The path to a new CLIC main-linac module

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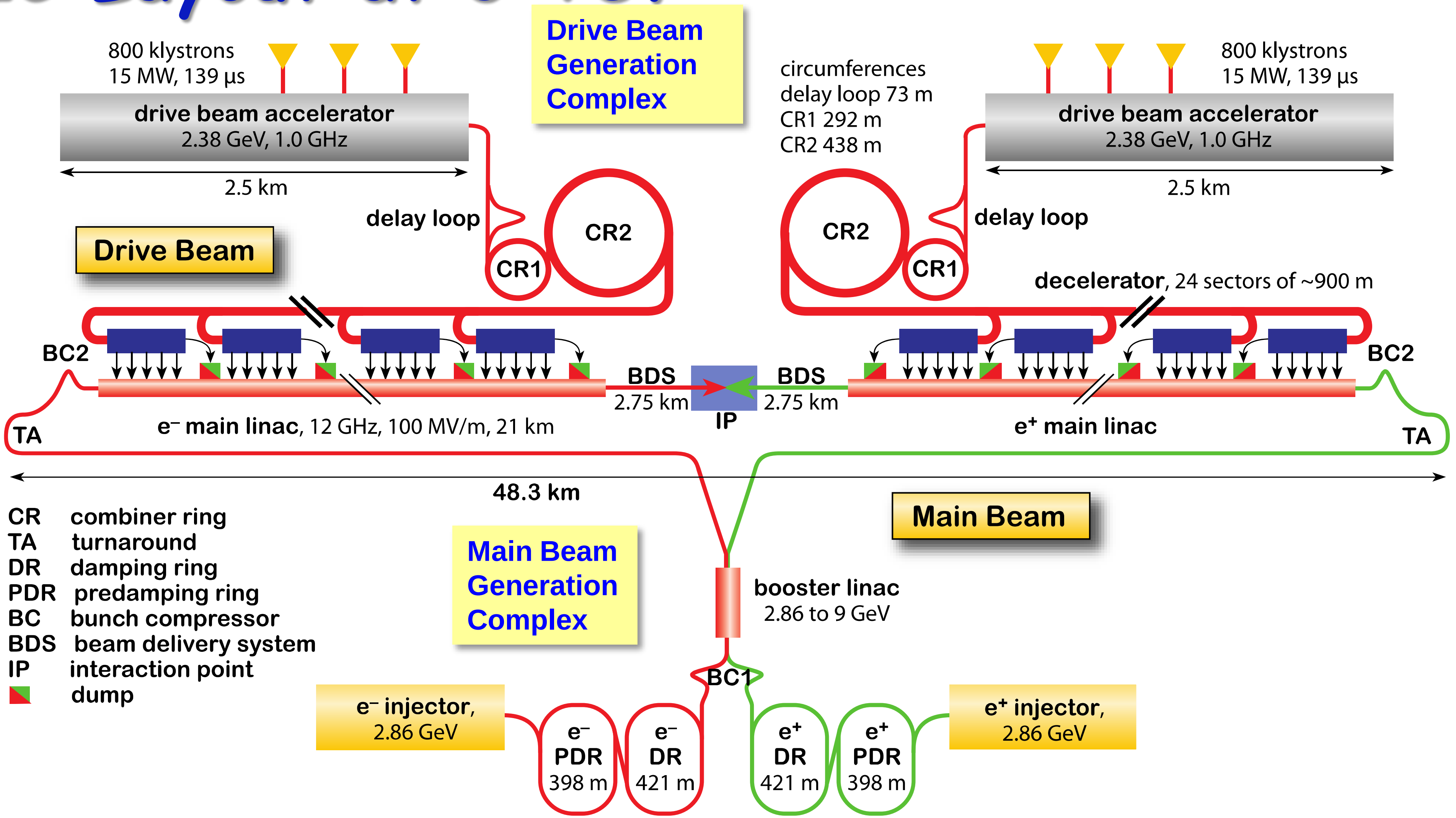
and all related groups

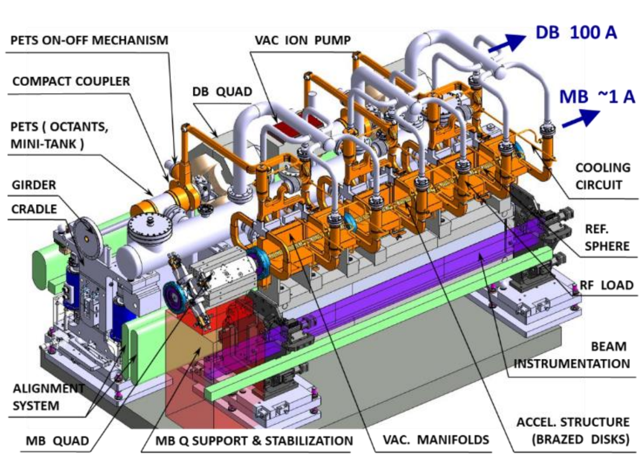
CLIC Layout at 3 TeV

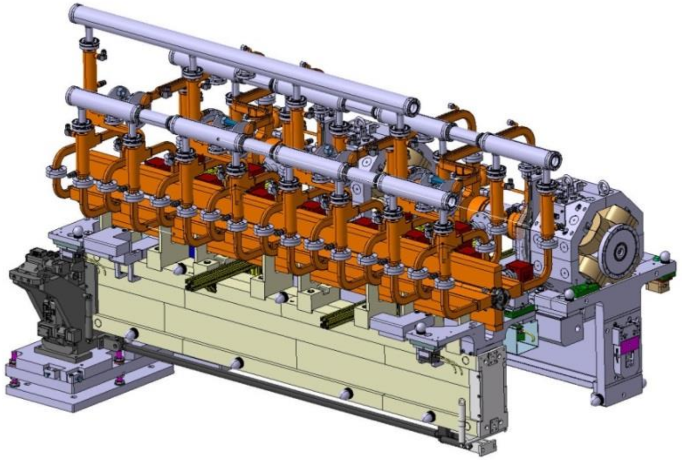


Outline

- CLIC module history and horizon
- State of CLIC module study CDR (2012)
- State of the art
- Benchmarking: Cost model
- Reevaluation of design choices

History and Horizon





30 GHz two beam module prototype with RF power in CTF2

Feasability demonstrated
Completed design
Mechanical prototype

Evolved design
Two additional mech. protoypes
Real RF-prototype

New 3D design ready for prototyping

1990´s

2012

CDR

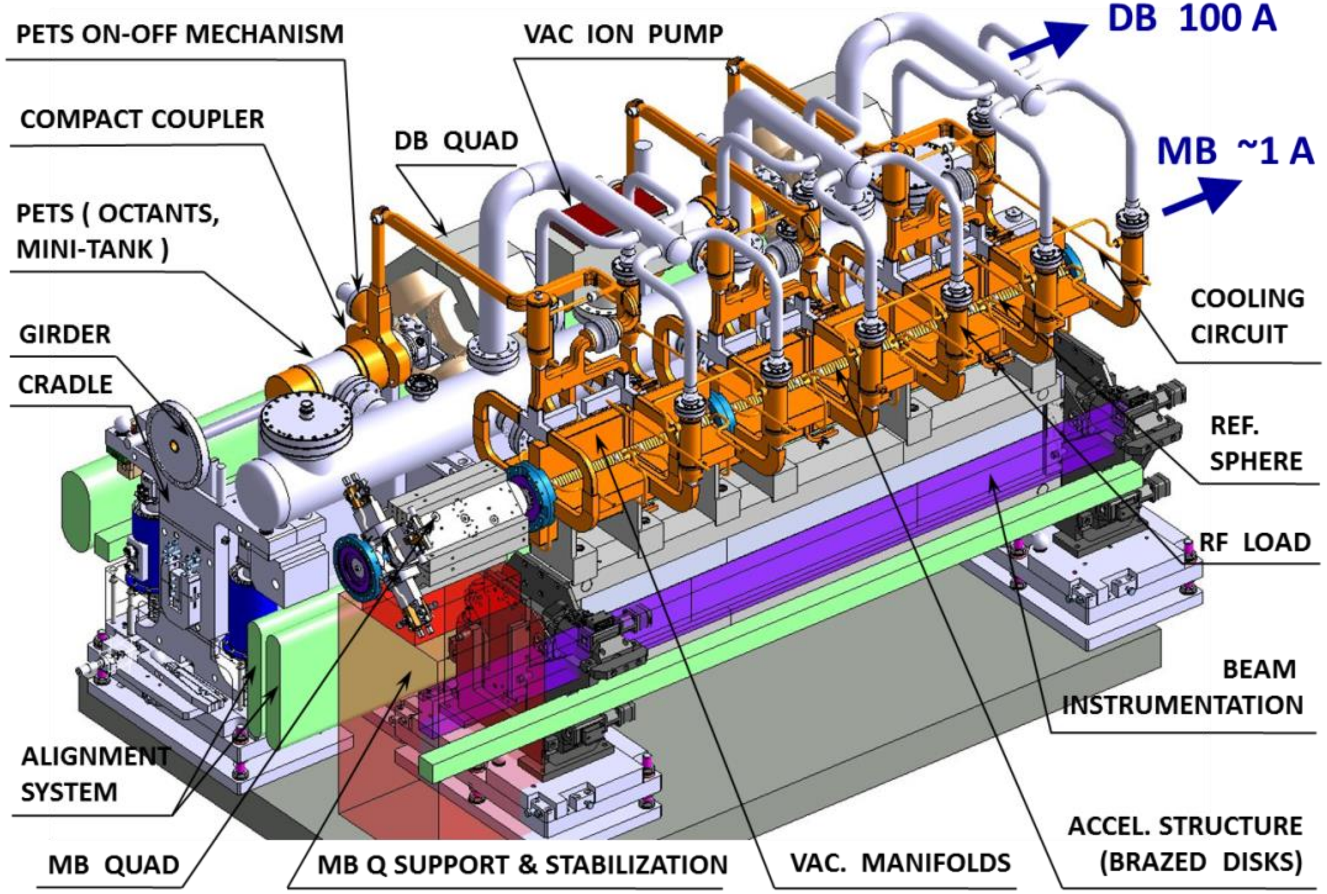
2016

Today

2019

European strategy update

State of CLIC module study CDR (2012)

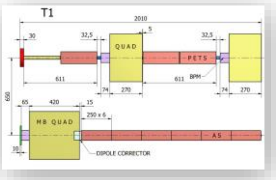


A. Samoshkin

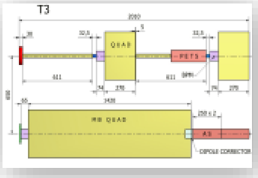
CLIC at 500 GeV (4232 modules)
26920 Accelerating structures
13460 PETS
~ 70000 RF components

CLIC at 3 TeV (21460 modules)
142760 Accelerating structures
71380 PETS
~ 400000 RF components

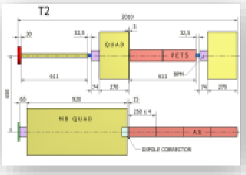
State of CLIC module study CDR (2012)



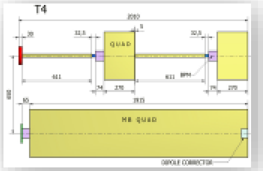
Module Type 1
3 %



Module Type 3
9 %



Module Type 2
12 %



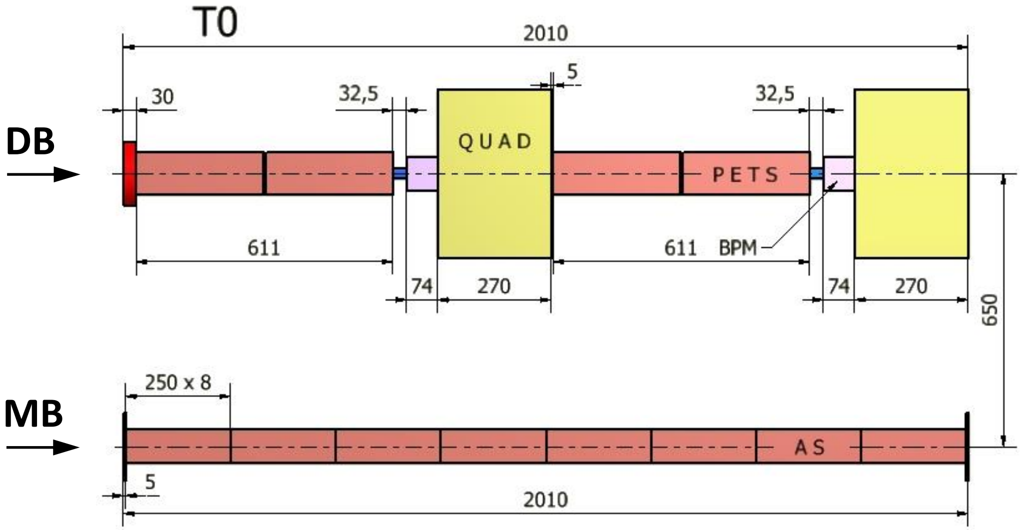
Module Type 4
3 %

1 to 4 pairs of AS replaced by MB Quadrupoles

CLIC Module Type 0
73 %

Standard Module
(L = 2010 mm)
DB (100 A)
4 PETS, 2 Quads with BPM
Each PETS feeds 2 AS

MB (1 A)
8 acc. structures
MB filling factor: 91%



State of CLIC module study CDR (2012)

CLIC project: alignment strategy

Beam off

- Mechanical pre-alignment — ~0.2 - 0.3 mm over 200 m
- Active pre-alignment — 14 - 17 µm over 200 m

Beam on

Beam based Alignment & Beam based feedbacks

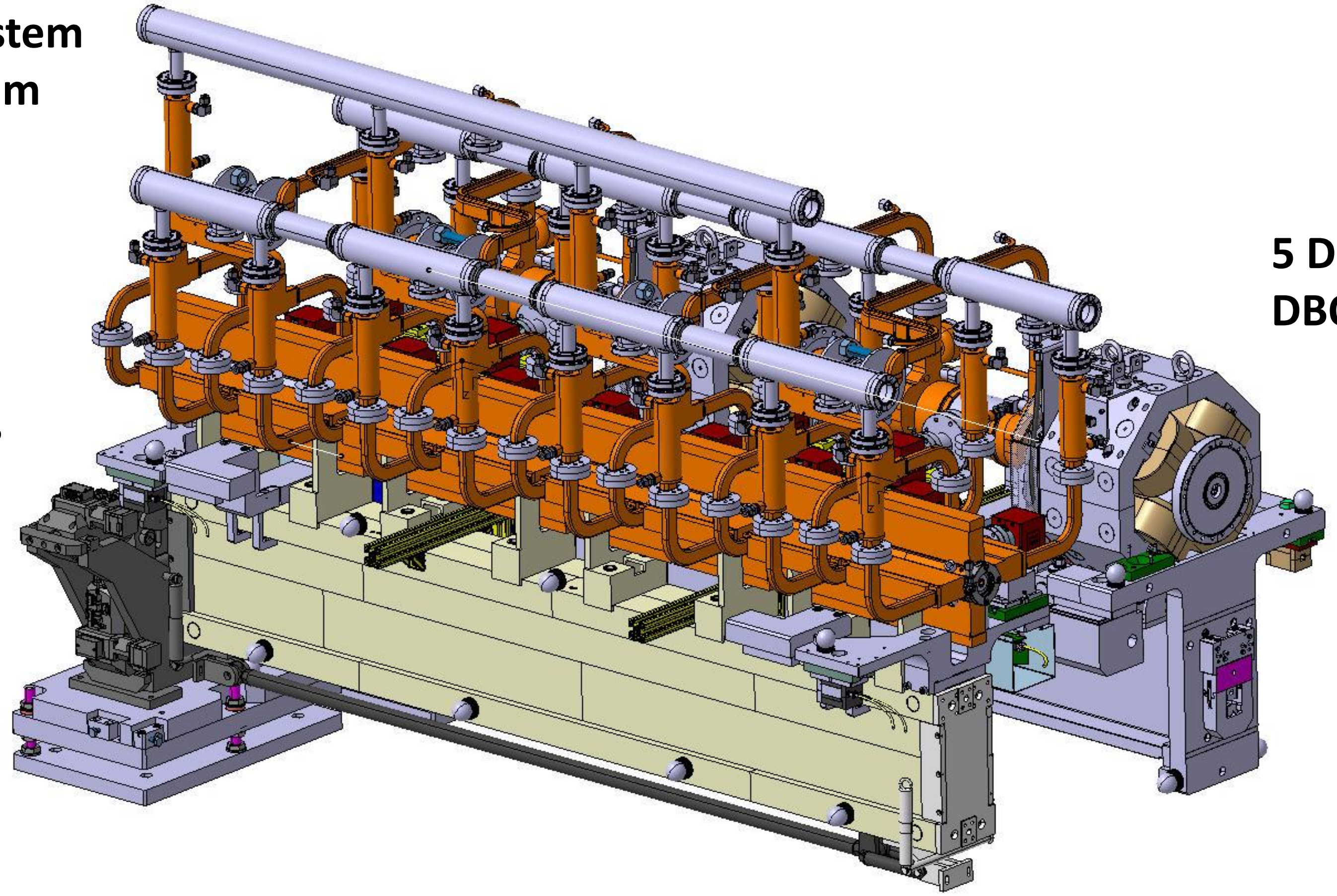
One to one steering	Dispersion Free Steering	Minimization of AS offsets
Make the beam pass through	Optimize the position of BPM & quads by varying the beam energy	Using wakefield monitors & girders actuators

→ **Minimization of the emittance growth**

State of the art

Improved vacuum system cancelling all vacuum forces

Individual minipumps pumping individual structures



5 DoF adjustable DBQ support

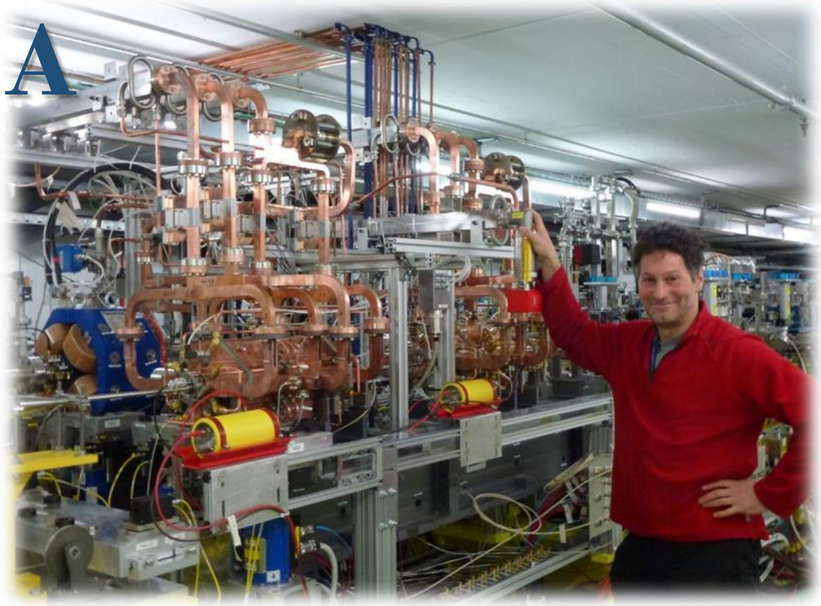
Improved design of articlation point (fully adjustable)

Reduced crosstalk between girders

State of the art

CLIC Module R&D

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



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

- First module review November 2013
  https://indico.cern.ch/event/281312/
- CLEX Module installation review
  http://indico.cern.ch/event/366835/
- Second review June 2015
  https://indico.cern.ch/event/393250/

State of the art

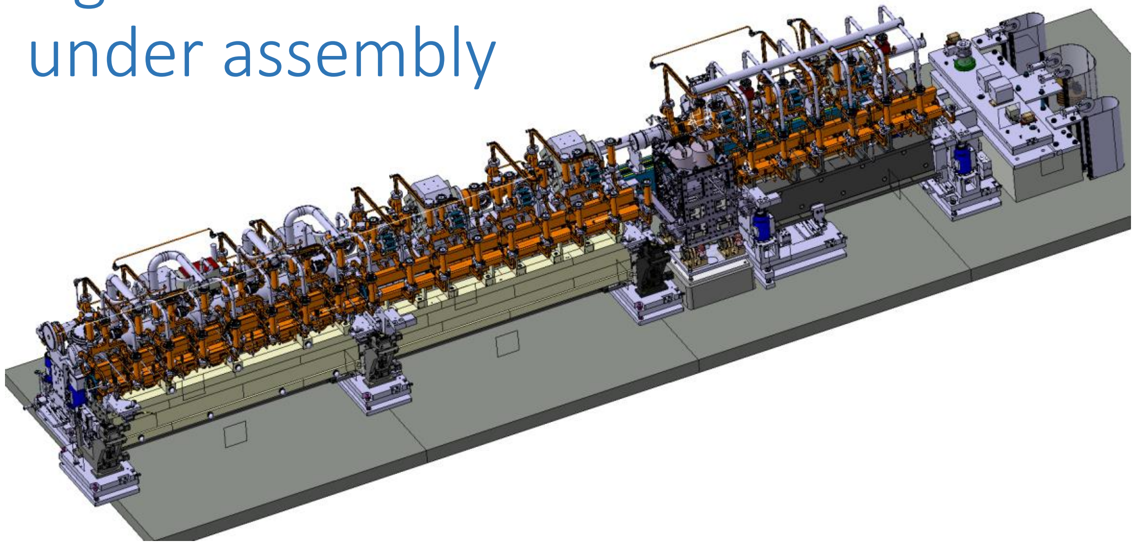
Experimental program for the CLEX module

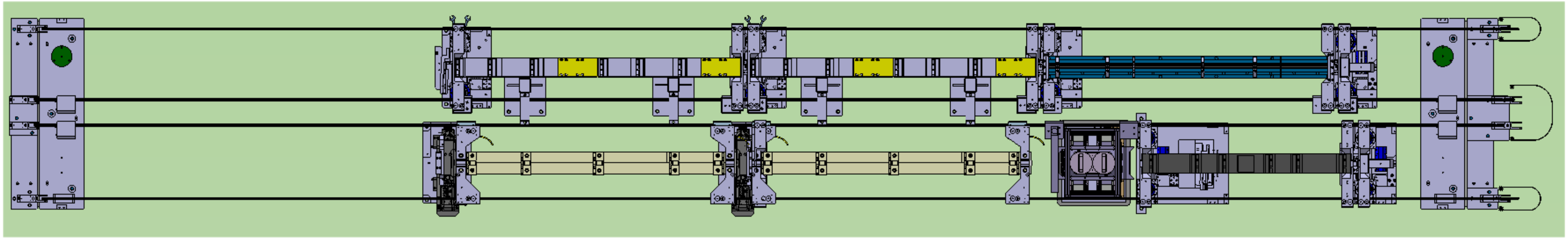
- **Two beam acceleration, rf signal consistency, power transfer, acceleration, phasing, breakdown handling, …**
- **Alignment studies, with and w/o beam, girder coupling, beam based alignment using WFM and BPM data, perturbation by accelerator noise, precision , reproducibility, fiducialisation, reliability**
- **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**

- **See for example CLIC workshop January 2016 for results so far**

State of the art

Module program in the Lab
Configuration T0-T0-T1
under assembly





Existing T0
(not affected)

New T0
(modified)

New T1
(CLEX design)

State of the art

Experimental program for the Lab-module string

- **Thermo-mechanical measurements with improved modules:**
  Alignment and temperature response measurements
  Thermal coupling between girders and modules
  Thermo-mechanical comparison of T0 and T1
  Failure modes: Control of time constants through water flow
- **Validation of numerical simulation model**
- **Outgassing of structures with SiC**
- **Module interconnects T0-T0-T1**
- **Alignment of mini module-string**
- **Girder coupling**
- **Cradle -girder link, alternatives**
- **Adjustable V-supports**

Benchmarking: «Value» model

Aim: Proper tool for evaluation and benchmarking of different design options and variants

- Current «cost» model from CDR includes monetary value of individual components

$\Rightarrow$ Extend and document CDR cost model to include updated components cost, cost for assembly and manufacturing/assembly time

$\Rightarrow$ Introduce different design options and variants and evaluate their respective cost

Criteria for assessing value of each proposed design change:

- Cost reduction
- Machine performance (achieve luminosity requirements, etc.)
- Machine robustness (aging of machine and related systems, safety margin in redundancy, etc.)
- Increase in ease of operation (reduction of operational parameters, automatisation, etc.)

Most important criteria is cost. A cost increase will only be tolerated if the other criteria suggest significant improvements.

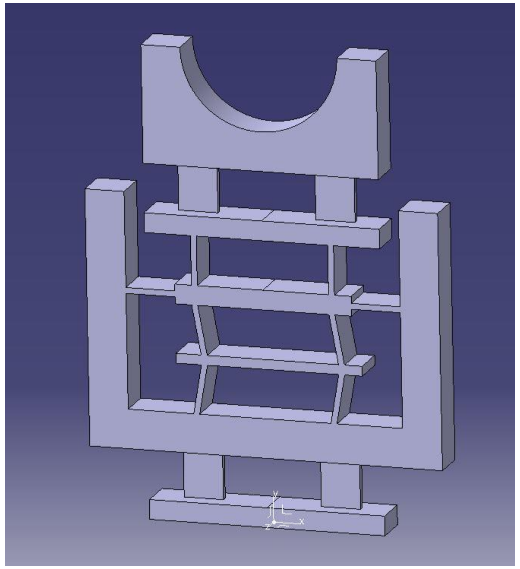
Overall optimization aim: Value increase and Cost decrease

Reevaluation of design choices

1. Relevant components **fully position adjustable**
2. Reconsideration of **relative beam positions**
3. Unified **common girder** for MB&DB and reconsideration of **girder crossection**
4. Reconsideration of **girder length**
5. Reconsideration of **girder material**

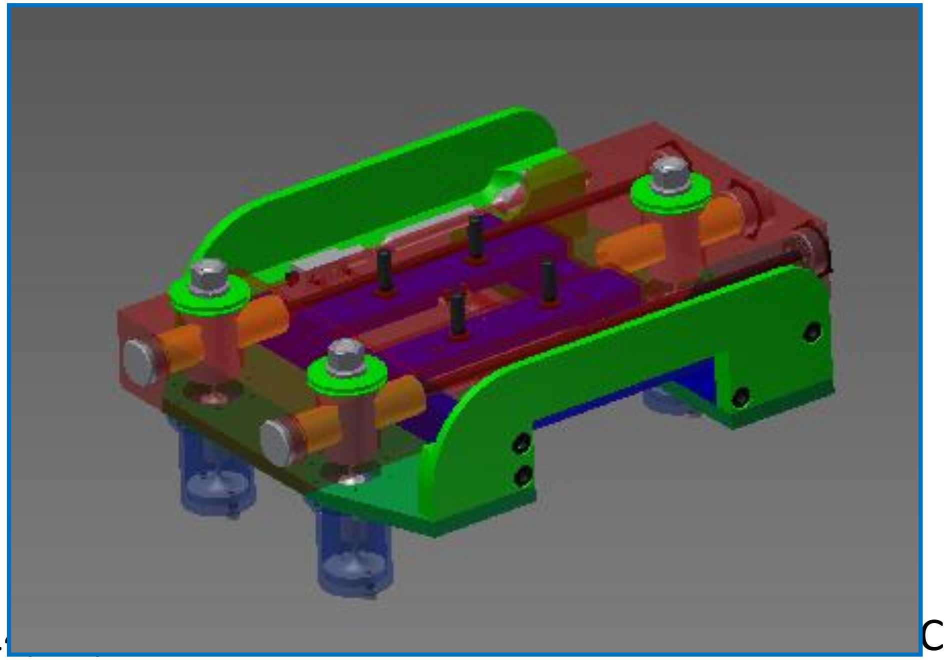
6. Ultra compact and **integrated components**
7. Reconsider concept of **«exotic modules» (T1-T4)**

All component supports fully adjustable (SAS, PETS, DBQs)



Draft for flexure based SAS/PETS support (X-Y plane adjustable; Z-axis flexible but adjusted seperately)

Prototype for 5 axis adjustable DBQ support



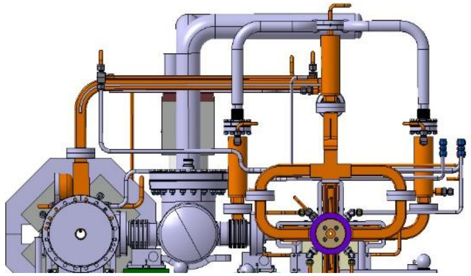
Current philosophy:
Manufacture all beam position relevant measures to extreme high tolerances -> assemble -> hope for the best

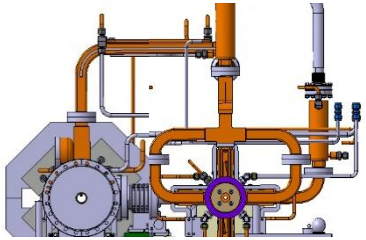
PACMAN

New philosophy (PACMAN):
Relaxe all beam position critical tolerances by orders of magnitude and make all supports of critical components fully adjustable -> assemble -> adjust a full module and fiducialize (potentially re-checking individual positions in tunnel again through fiducials)

Relative beam positions

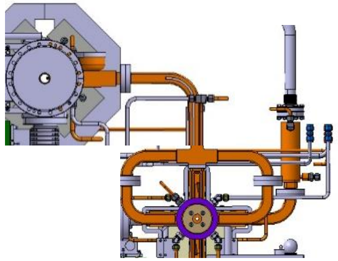
Reduce horizontal inter beam distance by e.g. 250mm to 400mm





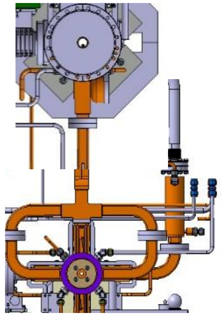
- **More compact design thanks to absence of central vacuum tank**
- **Space allocation of module in tunnel reduced (smaller footprint)**
- **Allows for more options on supporting concept**
- **Only limiting envelope: MBQ-DBQ**

Allow for vertical offset of DB being higher up e.g. 400mm



- **Potential for more compact design**
- **Easier space allocation for in/ejection of DB**
- **Easier maintenance access to DB from tunnel**

Full vertical arrangement DB on top of MB



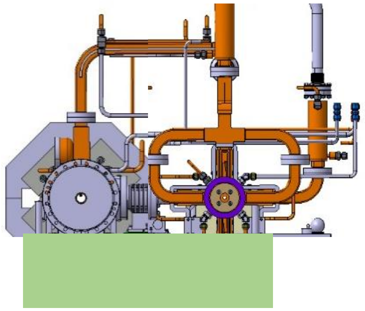
- **Minimal footprint of module**
- **Easier space allocation for in/ejection of DB**
- **Full maintenance access to DB from tunnel**

Common girder for DB and MB

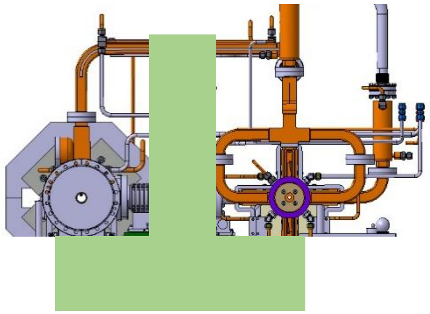
Pros:

- **Half number of actuators, controlers and survey sensors**
- **No geometrical crosstalk**
- **Big potential for integration of cabling+cooling into girder**
- **Much simpler and compact assembly and installation**

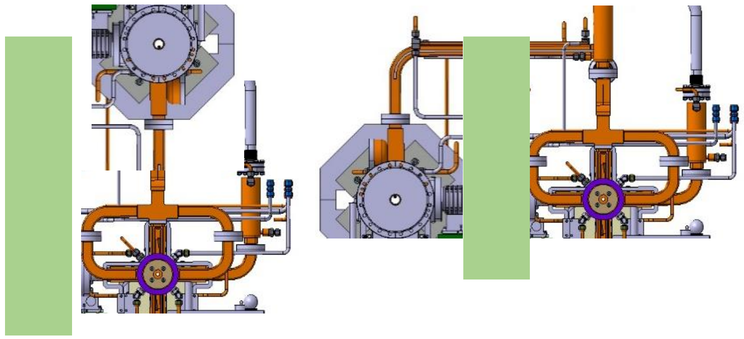
Classical: 500mm wide



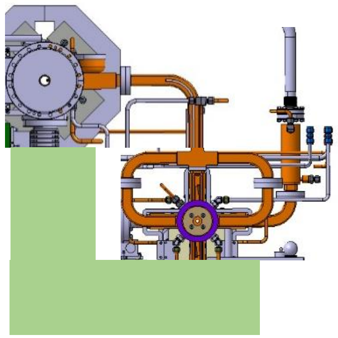
Inverse T-structure (for shielding and easier suspension of components)



Vertical girder



L-Shape girder



Alternative girder materials

Hypothesis: silicon carbide result of two major limitations:

- Limit sag to below 10um
- Limiting weight of 2m girder to approx. 250kg

Assuming fully adjustable support and an alignment «PACMAN style»; **and**
Assuming (no or very) high load limit on actuators
=> a significantly cheaper/more functional material can be considered

Two main contenders:

1. Mineral Cast (aka e.g. Epucret)
2. Structural Steel (aka black steel)

Alternatives:

- Cast steel
- Mineral concrete

Girder length

Hypothesis: 2m module length result of design choice

- DBQ positioning/correction possibilities without corrector coils
- Snake (master slave) support configuration

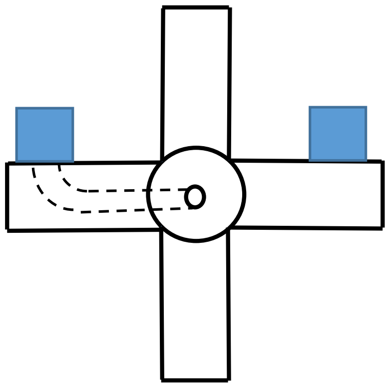
Assuming fully adjustable supports and an alignment «PACMAN style»
in principle this 2m limit could be renegotiated

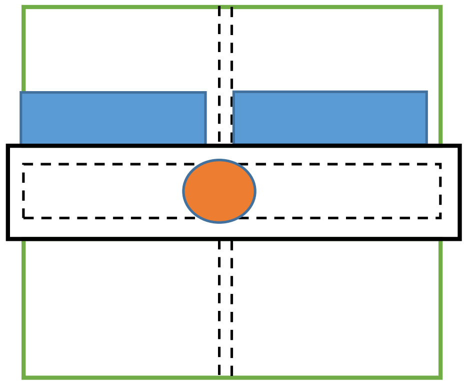
PACMAN just needs to be able to thread one common wire through all components on one girder
⇒ Difficult for 2m, potentially parabolically increasingly difficult (=> vertical module bench…)

Modules of 3m or even 4m seem *theoretically* viable

Request and assume development of more integrated components:

- super compact SAS (full length manifolds, integrated loads, optimized cooling circuit, one vacuum pumping port,…)





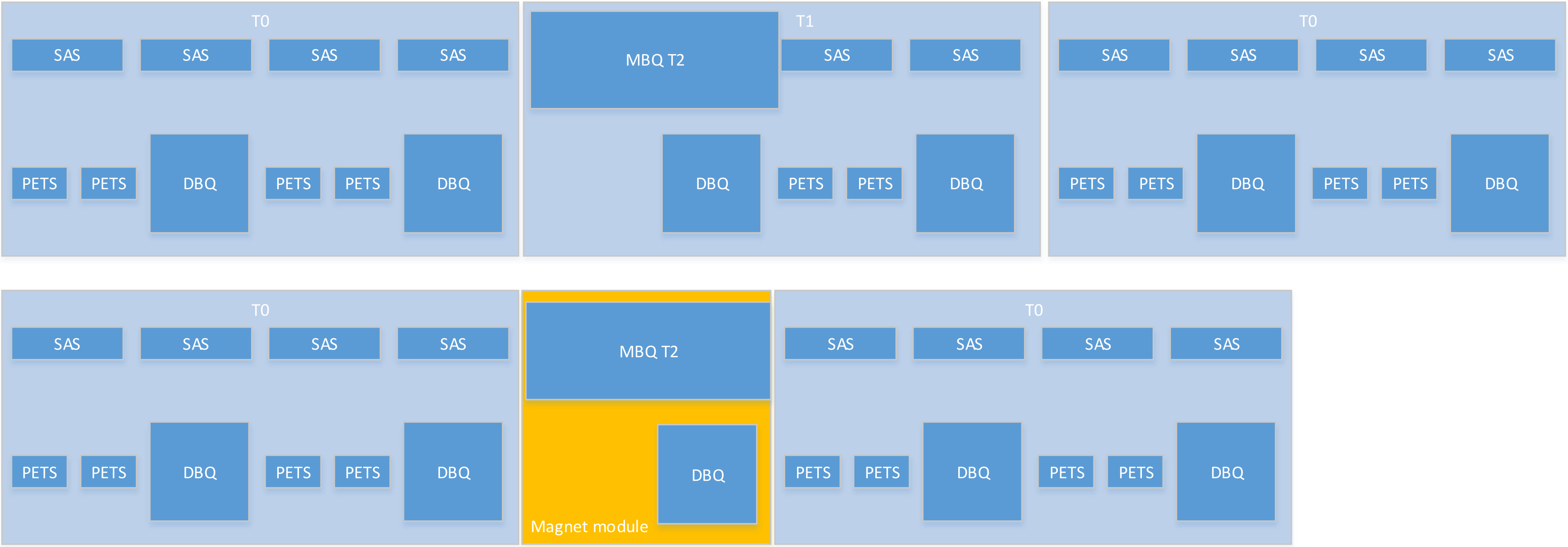
- Super compact PETS (no tank design, one vacuum pumping port, optimized cooling,…)
- MBQ magnet itself and supporting system (understanding envelope limitations)
- DBQ (understanding envelope limitations)

⇒ Entire vacuum system, sensorics, piping and cabeling could be much more efficient and clean

⇒ Much easier assembly process

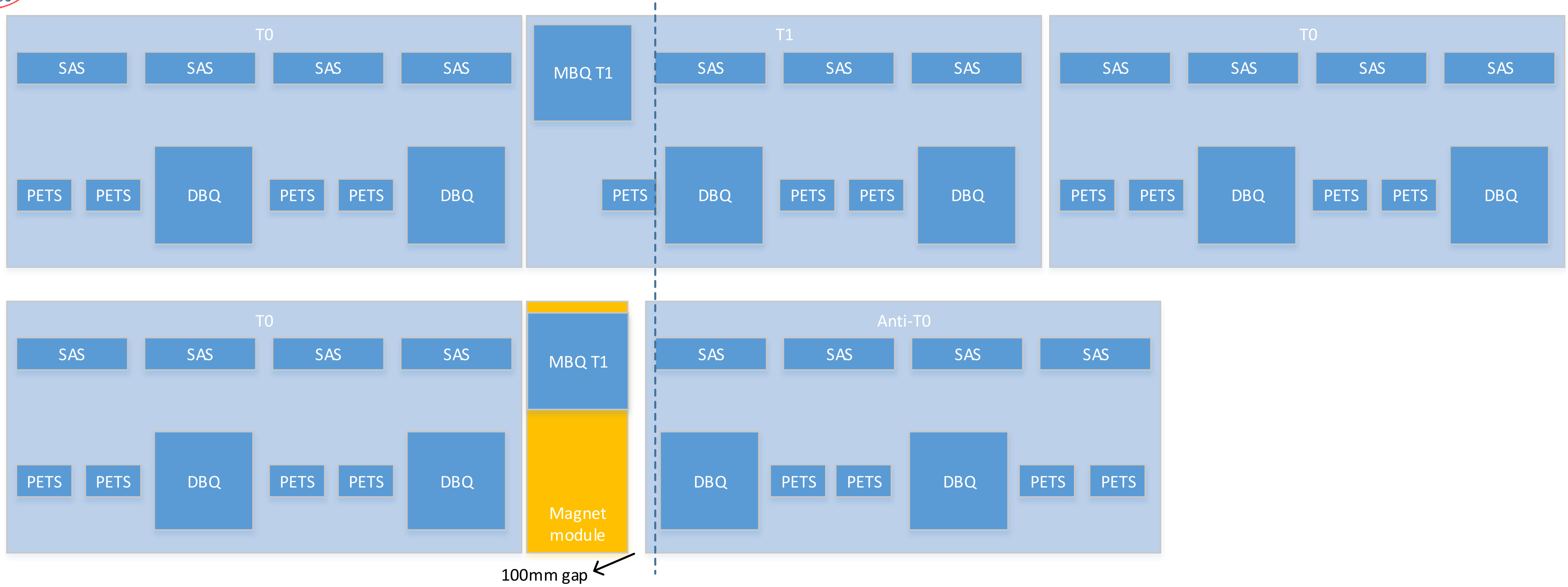
➔ More cost efficient!

Simplify module types – T2 & T4



- T2 can be replaced by a 'magnet module'
- T0s continue normally afterwards
- The DBQ can be independently supported or on half-length girder (only if 2 girder configuration remains)
- Same principle for T4s

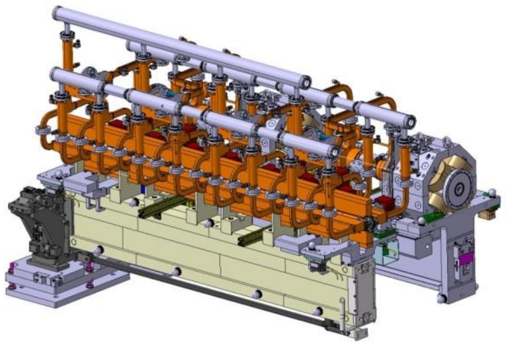
Simplify module types – T1 & T3



- T1 replaced by magnet module
- ‘Anti-T0’ continue afterwards until next MBQ
- Anti-T0 identical to T0 but inverted
- 10cm gap needed – 0.3% effect on filling factor (i.e. 65m of tunnel)
- MBQ length can be revisited, multiple lengths easily adapted
- Same principle for T3s

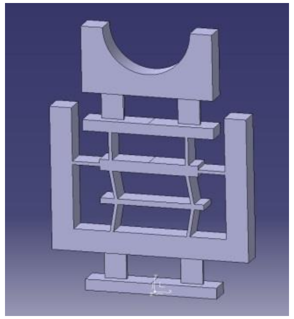
Summary

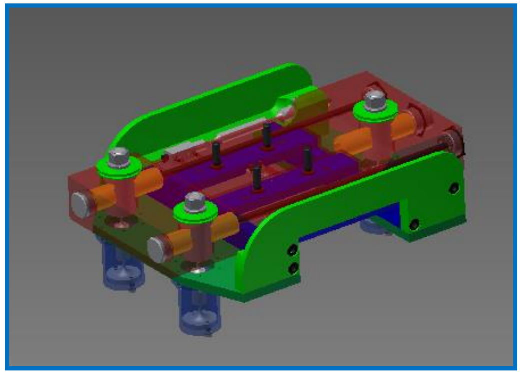
- CLIC module history and horizon

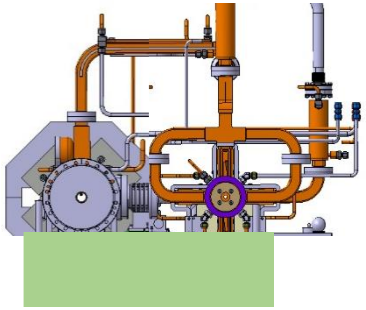


- Benchmarking: Cost model

- Reevaluation of design choices







Thank you for your attention!