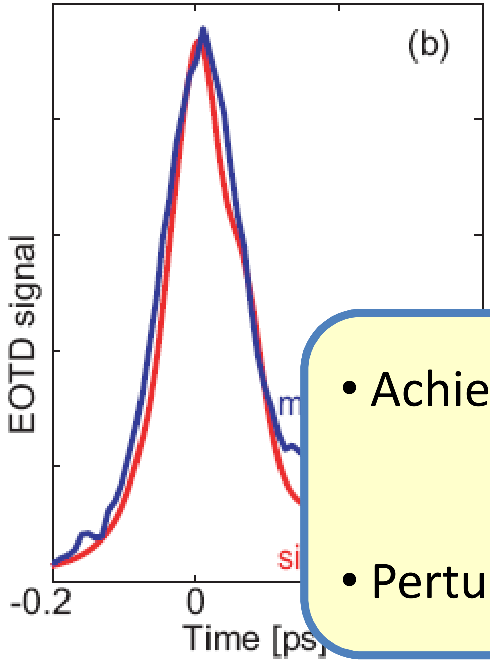
with FLASH bunch compressors detuned



FLASH. Free-electron laser FLASH DESY

Physical Review Special Topics - Accelerators and Beams 12, 032802 (2009)

Benchmarking EO at FLASH against LOLA



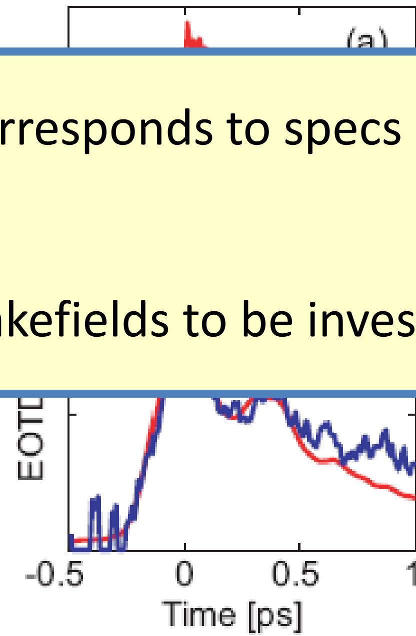
- Achieved Resolution corresponds to specs
- Perturbation due to Wakefields to be investigated

se deflecting

ive)

poral decoding

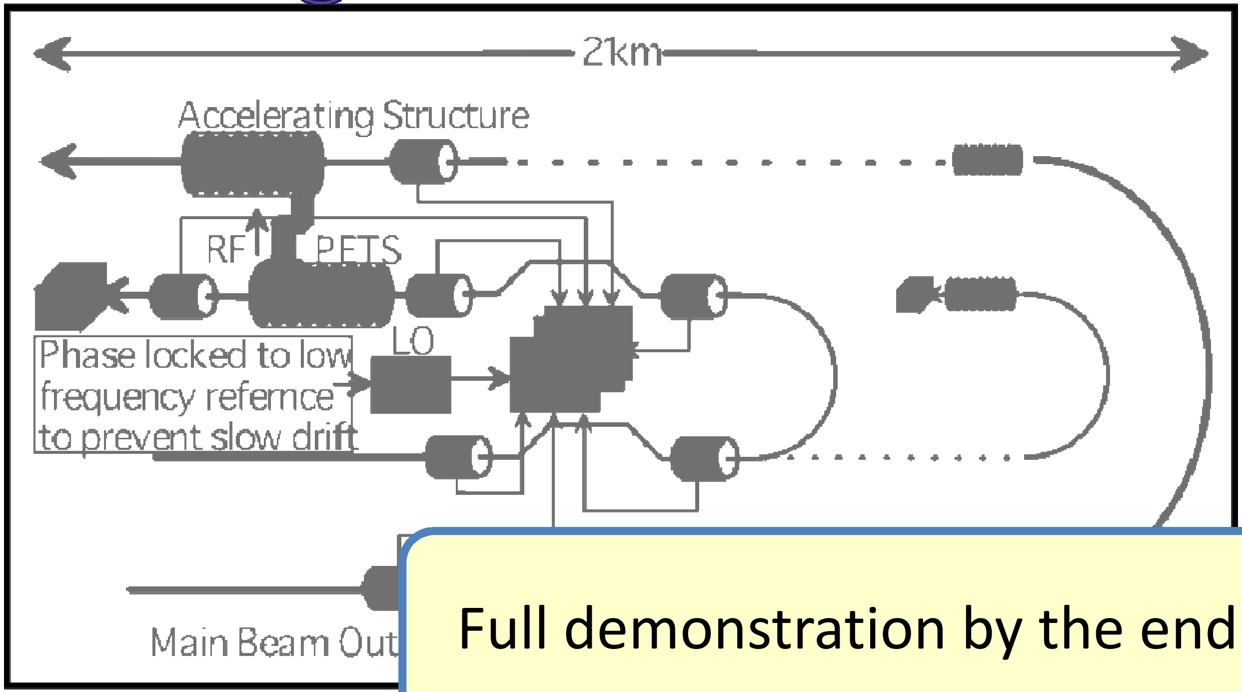
(non-destructive & compact)



Physical Review Special Topics - Accelerators and Beams 12, 032802 (2009)

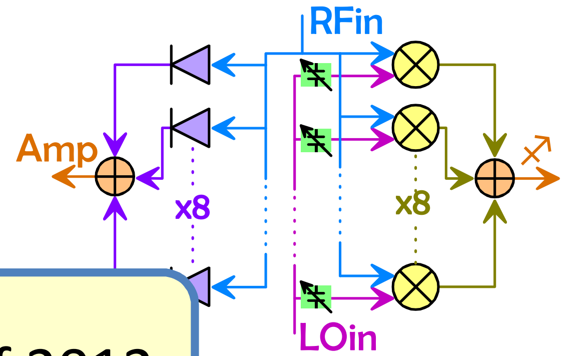
20-50fs timing synchronization

MB – Db phase synchronism



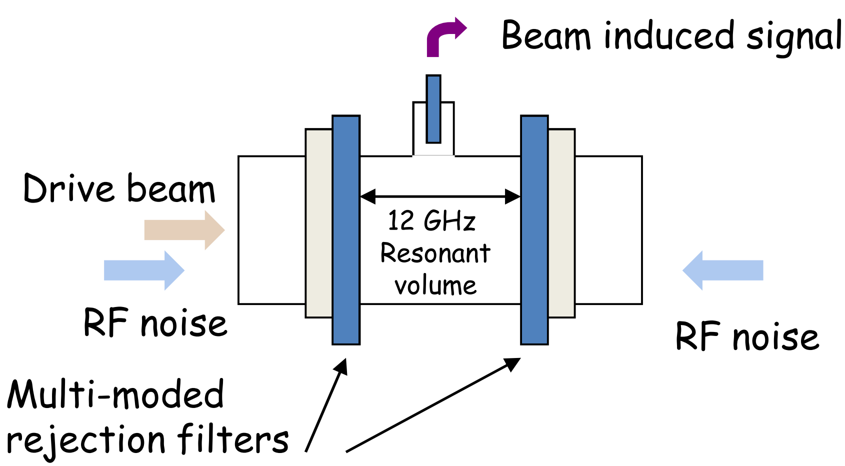
12 GHz electronics (A. Andersson)

- Use mixers directly at 12 GHz
- Use an array of many devices, sum their outputs for a reduction in noise



Full demonstration by the end of 2012

12 GHz low impedance noise-free pick-up concept by I. Syratchev, to be followed by M. Marcellini within FP7-EuCARD

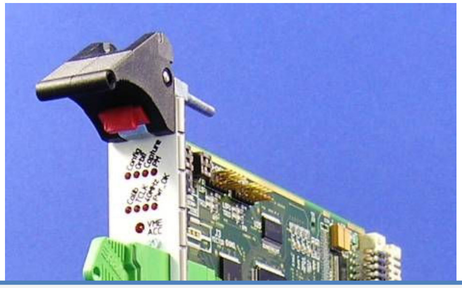


Sapphire Loaded Cavity Oscillator with ~2 fs integrated phase noise.

- Stable distribution of low frequency reference for long term stability
- Low noise local oscillator at each turnaround

Number of devices

- Electronic Standardisation
  - Single type of digital electronics acquisition card used for the majority of LHC



<u>Follow similar concept for CLIC</u>

- – ***<u>Elimination of cables</u>***
- – ***<u>Standardized Digital Acquisition on local crate with single connection via synchronous ethernet for timing/clock (White Rabbit – BE/CO - Javier Serrano)</u>***
- – ***<u>Radiation hardness ?</u>***

lapp S. Vilalte, J. Jacquemier, Y. Karyotakis, J. Nappa, P. Poulier, J. Tassan

  - Cheaper production

Perspectives & Conclusions

- Specifications for BI in rather good shape:

  Still waiting for specifications for beam loss monitoring

  Some further clarifications with beam dynamics experts needed

- For all demands technical solutions exist (within a factor 2...3)
  - Complex and non standard Post-collision beam line
  - High number of instruments: Cost optimization will be needed

- Cost optimization and prototyping

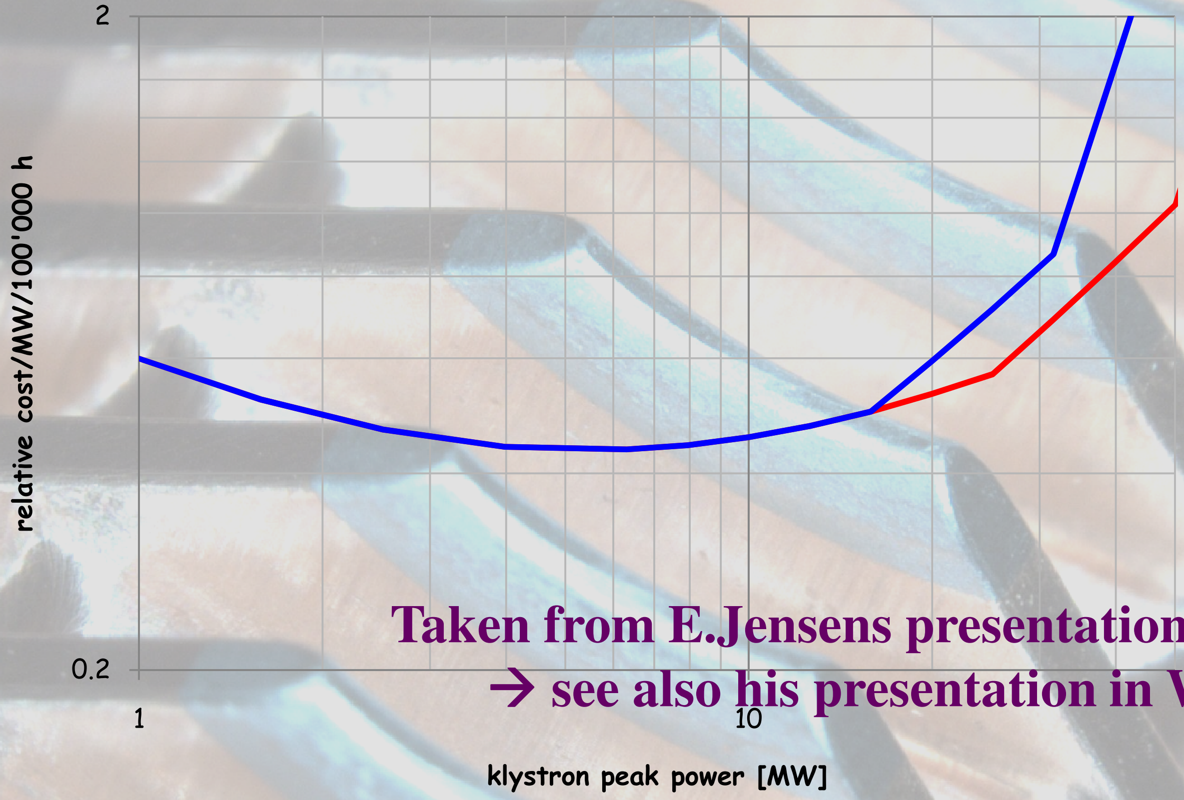
  (this will be the main activity in the 2011 – 2016 CLIC TDR phase)
  - Simplicity if applicable (not always compatible with tight tolerances)
  - Standardization (detectors, electronics) is a key concept
  - Gain in Mass production ?

- ***Work for 3 "feasibility items" is followed by the CTC:***
  ★ *- Active nm-level stabilization*
  ★ *- CLIC machine protection*
  - MB and DB phase synchronism
- ***Work on preparing and documenting the hardware baseline**: examples:*
  - CLIC PBS in EDMS
  ★ *- tunnel cross section, CLIC cooling and ventilation*
  - 2 beam module design, hardware integration, module instrumentation
  → G.Riddone talk this afternoon
  - technical choices for active pre-alignment system
  - beam based feedback systems
  - MDI, choice of FF magnet technology, sub nm-stability
  → L.Gatignon talk this morning
  → A.Jeremie talk just after this one
  - dump lines and their instrumentation
  ★ *- beam instrumentation*
- ***Launching of individual technical studies/optimizations in preparation of the TDR phase:***
  ★ *- choice of individual DB klystron power*
  ★ *- DR extraction kicker specs and technical solutions*
- ***Cost optimization:***
  ★ *- Reduction in number of BPMs in drive beam*

→ One slide each

Cost for 100,000 operating hours and MW

- Even if this model may be wrong, there will be a cost per MW and per operating hour: With the above model, this becomes:



Taken from E.Jensens presentation in the CTC
→ see also his presentation in WG5

- Blue: present state of the art
- Red: assuming a major investment into the development of a dedicated 30 MW tube

Summary: CLIC Pre Damping and Damping Ring Kickers: Stability Requirements

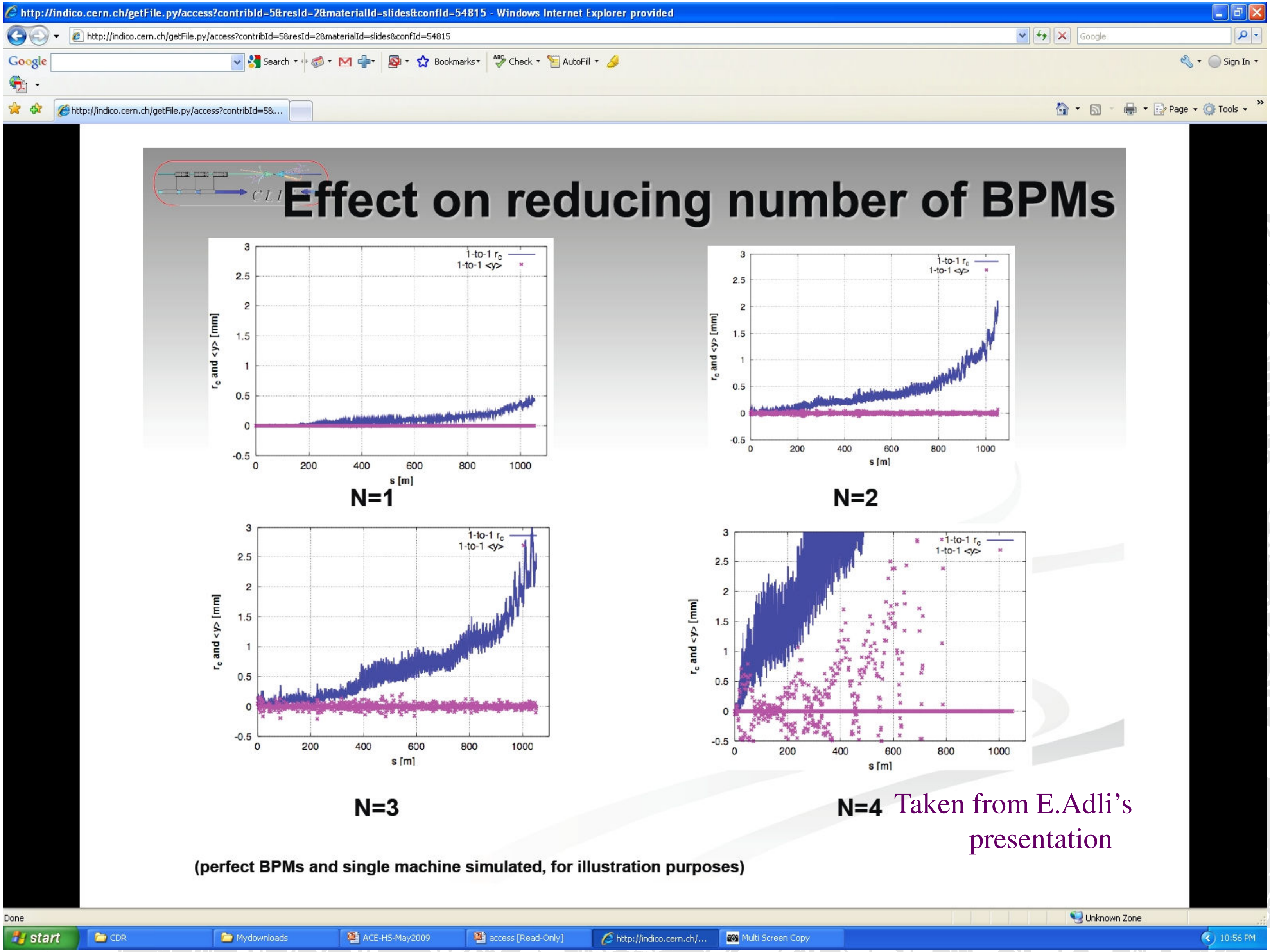
1. Beam coupling impedance issues will require the use of striplines, rather than a ferrite loaded kicker magnet;

2. 2. Short duration pulses (fast rise and fall) are advantageous for minimizing the total duration of the pulse. Hence a multi-cell inductive adder may be a good choice to:
   • Minimize dissipation in terminators (and therefore thermal effects);
   • Achieve reliable insulation, especially at ends of striplines, and adequately low beam coupling impedance of striplines – R&D required;

3. Stability of DR extraction kicker (0.015% reqd.) will be a significant challenge especially because of relatively long (160ns) pulse length. The following require R&D:
   Power supply – probably OK for slow charging; Choice between PFL & alternative (e.g. inductive adder); Switch; Transmission cable;
   Feedthroughs; Striplines; Terminator.

4. A double kicker system relaxes the requirements for individual kickers, but this has never been tried at CERN. KEK-ATF achieved a factor of 3.3 reduction in kick jitterangle, w.r.t. a single kicker: the fact that the gain was not even greater is attributed toerrors in the optics and errors in estimating horizontal displacement (due to insufficient position resolution of the BPMs) – can this be improved upon? – R&D required.

October 12-16, 2009 M.J. Barnes: CLIC'09 Workshop → WG3 and WG5



Choice not obvious: tradeoff between number of BPMs and precision; availibility, cost versus precision, risk….

Conclusions

- Technical Work until CDR defined
- We play low on technical documentation, but a CLIC PBS for 3 TeV and 500 GeV exists in EDMS and we have close to 100 specification documents in it.
- We will review the hardware baseline end of this year and than freeze it for the CDR (does not exclude progress…)
- Deadline for CDR is December 2010 with a council decision on the continuation of the CLIC study in June 2011. A draft of the CDR for the 2010 workshop is probably wishful thinking…
- There are very motivated and competent teams working on the various subjects.