



# CLEX Two Beam Module lessons learned



- Two module reviews in the past 2013 and 2015
- Review of experience with the CLEX module
- Regular presentations and updates in workshops and project meetings
- Numerous findings, clear recommendation  
→ work on a new generation module concept



# CLEX Two Beam Module lessons learned



- Superstructure SAS
- Installation
- Integration
- Alignment
- Experimental Program in CLEX



# CLEX experience review



Summary of the CLEX module production and installation review

Review held the 25.2.2015 in the module working group

Presentation can be found at: <http://indico.cern.ch/event/366835/>

- Superstructure SAS too complicated and fragile object, design issues identified  
→ SAS design needs to be reviewed fundamentally, taking into account rf design changes; will be followed by Nuria's team
- Improve and integrate cooling system design of modules, fix BPM to quad, how to align the structures longitudinally, better integration of subsystems ( BLM's, cables other sensors)
- Alignment issues identified, placing of fiducials, link between girder and cradles lost, motor failures, coupling of main and drive beam, BPM and Quad have o be linked  
→ improve integrated design, follow up with more measurements
- Compact loads needed
- General communication issues, more exchange needed between rf-design, mechanical design, experimental team, diagnostics and magnets.  
Several waveguides had the wrong phase

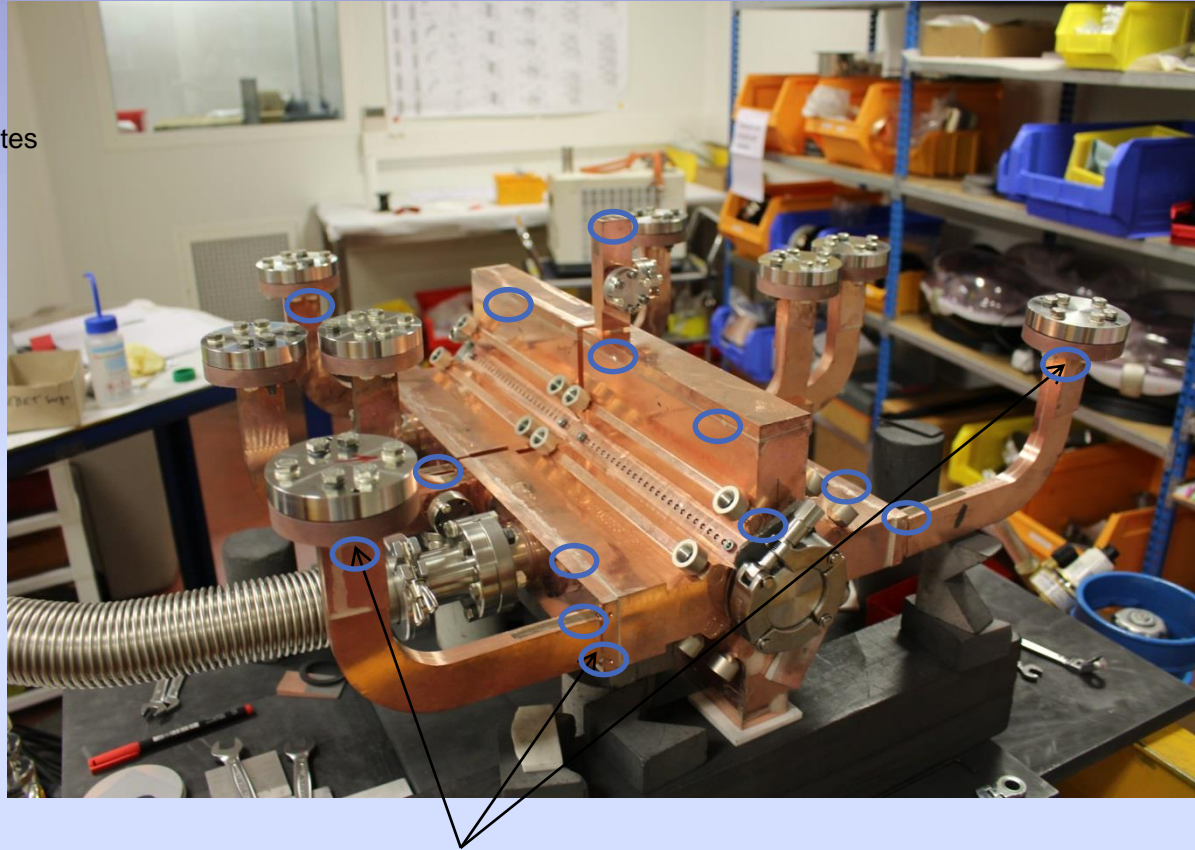


# Final leak check

## CLEX Module experience review



○ Localisation principale des fuites



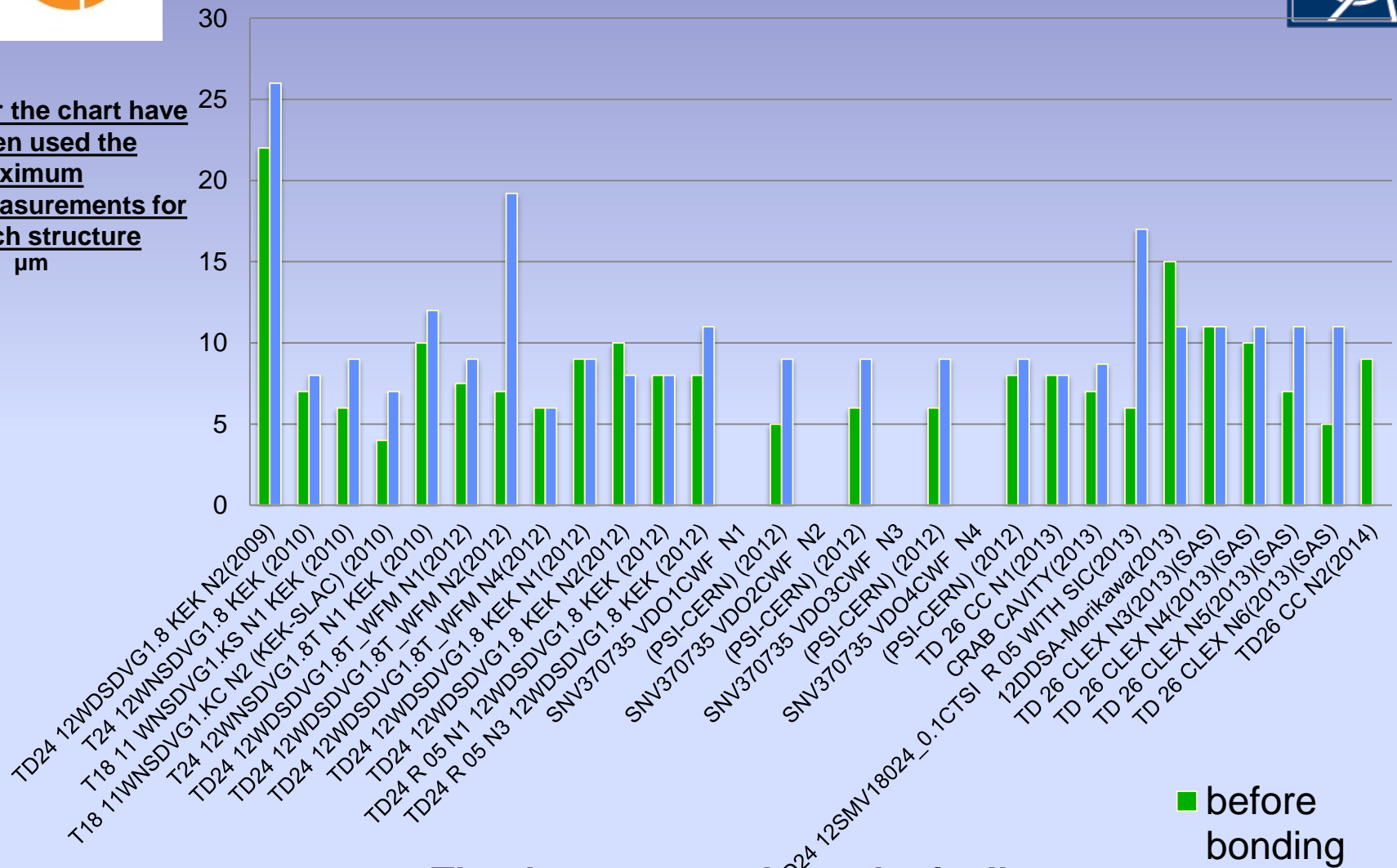
Attention au serrage des brides un gros risque de vriller les guides d'onde , risque de fissures en dessous des brides  
Prévoir un outillage pour bloquer les guide et WFM



# History Chart



**For the chart have  
been used the  
maximum  
measurements for  
each structure**  
 $\mu\text{m}$

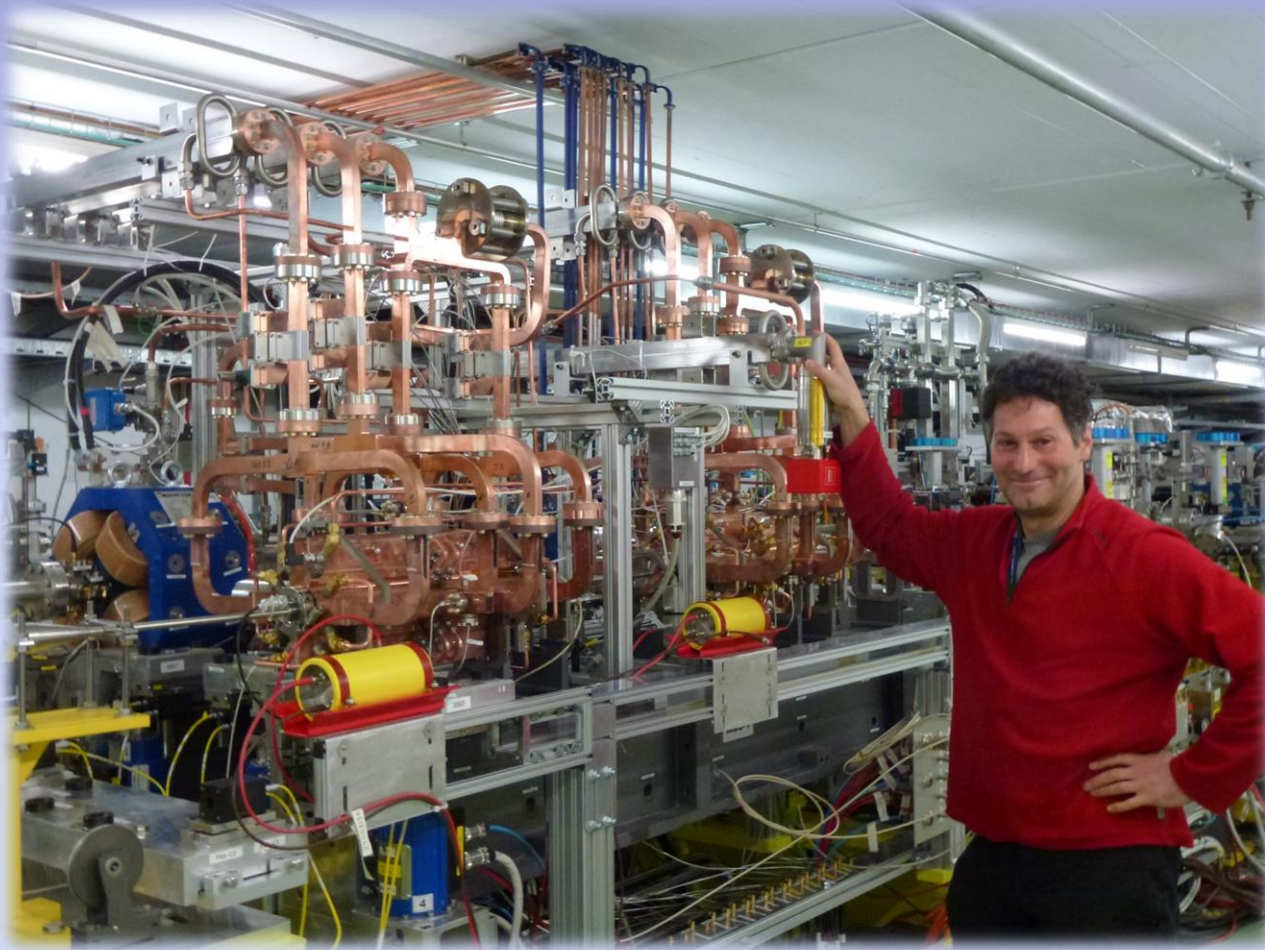


**The data are set chronologically**



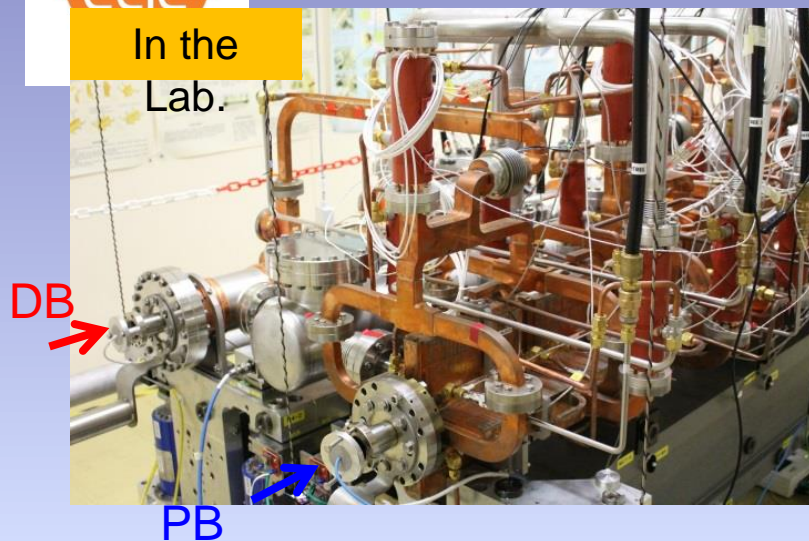


# First CLIC prototype module completely installed in CLEX



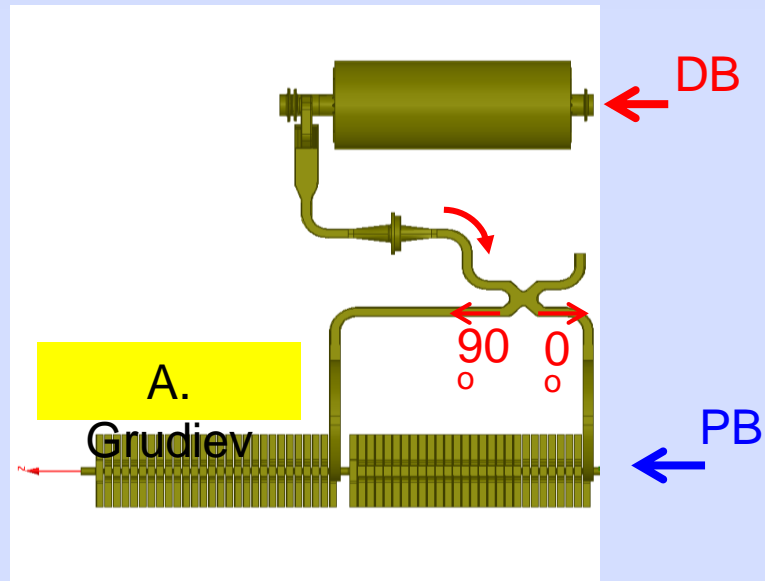
Many compromises to use the module in CLEX !

In the  
Lab.



**Needs fundamental redesign !**  
**Less flanges, lower losses,**  
**lower centre of mass**

In CLEX

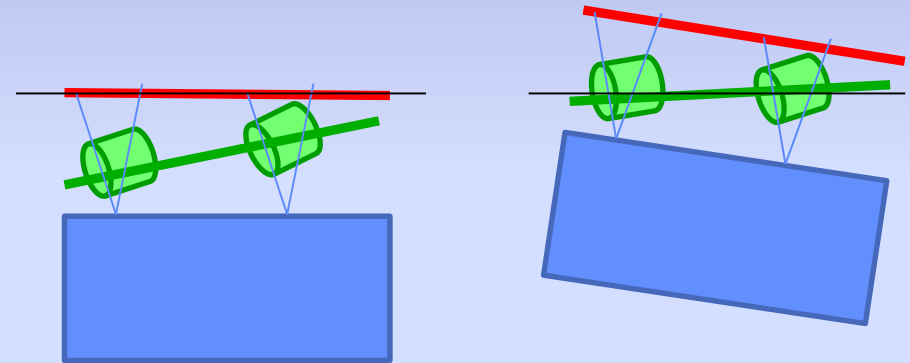




# CLEX Alignement

Component Drive Beam		Radial ( $\mu\text{m}$ )	Vertical ( $\mu\text{m}$ )	Error budget ( $\mu\text{m}$ )
PETS1	Enter	65	37	100
	Exit	-27	15	100
DBQ1	Enter	-9	-4	20
	Exit	-2	19	20
PETS2	Enter	28	78	100
	Exit	-51	58	100
DBQ2	Enter	8	11	20
	Exit	-3	-14	20

Component Main Beam		Radial ( $\mu\text{m}$ )	Vertical ( $\mu\text{m}$ )	Error budget ( $\mu\text{m}$ )
AS1	Enter	-51	-59	10
	Exit	-161	-16	10
AS2	Enter	-68	-85	10
	Exit	-139	-103	10

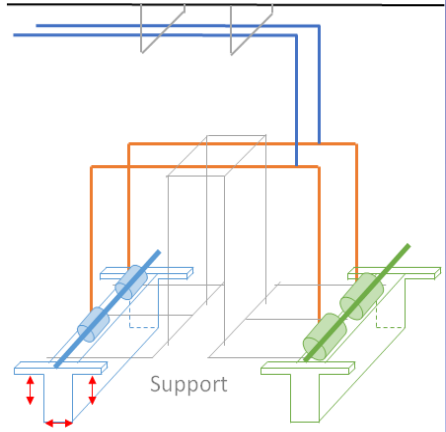


Component Main Beam		Radial ( $\mu\text{m}$ )	Vertical ( $\mu\text{m}$ )	Error budget ( $\mu\text{m}$ )
AS1	Enter	29	-24	10
	Exit	-65	39	10
AS2	Enter	46	-8	10
	Exit	-10	-7	10

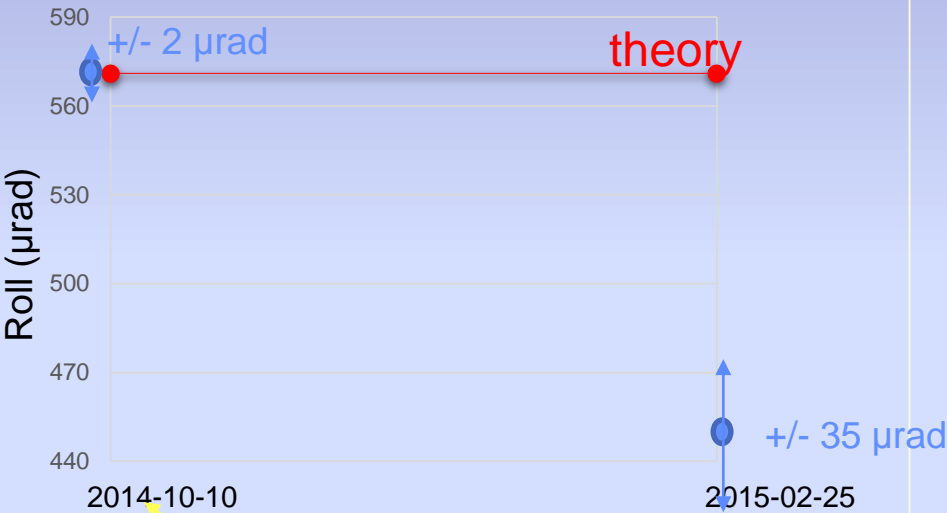




**CLEX**



### Roll (Drive Beam)



### Roll (Main Beam)



Drive Beam	Theory
Roll (μrad)	571
Radial (μm)	232
Vertical (μm)	0

Without constraints	End of installation	Difference
573	449	124 μrad
237	173	64 μm
0	1	1 μm

Main Beam	Theory
Roll (μrad)	0
Radial (μm)	0
Vertical (μm)	0

Without constraints	End of installation	Difference
0	56	56 μrad
0	43	43 μm
0	2	2 μm



# CLEX constraints

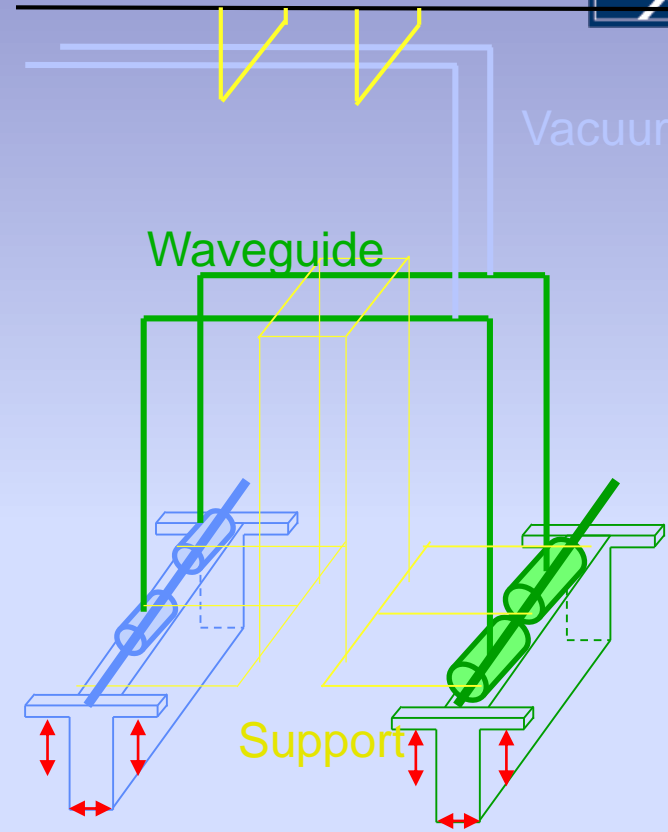
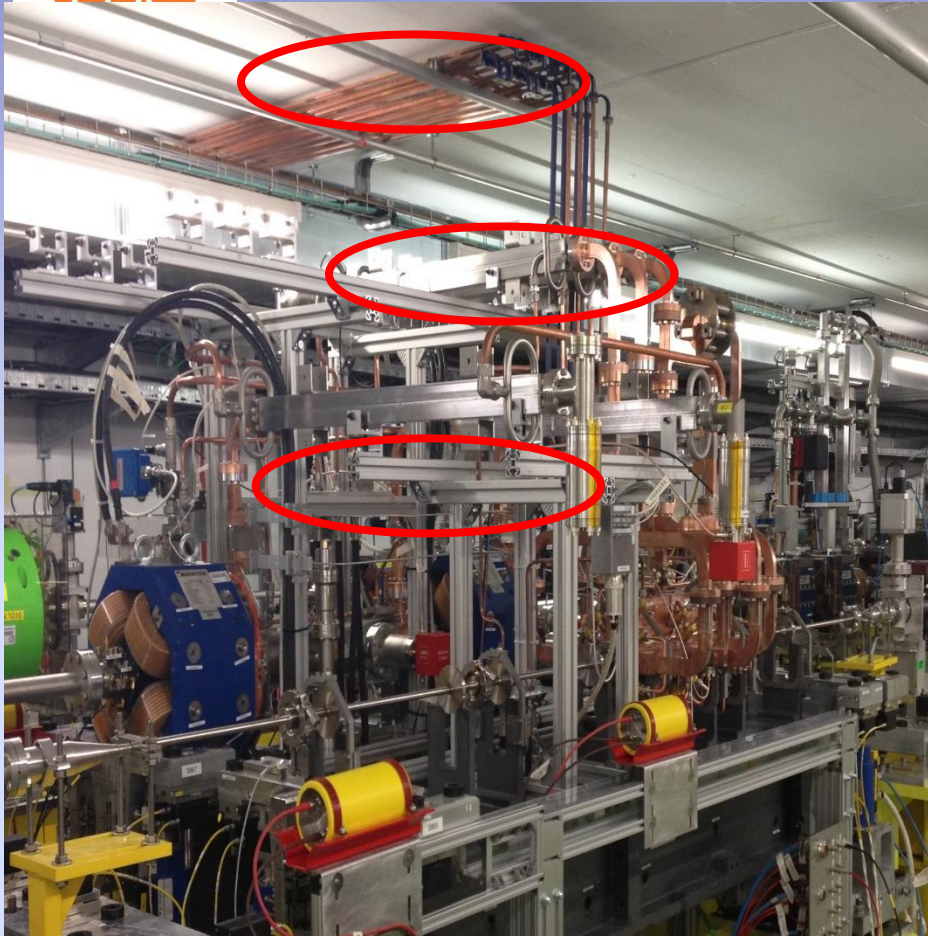


Ceiling

Vacuum Network

Waveguide

Support



## Constraints due to :

- Connection to the waveguide
- Connection to the vacuum network
- Support



# Experimental program for the CLEX module



## List of ideas

- Two beam acceleration, rf signal consistency, power transfer, acceleration, phasing, breakdown handling, ...
- Alignment studies, with and w/o beam, girder coupling, beam based alignment using WFM and BPM data, perturbation by accelerator noise, precision, reproducibility, fiducialisation, reliability
- BPM studies, resolution, performance
- Wake Field Monitor studies, electronics, resolution
- Temperature management, control flow rates, temperatures, measure changes in beam environment
- Find, understand and possibly solve shortfalls of present systems

**These studies have not been completed !**



# Conclusions

- **Huge piece of work** but finally successfully installed
- Very valuable experience because much closer to the real requirements, vacuum, integration into a real machine, real rf structures which need right phase and calibration
- **A big step towards a realistic module even if it is quite different then the CDR module**
- **First results with beam and from alignment confirm the importance of that module**





## List of changes and improvements for the next generation CLIC module



Some documentation exist already:

See Module review, lessons learned review CLEX installation, Critical item compendium

- Let's assume we go away from a tolerance based design to a adjustable design:  
Enough evidence found in existing module experience

### Necessary Improvements:

- **Support of rf structures and PETS:**  
adjustability, two point support, longitudinal adjustability, fixations, alignment references
- **Vacuum system:**  
separate or manifold, number of pumps, mechanical design of system (force free), cost ?
- **Coupling between girders:**  
Need to be solved if we stay with independent girders, not good enough right now
- **Phasing of the structures:**  
No clear tolerances and strategy, probably needs to be designed into the module
- **BPM fixation in DB Quad:**  
New mechanical concept needed, couple fix or adjust, depends on PACMAN as well, current solution insufficient
- **Cooling system integration:**  
system has to be designed in from the beginning. Too many pipes right now



## List of changes and improvements for the next generation CLIC module



### Necessary Improvements:

- **Articulation point, girder support and regulations:**  
Simply not practical in the current design, should we keep it or better independent girders
- **WPS supports and reference to girder:**  
Reference get's lost in current design and setup, integration with girder needed

### New features or concepts investigated:

- New girder design, made of cast concrete, one piece including cradle and WPS
- How about putting WPS on object which should be aligned ? RF-unit, numbers?
- One support for both beams, less movers, less sensors
- Longer support, less movers, less sensors
- DB- Quad support separate, beam dynamics requirements
- Relative orientation of the two beams
- Vacuum sectors
- New waveguide system, can we simplify, do we need the hybrid (save one load)
- Thermal handling of the module, operating temperature vs alignment temperature  
Compensate with water cooling
- Breakdown response in terms of temperature management
- Tunnel cooling and temperature stabilisation overall
- New force free vacuum system design
- New waveguide concept, no choke mode flange



## List of changes and improvements for the next generation CLIC module



RF-unit:

Currently double PETS + 2 superstructures, no flanges, is this really feasible, reasonable ?

SAS-design:

**Mechanical design of outer part should be driven by module requirements:**

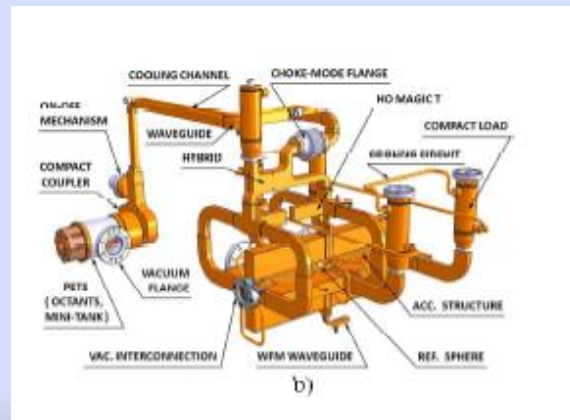
Support interfaces, deformability, alignment features, simplify vacuum and water cooling interfaces,

Integrate double feed coupler to have only one rf flange, can we integrate high power load as well.

High power load needs urgent validation in any case.

Superstructure concept, valid ?, How long can we go

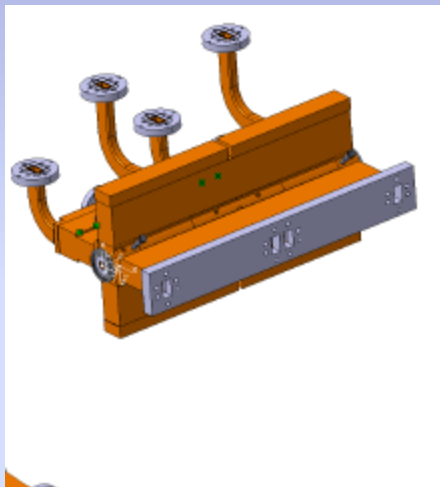
Structure straightness not validated



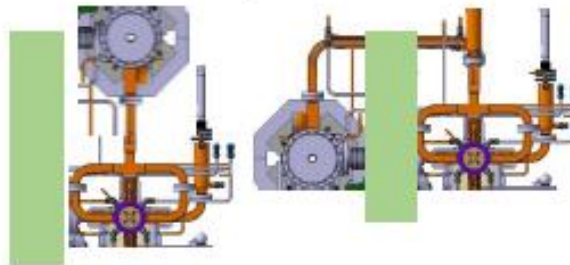
**4x this!!**



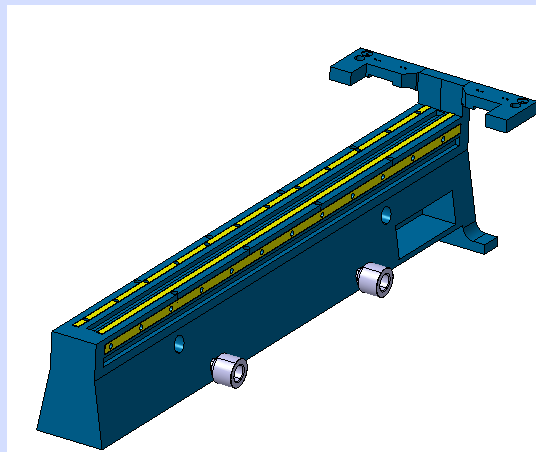
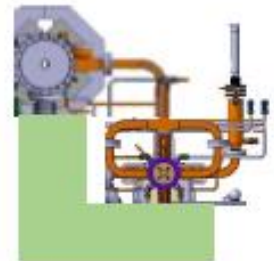
## Some visionary sketches from the module crew



Vertical girder



L-Shape girder



Alex, Markus, Petri





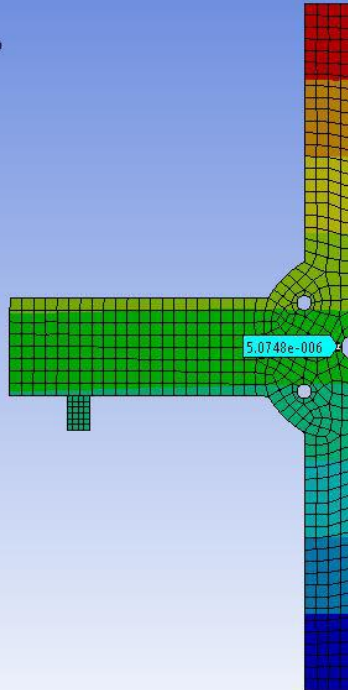
# More detailed analysis is needed, large potential for improvements



## C: Static Structural

Directional Deformation  
Type: Directional Deformation(Y Axis)  
Unit: m  
Global Coordinate System  
Time: 1  
24/08/2016 17:09

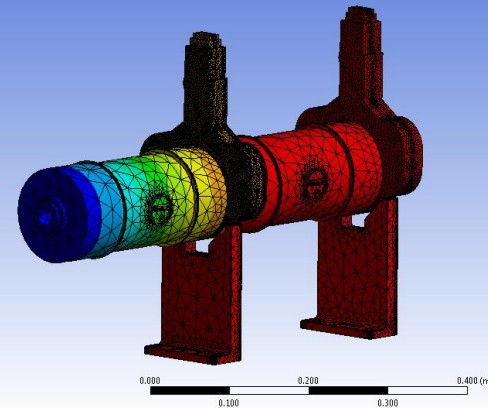
4.5476e-5 Max  
3.6495e-5  
2.7513e-5  
1.8532e-5  
9.5501e-6  
5.6861e-7  
-8.4129e-6  
-1.7394e-5  
-2.6376e-5  
-3.5358e-5 Min



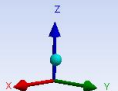
0.000

B: Static Structural  
Directional Deformation  
Type: Directional Deformation(Z Axis)  
Unit: m  
Global Coordinate System  
Time: 1  
20/06/2016 15:44

1.1378e-10 Max  
-3.2702e-7  
-6.5595e-7  
-9.8399e-7  
-1.3132e-6  
-1.6401e-6  
-1.9681e-6  
-2.2961e-6  
-2.6242e-6  
-2.9522e-6 Min



ANSYS  
R17.1  
Academic



Alex, Antti



## **How could a new concept look like ? Not worked out yet, more a design goal**

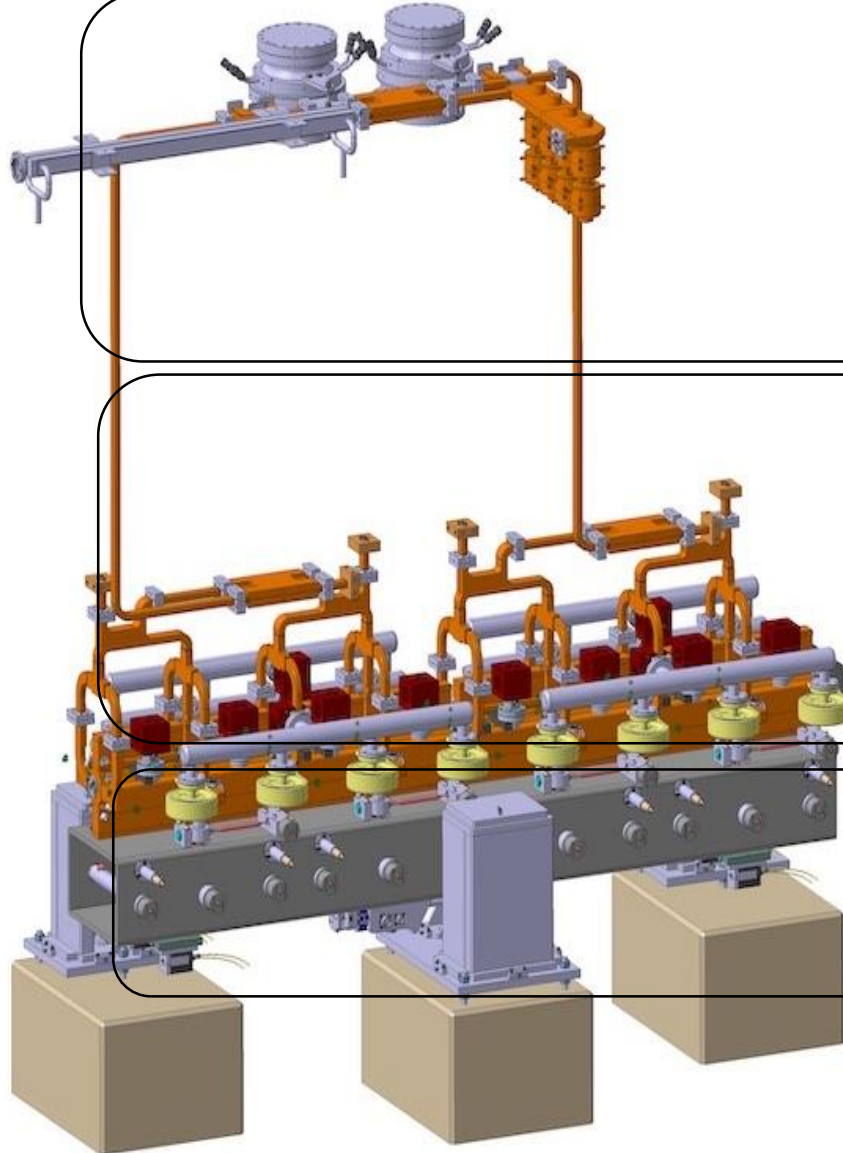


- ☐ **Precise pre-alignment in the tunnel after transport, laser tracker (PACMAN)**
- ☐ **Steel girder with WPS support integrated, adjustable supports for SAS  
Stiffness and vibration considerations, likely less costly**
- ☐ **Introduce shorter vacuum sectors, 900 m unrealistic**
- ☐ **Rough pre-alignment and assembly on surface in dedicated facility, 'clean area'. Main point of quality control and acceptance test, likely at CERN**
- ☐ **Produce, measure, test, fiducialise components, Quads, PETS\*, SAS\* possibly already integrated in a module (PACMAN)**
- ☐ **Rf high power test would be best on assembled module, how ?  
Define better rf-unit**
- ☐ **Re design structures ,PETS and waveguide system for future assembly into the modules**
- ☐ **Integrate vacuum system and cooling system**



# Conclusions

- A large number of shortfalls/mistakes or possible improvements have been identified in the past  
Many related to integration of module components and manufacturability of the module but significant beam dynamics requirements are missing as well
- New concepts have been studied and a vision of a new module is shaping up
- Up to now we built PETS, Accelerating structures, cooling systems, vacuum systems, waveguide systems for single structure high power tests.  
Very little has been done towards a full module integration



**High Power system:**  
Maybe most specific to CLIC, high power handling, thermal stability, efficiency

**Waveguide system:**  
Relevant for all projects, compact, low loss, assembly friendly, cost, phasing, stability  
**Cooling and vacuum:**  
Relevant for most projects, cost assembly, performance, integration

**Supporting system:**  
Relevant for all projects, small cost, Has to meet beam dynamics requirements  
→ Emittance preservation

All parts can be worked on separately but each time we combine we gain a lot towards a real CLIC module





# References

- **Module reviews:**  
<https://indico.cern.ch/category/5216/>
- **Module meetings:**  
<https://indico.cern.ch/category/2630/>
- **LAB activities summary 2015-2018, EDMS 2054219**
- **Critical design items, EDMS 2086287**
- **R&D since CDR, EDMS 2054199**
- **Thermal behavior of XBOX structure, EDMS 2086457**
- **Thermal tunnel studies, EDMS 2224093**