Muon Collider Magnet Moving For Neutrino Mitigation

C. Accettura, F. Bertinelli , A.Kolehmainen, T. Räty
With several inputs of C. Carli, P. Borges de Sousa, L. Bottura, S. Fabbri, K. Skoufaris

IMCC Annual Meeting

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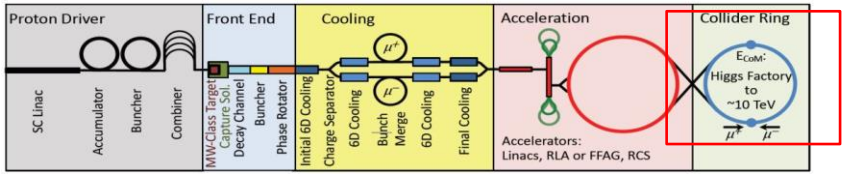
Outline

- Introduction and motivations
- Assumptions
- Magnet alignement and lay-out change jack system – Solution 1
- Combined jack – Solution 2
- Tunnel space
- He supply
- Changing magnet lay-out
- Conclusions

Collider ring neutrino radiation mitigation



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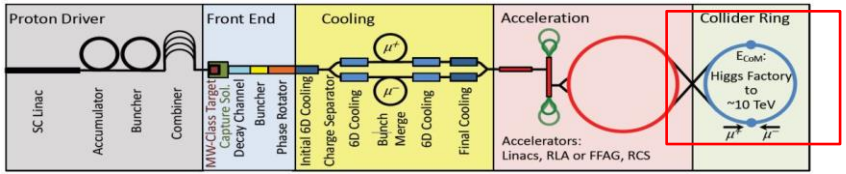

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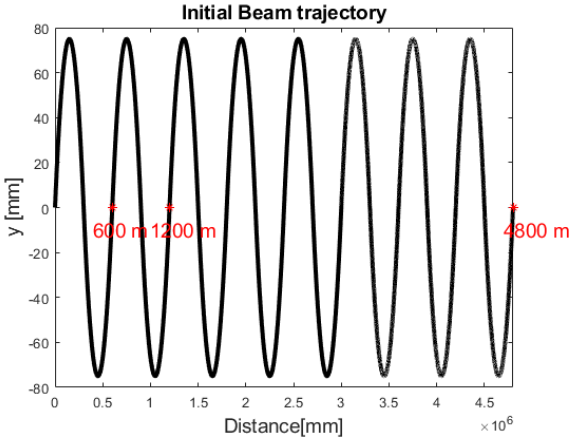

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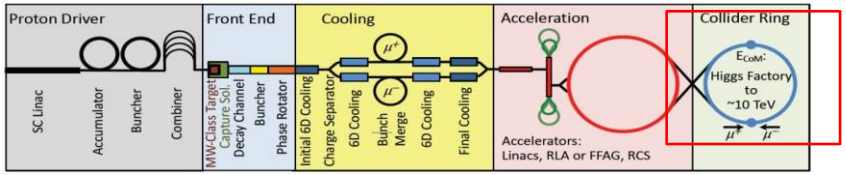

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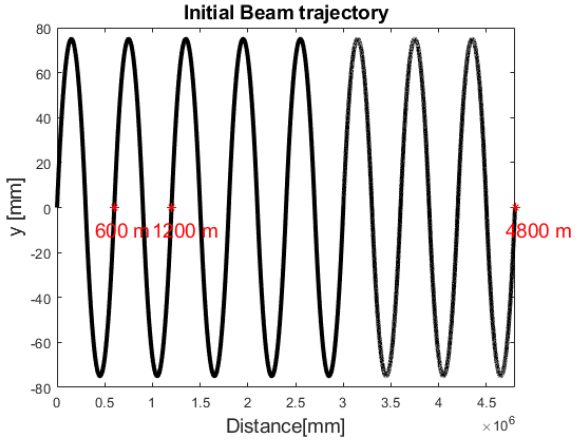

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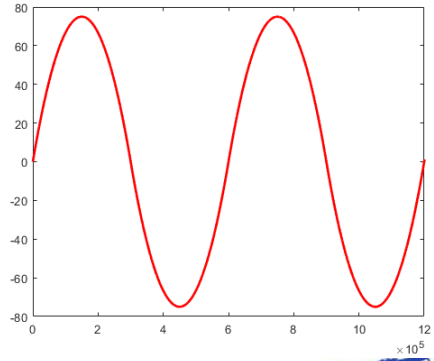

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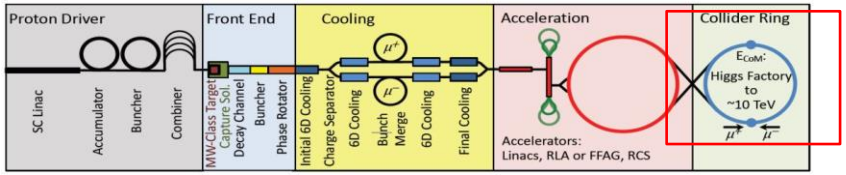

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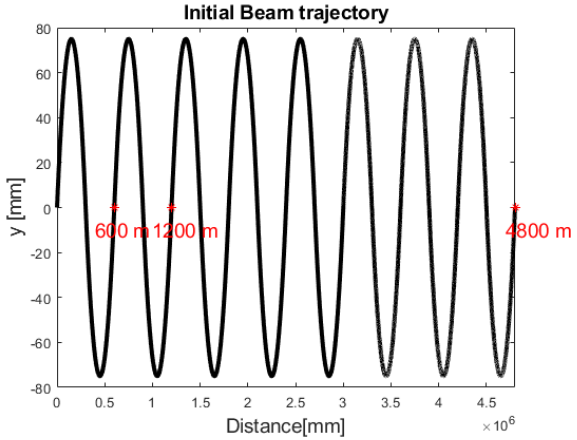

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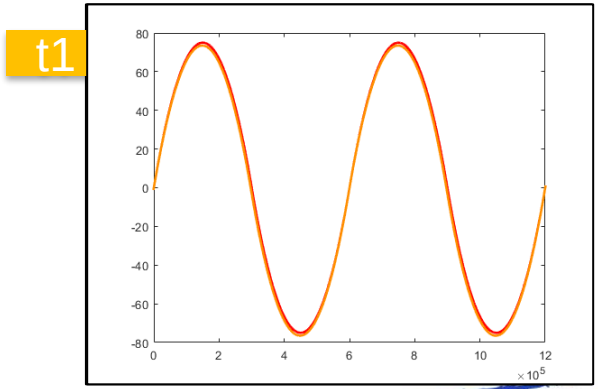

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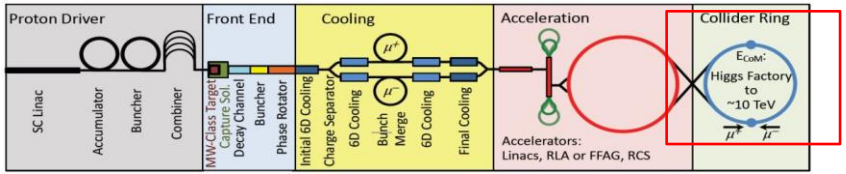

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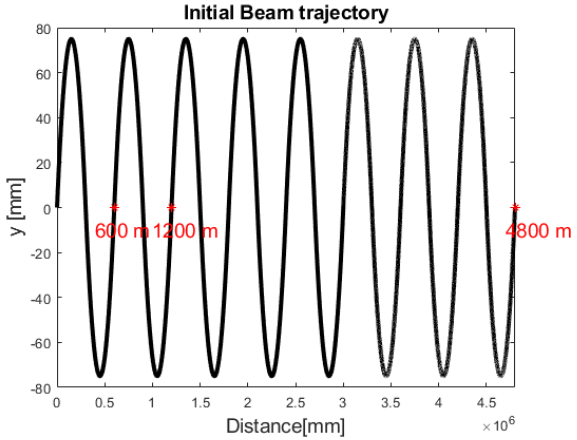

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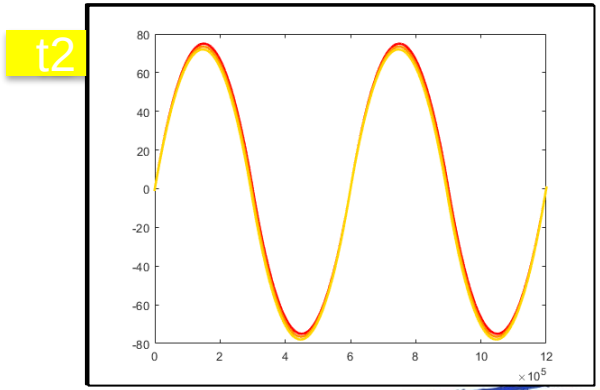

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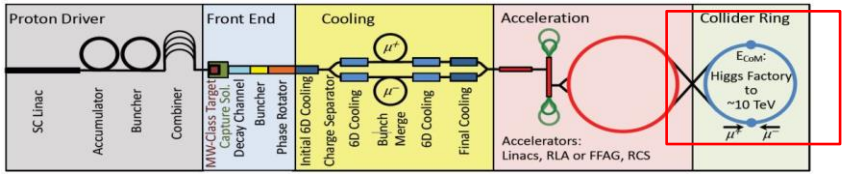

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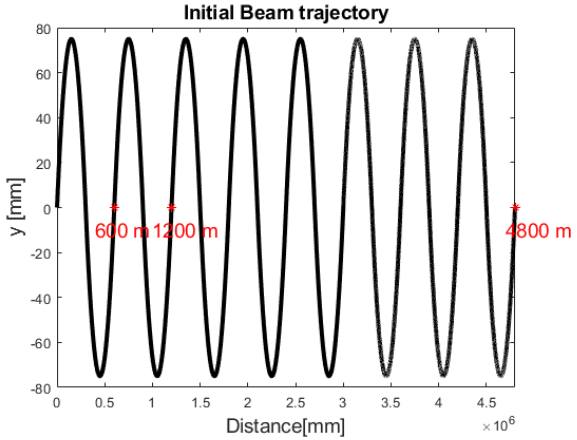

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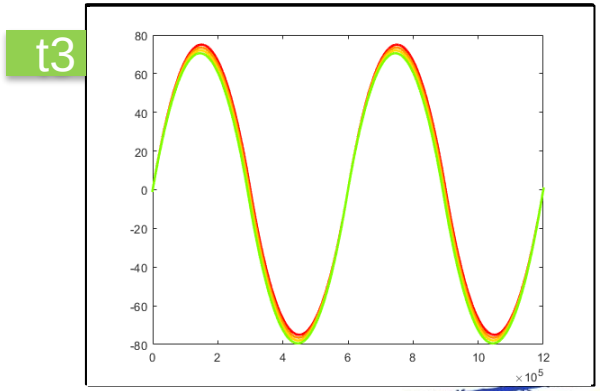

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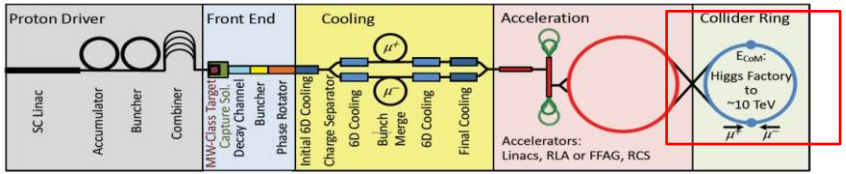

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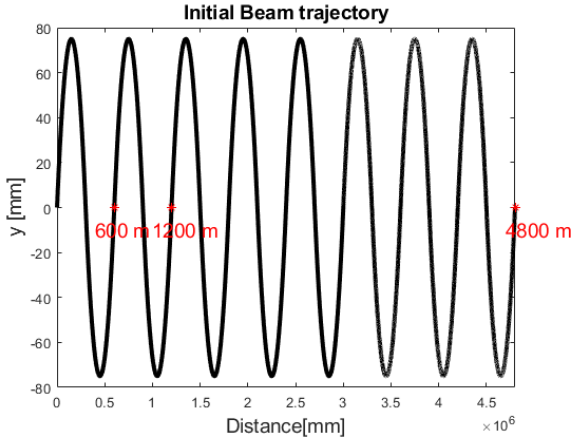

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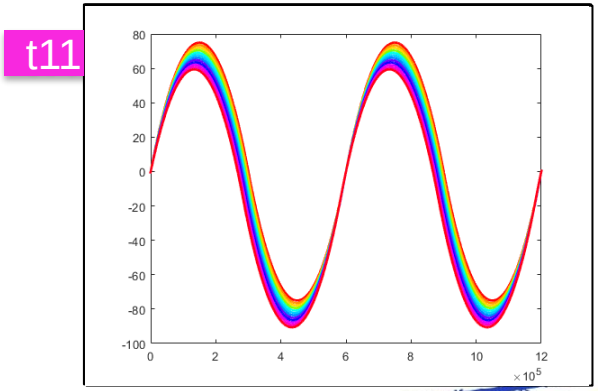

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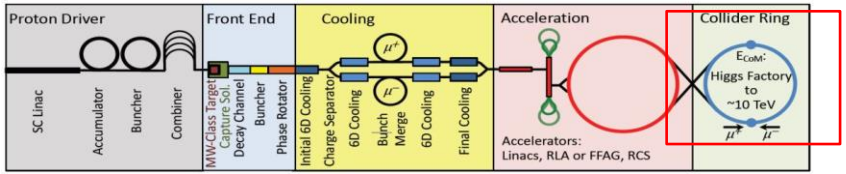

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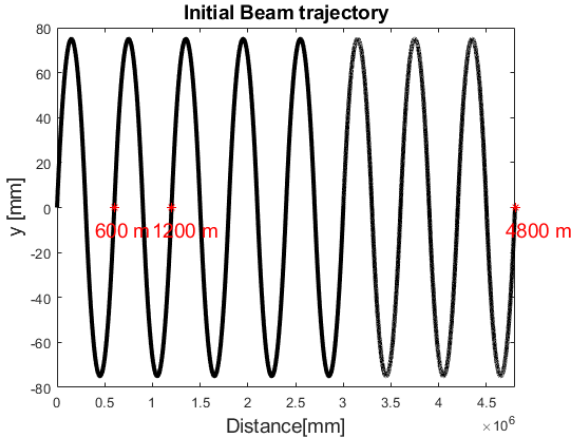

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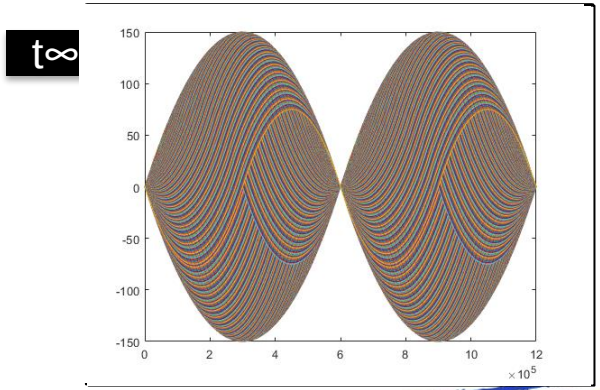

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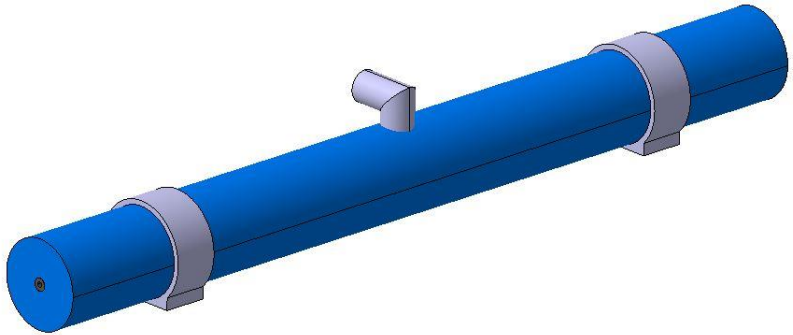
- **DIPOLE MAGNET MODEL**
  - Inspired by LHC magnets
  - L = 10 m, D = 1 m
  - Mass: 24.5 T approximately(based on LHC D2 magnet and W-shield model)
  - Length of interconnection = 500 - 800 mm(coldmass – coldmass)
  - Cold bore Ø50 mm
  - Three jack supporting
  - Radiation similar to LHC – See talk of Claudia Ahdida for details!



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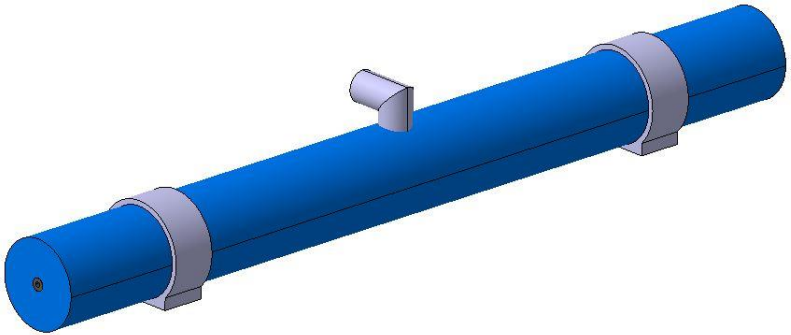

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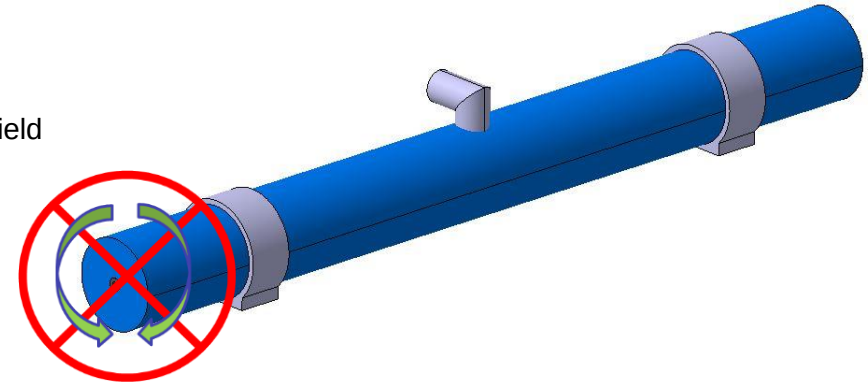
- **MOTORIZED MAGNET MOVEMENT:**
  - Only vertical movements have been studied
  - Horizontal field (for vertical kick) not given by magnet tilting (i.e. Correctors are needed)

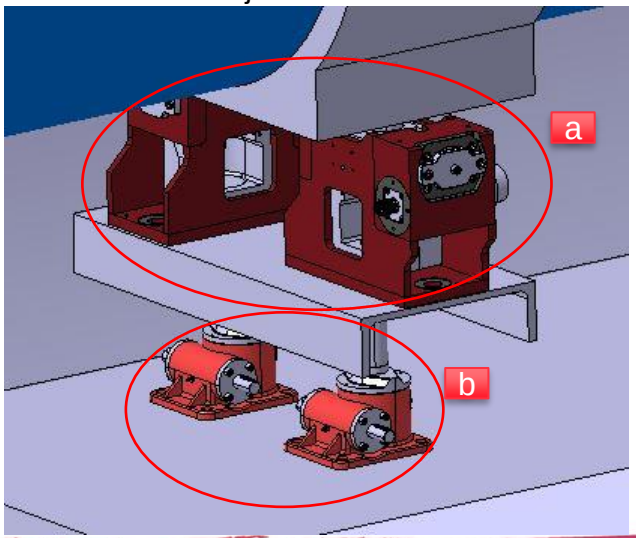


Overview of proposed solutions

- **Solution 1: TWO JACKING SYSTEMS**

a. **ALIGNMENT JACKS**
- Magnet alignment
- HL-LHC Jack

b. **MOTORIZED JACKS**
- Only vertical movement
- Commercial jack



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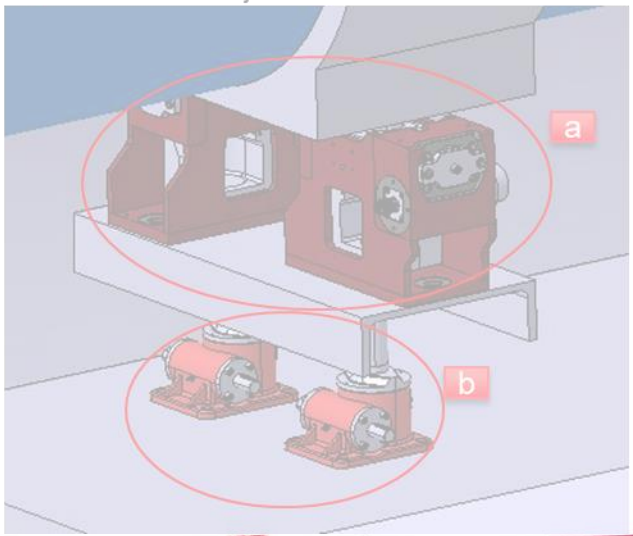
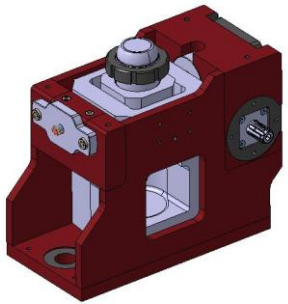
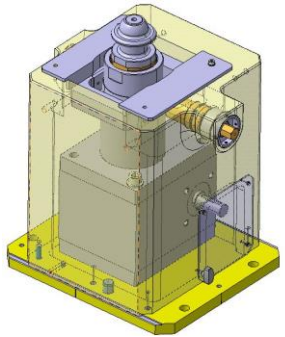


- **Solution 2: COMBINED JACK**
  - Combine the functions of the two jacks – alignment and lay-out change
  - Muon Collider specification requires a new design – concept work initiated with a jack supplier

HL-LHC JACK
- Max load 17 T
- Vertical stroke ±20 mm

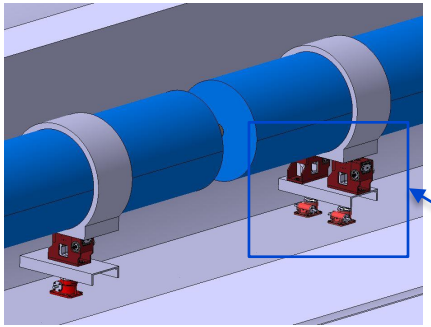


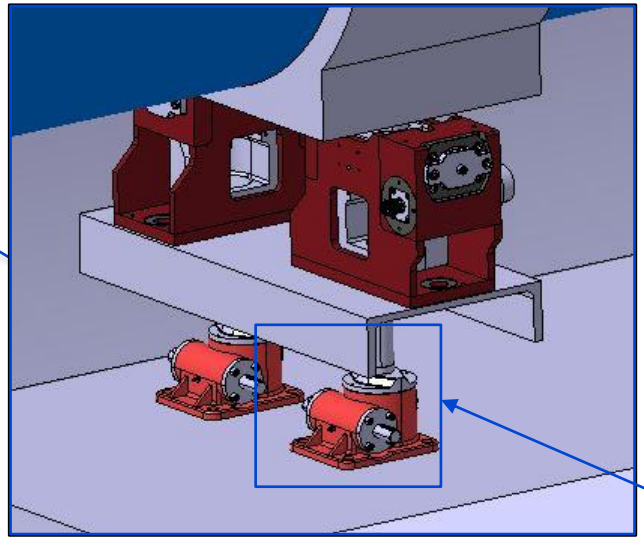
L4 JACK – inspired by LHC jack
- Max load 5 T
- Vertical stroke ± 15 mm
- Commercial wormgear jack



Both require three jacks together to create an isostatic support system!

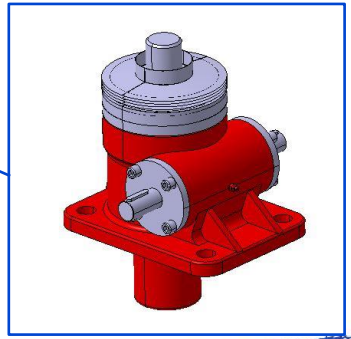
Two jacking systems – solution 1





COMMERCIAL JACK

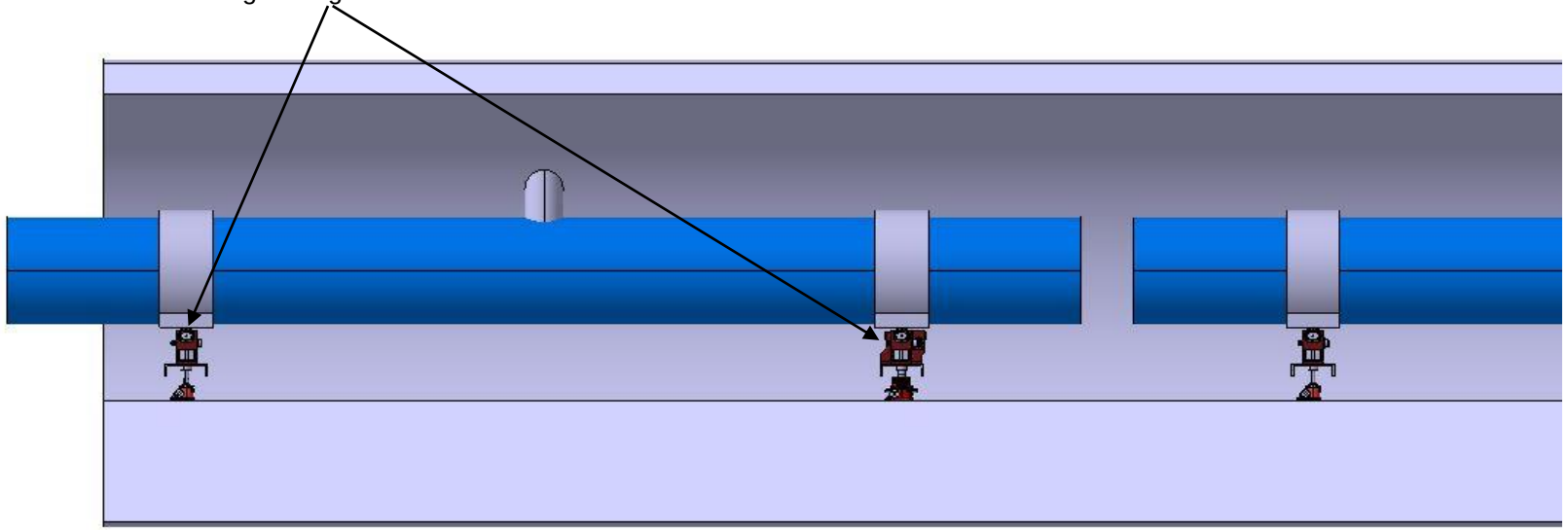
- Precision: ± 0.5 mm
- Mechanically driven
- Self-locking mechanism



Challenges: Alignment and lay-out change

ALIGNMENT JACKS

- Magnet alignment



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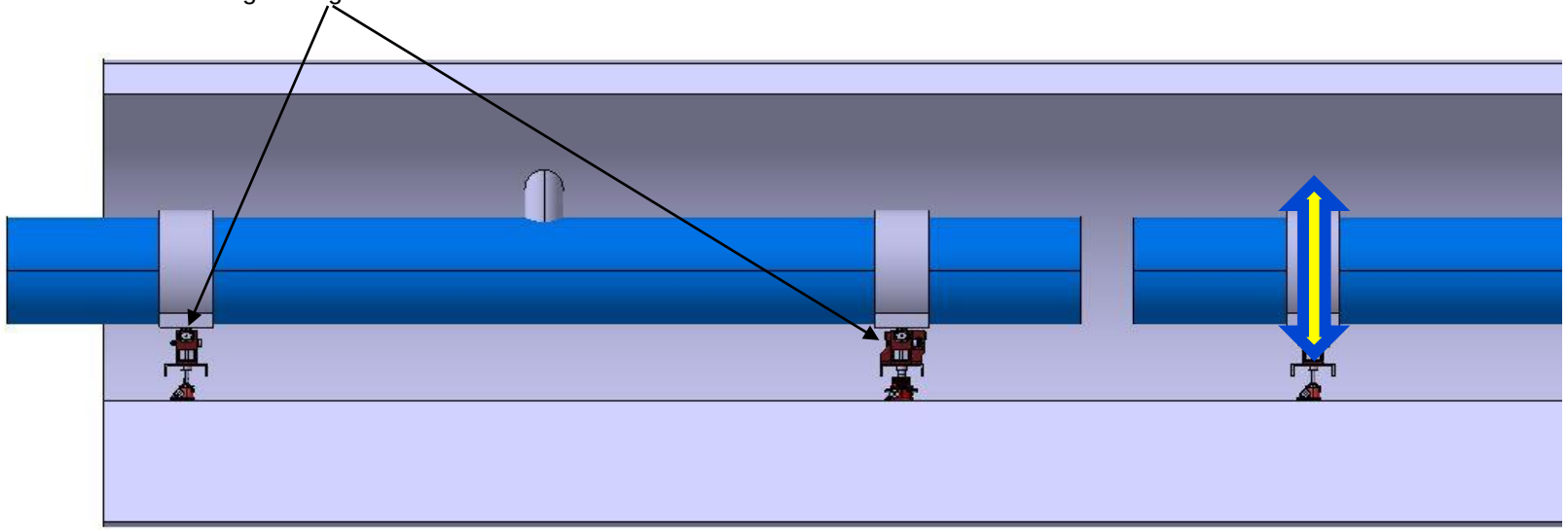
MOTORIZED JACKS
- Vertical movement ±50 mm

ALIGNMENT JACKS
- Magnet alignment



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ALIGNMENT JACKS
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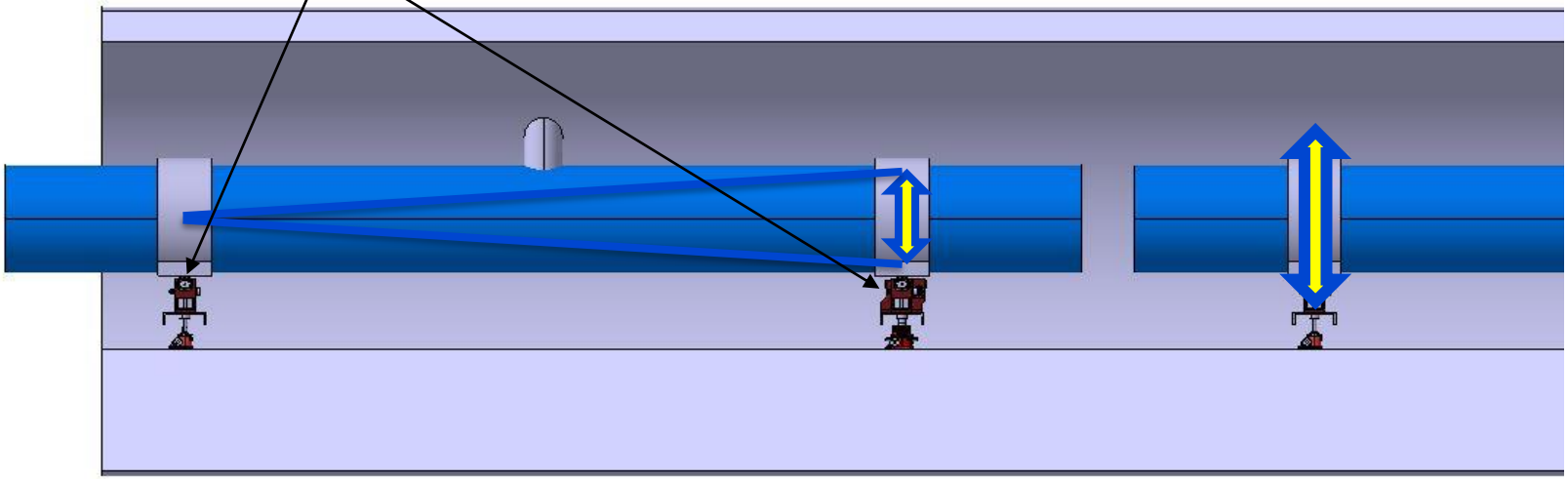
MOTORIZED JACKS
- Vertical movement ±50 mm
- Magnet tilt
- Parasitic movements in the alignment jack(< 3μm)



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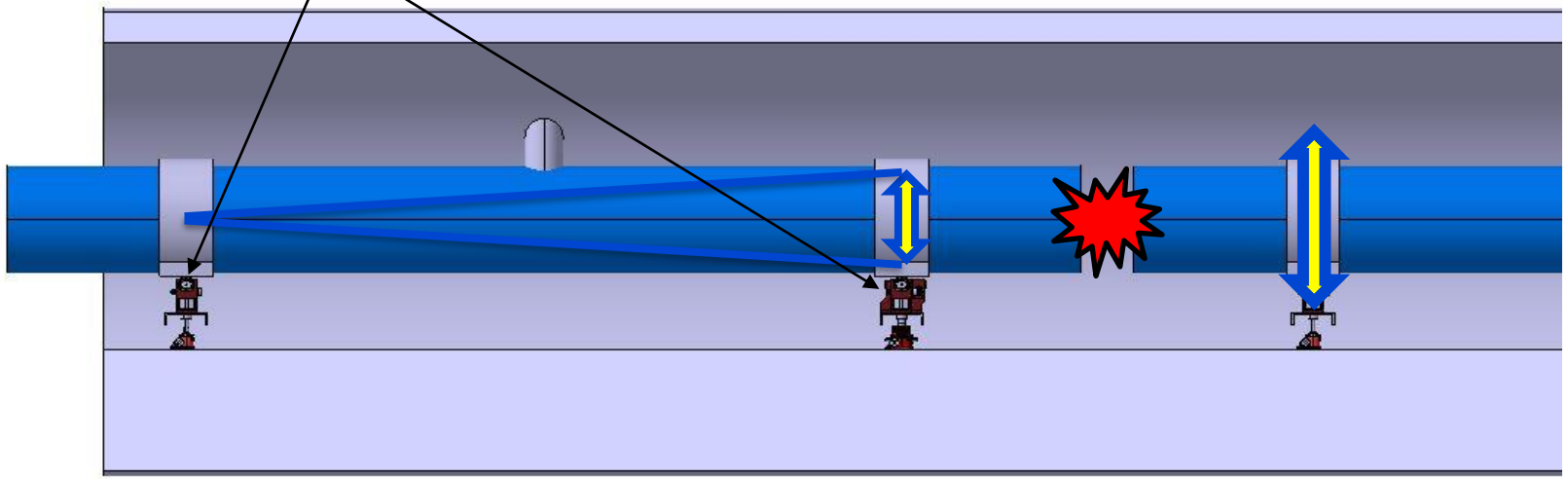
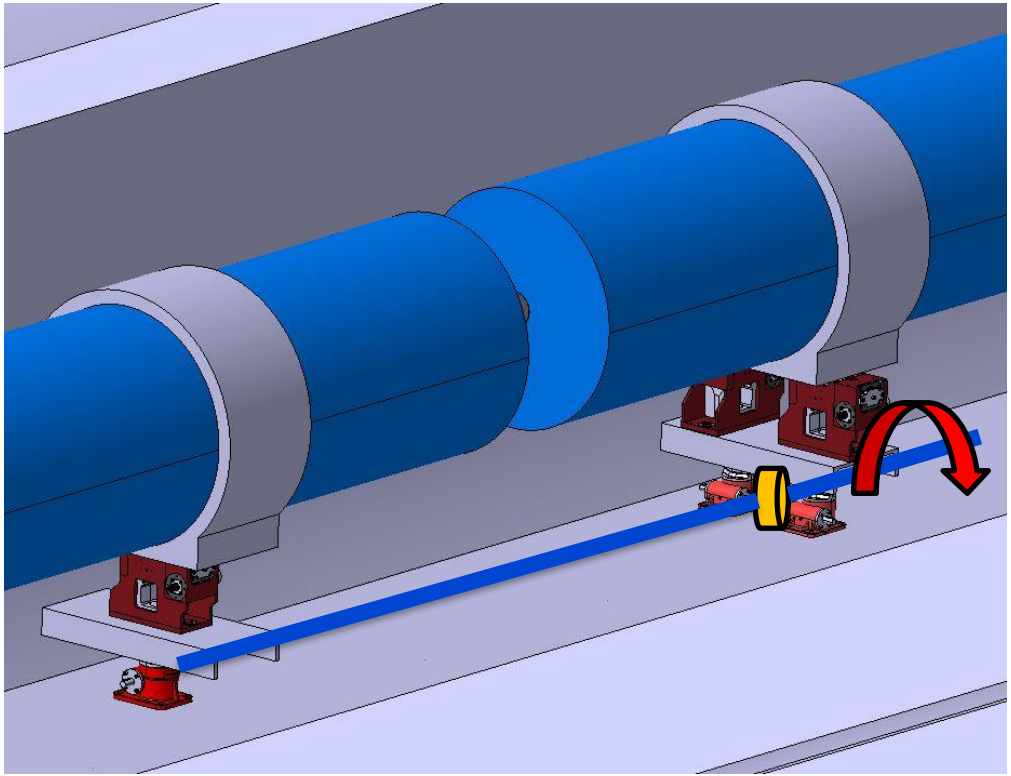


Maximum stroke in opposite direction over the interconnection will destroy the bellows!
SAFE OPERATION SHALL NOT RELY ON THE CONTROL SYSTEM!

Two jacking systems – solution 1a

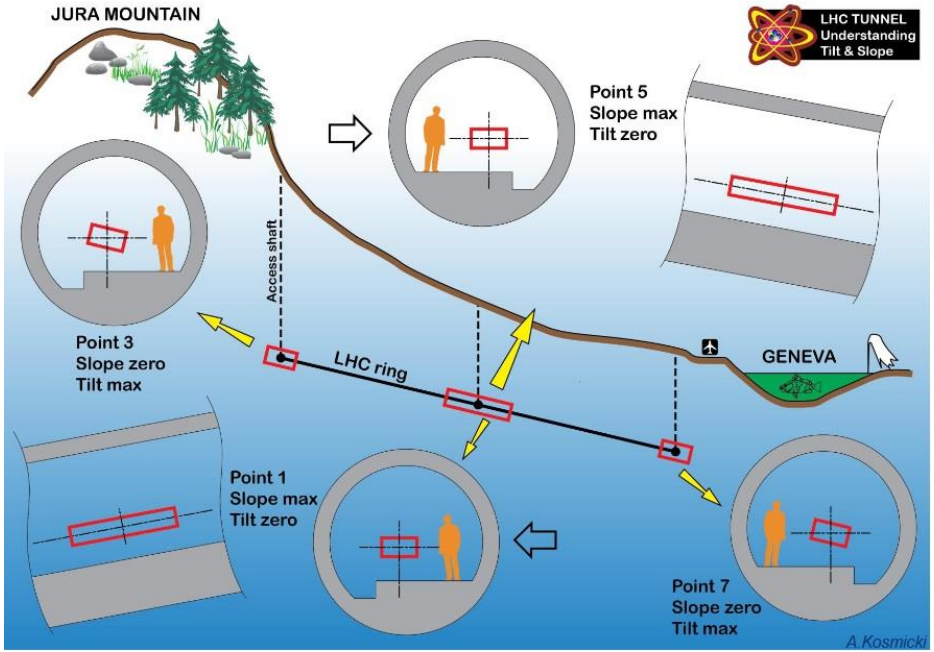


- **PARALLEL OPERATION OF JACKS ACROSS THE INTERCONNECTION**
  - Connect jacks mechanically
  - 4-way gearbox
  - Shafts
  - Single motor on the gearbox
  - IN STUDY – redundant system with two motors, requires two gearboxes

- **BELLOWS OFFSET BLOCKED**
- **ANGLE BETWEEN MAGNETS ALLOWED**

Supporting of motorized jacks

- **BENDING MOMENT ON THE MOTORIZED JACK**
  - From magnet tilt or roll due to the tunnel



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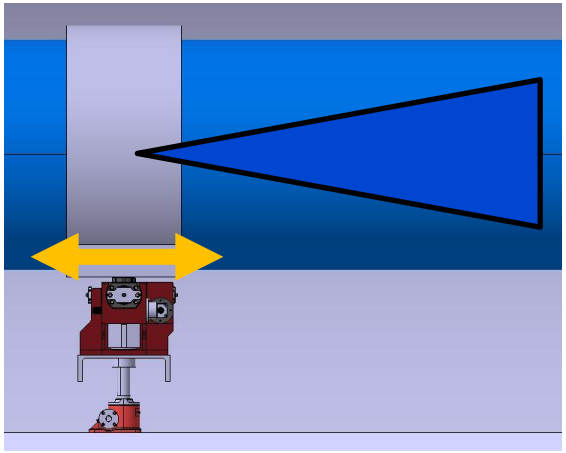

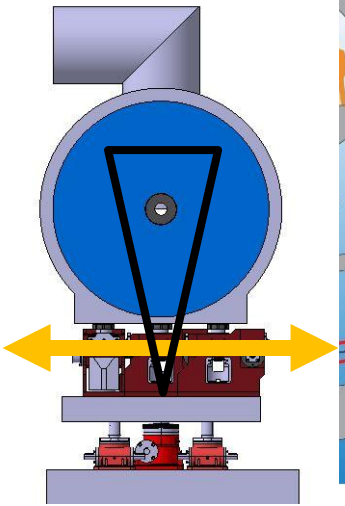

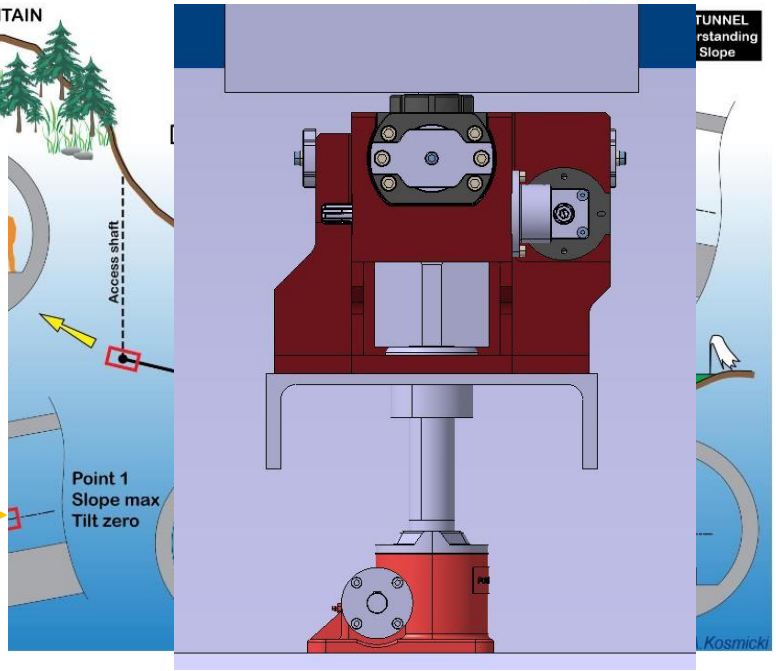

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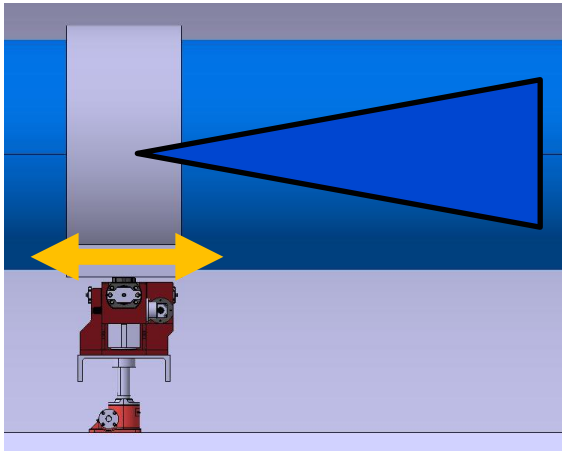
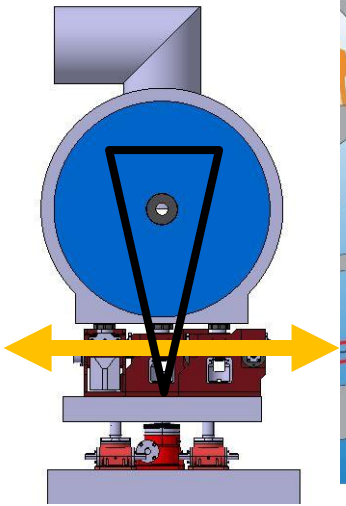
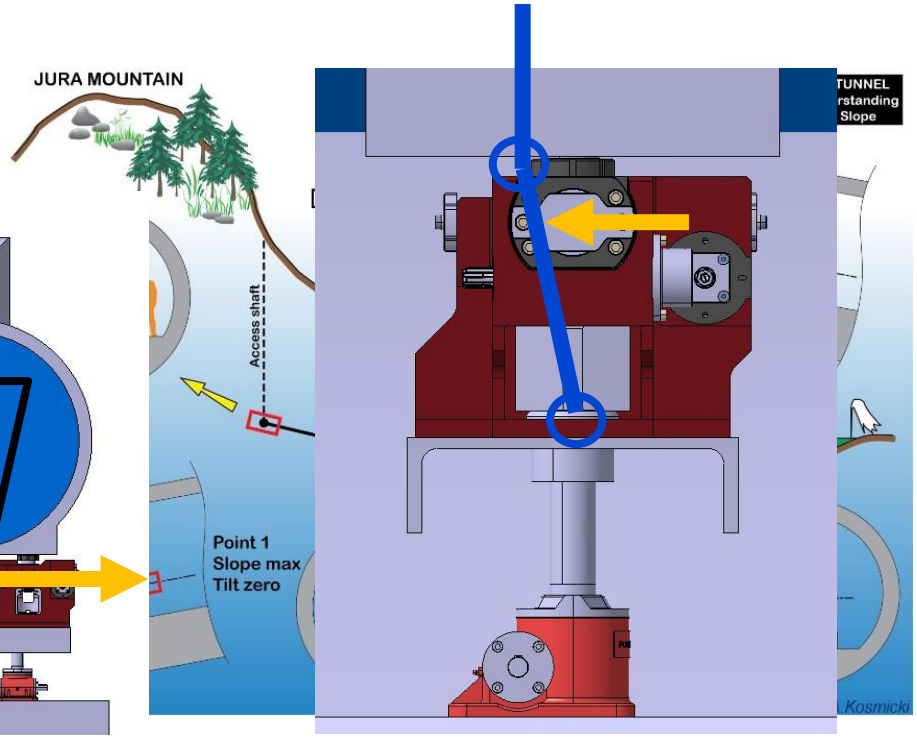
- **BENDING MOMENT ON THE MOTORIZED JACK**
  - From magnet tilt or roll due to the tunnel
  - From maximum lateral stroke of the alignment jack

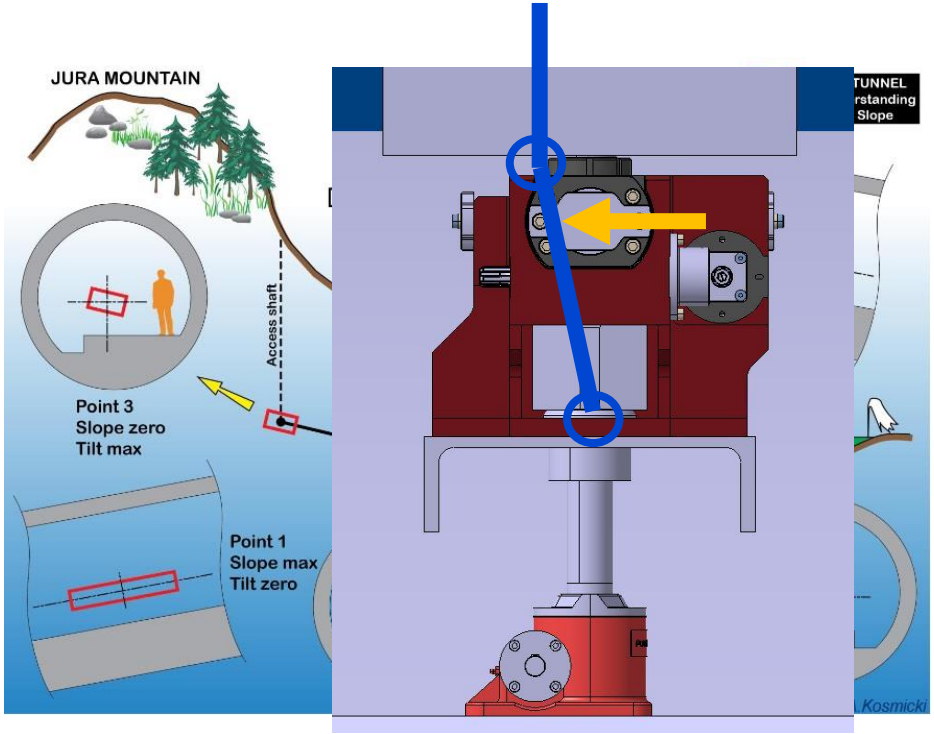




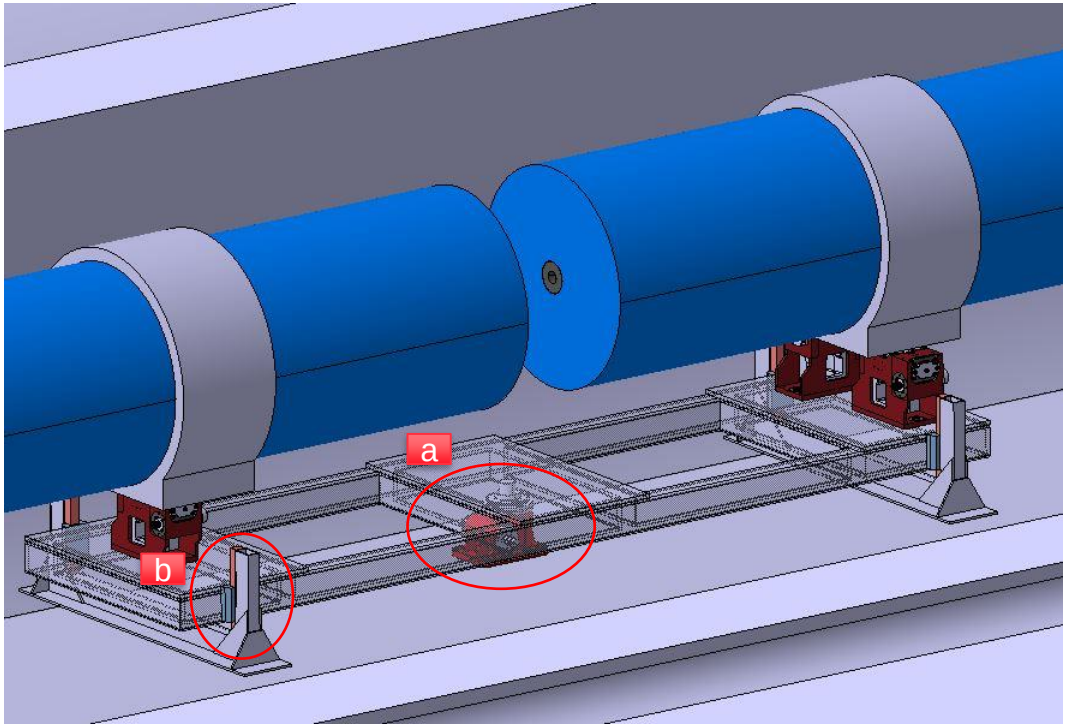


Supporting of motorized jacks

- **BENDING MOMENT ON THE MOTORIZED JACK**
  - From magnet tilt or roll due to the tunnel
  - From maximum lateral stroke of the alignment jack
  - To be calculated for different motorized jack options
  - Compare with allowed moments for the motorized jacks
  - Higher the stroke – higher the moment
  - **Motorized jacks may need supporting guides to protect them from bending moments!**



Two jacking systems – solution 1b

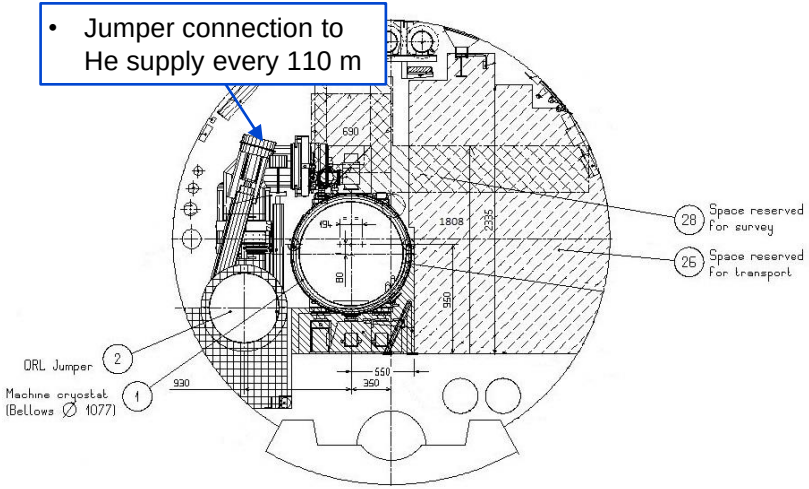


- **ALIGNMENT JACKS ACROSS THE INTERCONNECTION ON COMMON PLATFORM**
  a. One central jack for the height change
  b. Platform must have linear guides to avoid bending moment on the jack
  - One motor per interconnection = magnet
  - Motor for redundancy required?
- **Bellows offset blocked**
- **Angle between magnets allowed**

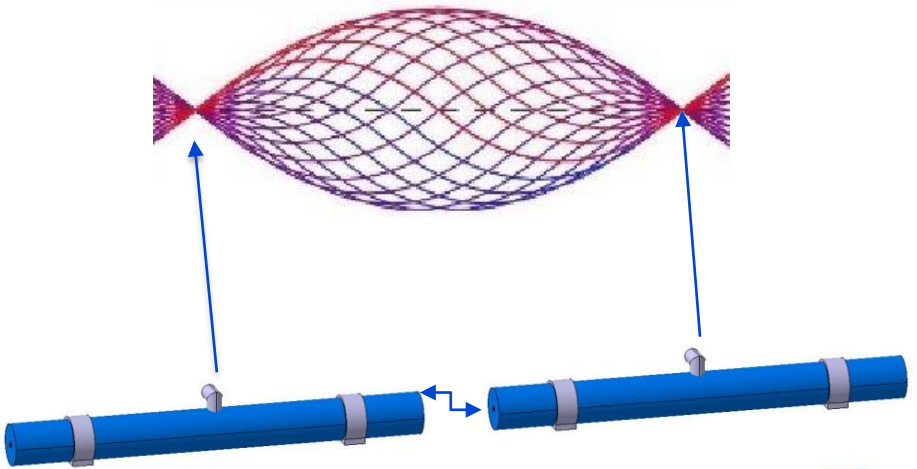
He supply

- **LHC TUNNEL**

- Jumper connection to He supply every 110 m

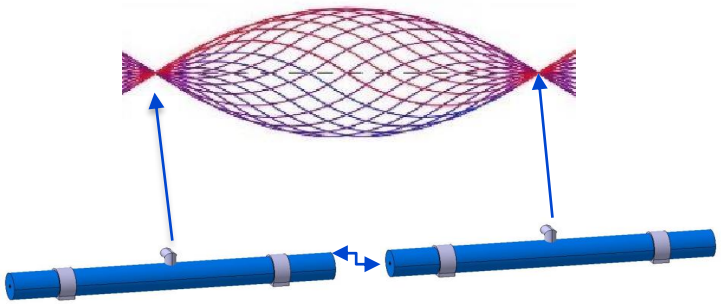


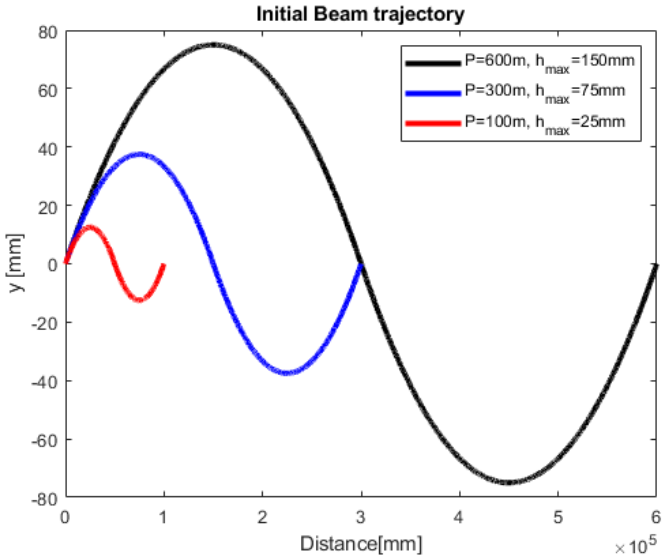
- **MUON COLLIDER TUNNEL**
  - Must be placed around the period node points – current jumper designs do not allow the vertical movement of the collider dipoles w.r.t rigid cryogenic supply installation



He supply

- **MUON COLLIDER TUNNEL**
  - First estimation: He supply at the ~LHC distance→ ~100m
  - Reduction of period
  - Reduction of maximum vertical displacement→ ±25 mm
  - Stronger vertical kick (horizontal field)





Power

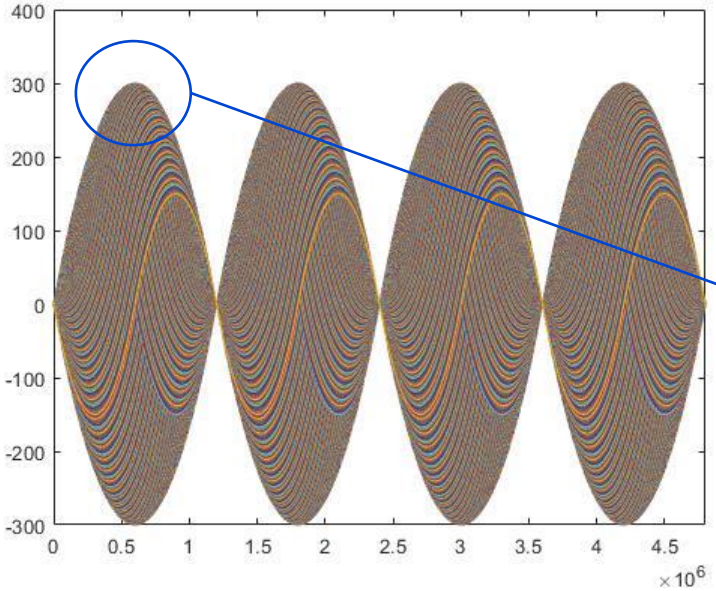
- **200 days of physics annually leads to 400 trajectory changes→ 20 years 8000 changes**
- **Powertotal = Nmagnets X Njacks X Powermotor ,if 10 m dipoles and 0.8 m interconnection > 800 magnets**

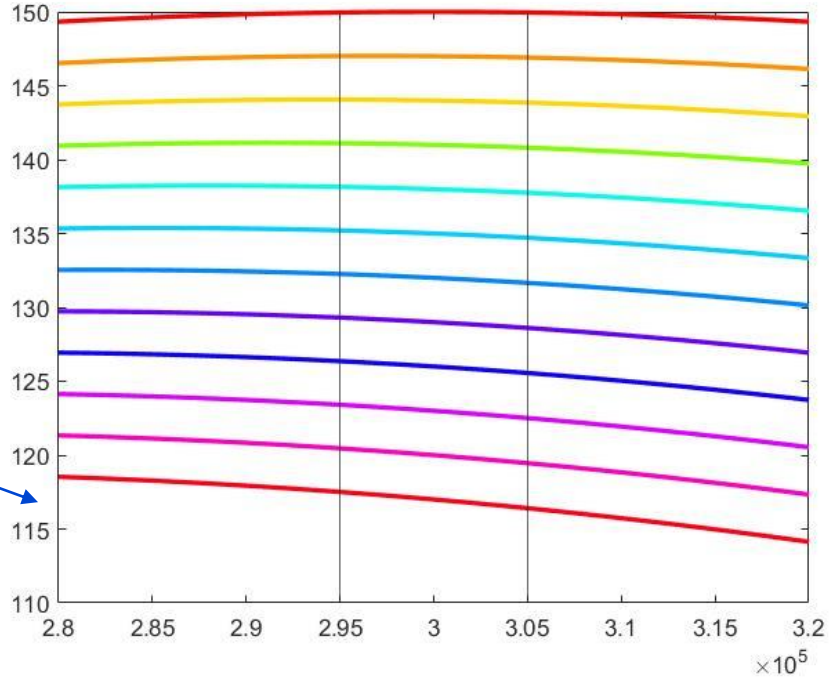
- **With 1 kW motor around 1 MW for parallel operation of jacks**
- Control system for movement and monitoring
- Reliable push-button lay-out change!
- Do we need to confirm measurements with external system?

- **Assume change propagated in smaller groups**
- Max number of motors to be defined
- Assume: group of 50 motors -> around 20 groups to move
- 3 minutes per group leads to one hour

Beam trajectories vs. Magnet movements

- **MAGNET APERTURE:**
- Can we accommodate several trajectories into one magnet?





Conclusions

- **In order to mitigate the neutrino radiation, the possibility of having moving magnet around the collider ring has been studied**
- **So far, no showstopper have been individuated, however open points to be clarified**
- ±25 mm seems ok for cryogenic and for jack mechanics→ is it acceptable? Increase of factor 6 in the horizontal magnetic field (~0.67 T)
- Two solutions to move the magnets presented→ is the precision enough (~0.1mm)?
- Can we extend this approach to all the muon collider arc magnets?

Next step

- **Concept selection and design engineering**
- **Two-magnets mock up-What do we need?**
  - 6 LHC jacks
  - 2 dipoles (2 LEP dipole magnets + additional weight? LHC dipoles? Resistive magnets?)


International
MUON Collider
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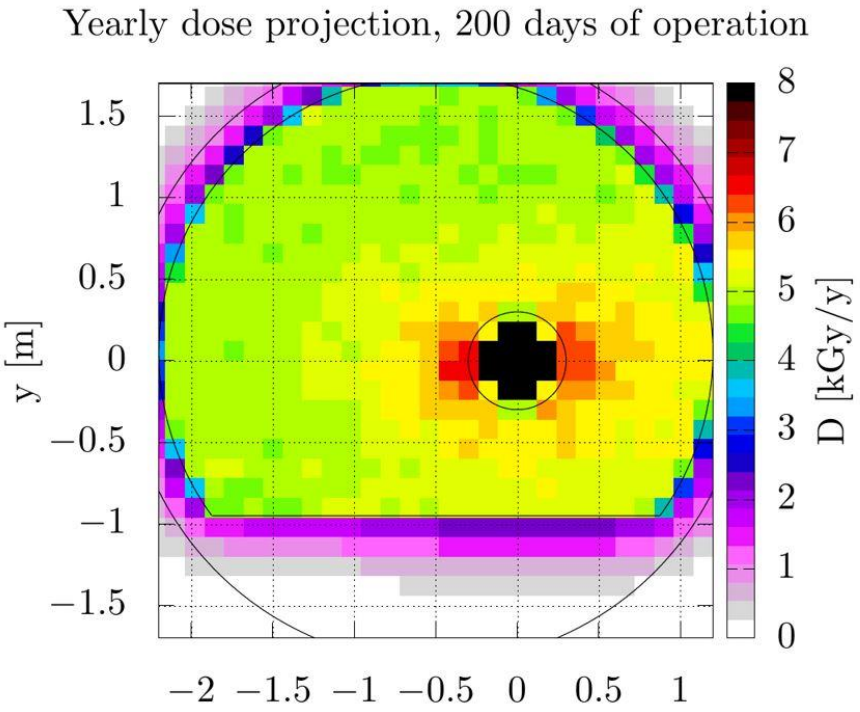
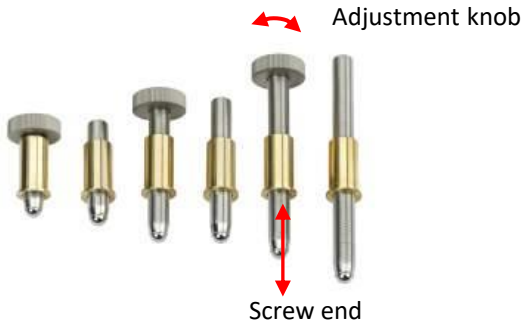
Thank you
for your attention!
Your questions please?

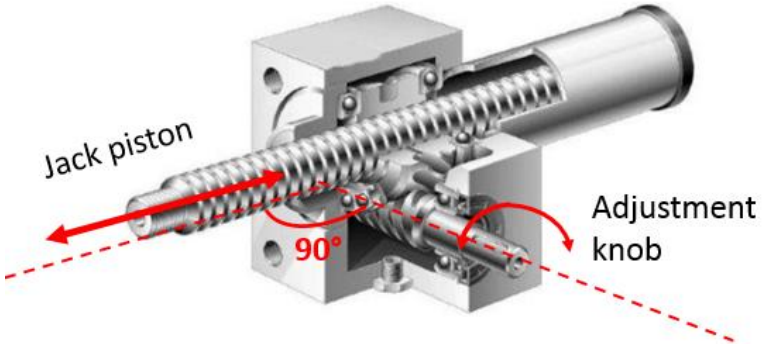
RADIATION



Courtesy of Daniele Calzolari

Real impact of play in adjustment jigs (screw mechanisms, jacks) on adjustment performance





- **<u>Simple screw adjustment</u>**
  - Play (seen on *screw end*) depends on quality of the thread machining
    - For typical machined threads (M x, Tr x, etc …) – play at *screw end* can vary from tenths um-s to even mm for bigger screws
    - For ball screws play depends on fitting quality – it is much lower than for ‘standard’ threads (typically 0 .. 20 um)
  - Angular backlash ‘seen’ on adjustment knob is proportional to screw pitch

<u>More complex mechanisms (e.g. power jack)</u>

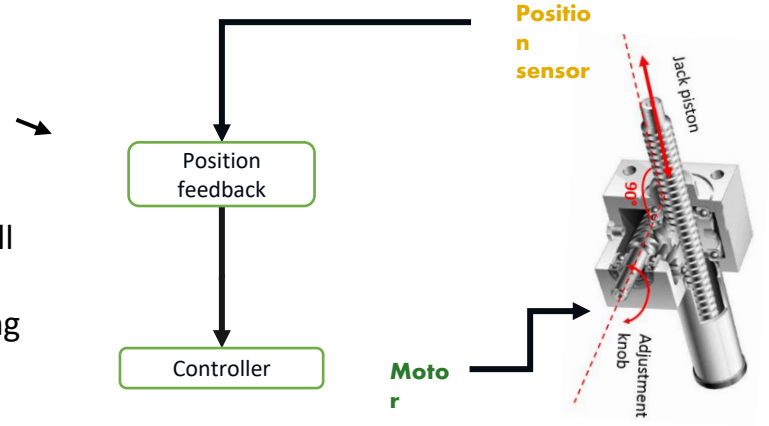
Play (seen on jack piston end) depends on quality of the *Jack piston* thread machining, and is relevant as in simple screw mechanisms
Backlash seen on *Adjustment knob* is much bigger and depends on *Jack piston* thread play and worm mechanism play

Real impact of play in adjustment jigs (screw mechanisms, jacks) on adjustment performance

- **For mechanisms using adjustment screws, the preloading of screws/thread pair plays big role to get best adjustment performance**
  - For pre-loaded ‘classical’ screws, the resolution (minimum motion) and precision (repeatability of position) of adjustment is typically in range of ~5..50um (this is e.g. classical configuration for vertical screws, supporting the load of adjusted components; for radial adjustment pre-loading springs are useful, to suppress screw play)
    - Pre loading of ‘classical’ screws can give resolution/precision parameters which are satisfactory and even comparable with ball screws in some cases
  - For non-pre-loaded screws, the adjustment resolution can be still ~5..50um (in single motion direction), but precision of adjustment will be defined by play on screw/thread

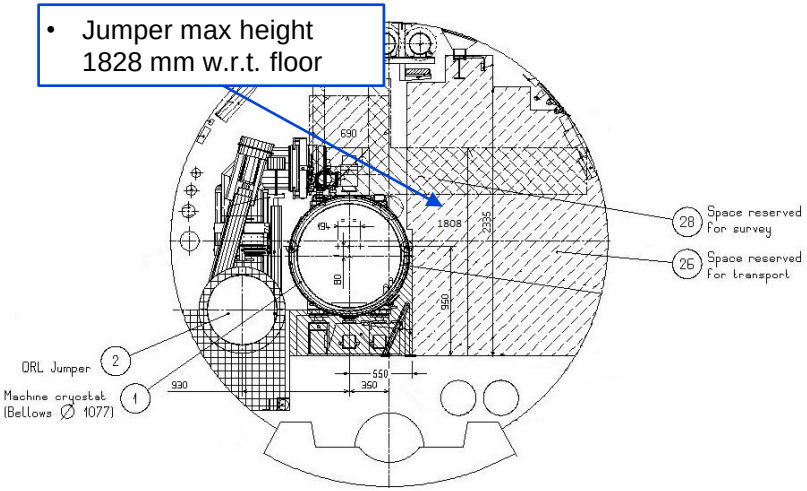
Use of closed-feedback-loop position control

Adding of position sensor, motorization and closed control loop to adjustment mechanisms allows to minimize the play effects in mechanisms – the controller follows the position measured by sensor The control system components and mechanics shall be designed/chosen in a way to fulfil also the other system requirements (stiffness, 3D play in supporting system, safety, etc..)

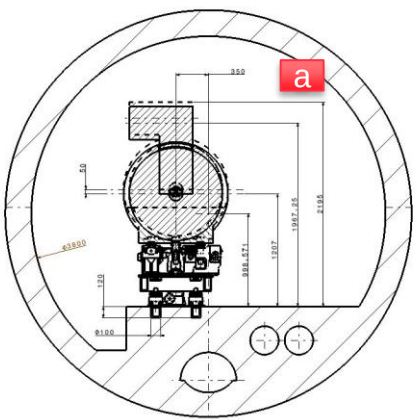


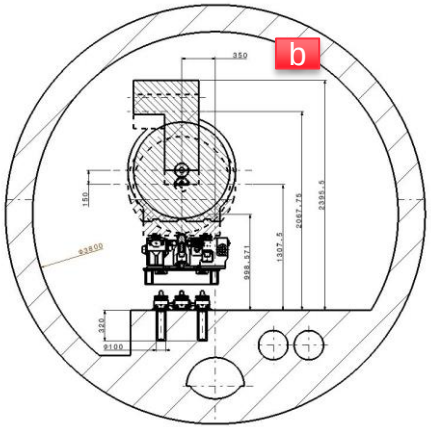
Tunnel space

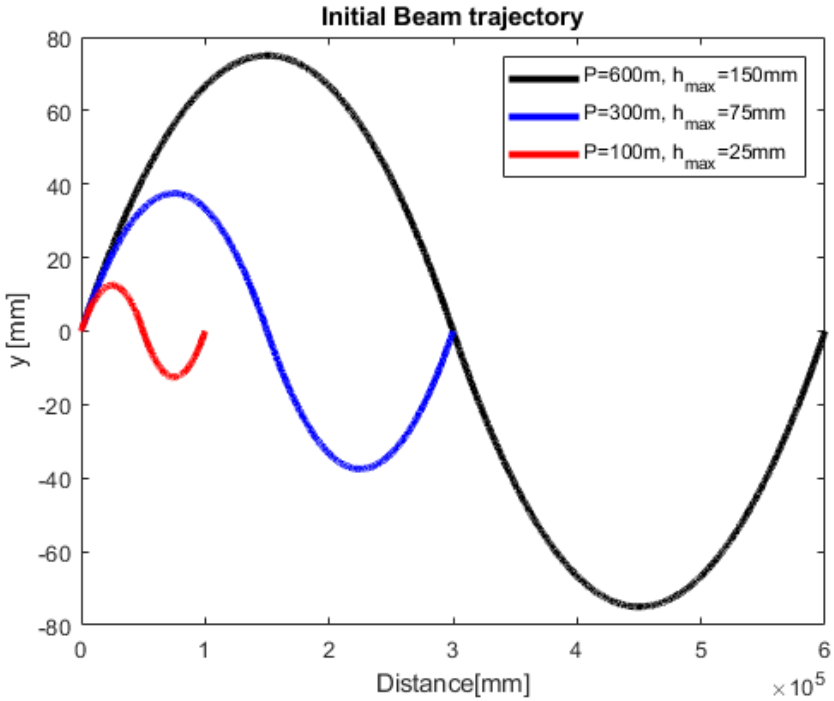
- **LHC TUNNEL**

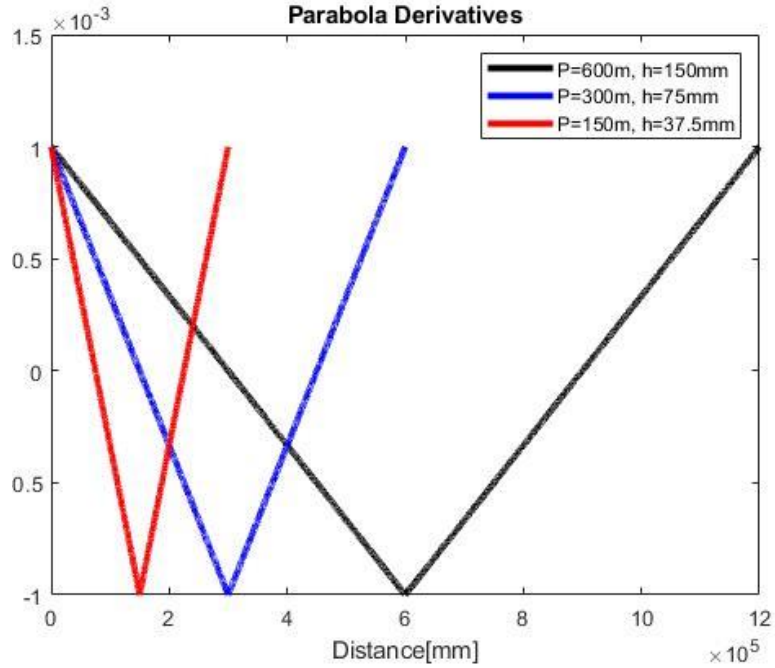


- **MUON COLLIDER IN LHC TUNNEL**
  a. Jacks with ±50 mm movement→Jumper max height 2215 mm w.r.t. floor
  b. Jacks with ±150 mm movement→ Jumper max height 2415 mm w.r.t. floor
- **This assumes part of the jack frame sits in a cavity!**






Initial Beam trajectory
P=600m, h_max=150mm
P=300m, h_max=75mm
P=100m, h_max=25mm
y [mm]
Distance[mm]
×10^5


Parabola Derivatives
×10^-3
P=600m, h=150mm
P=300m, h=75mm
P=150m, h=37.5mm
Distance[mm]
×10^5