Muon Collider Magnet Moving For Neutrino Mitigation

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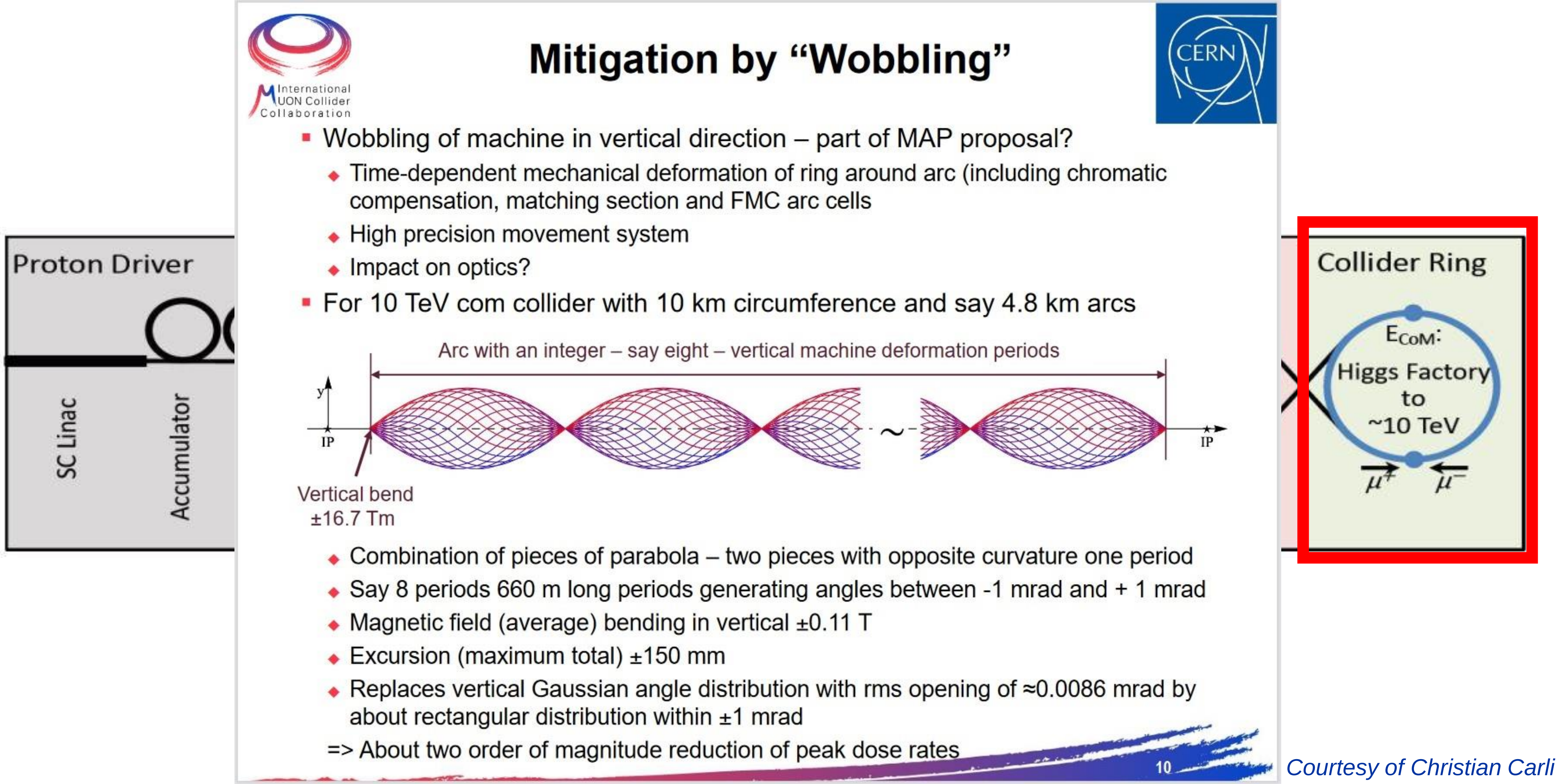
OUTLINE

- **Collider ring neutrino radiation mitigation**
- **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



Courtesy of Christian Carli

Neutrino flux requires change of beam trajectory every 12 hours

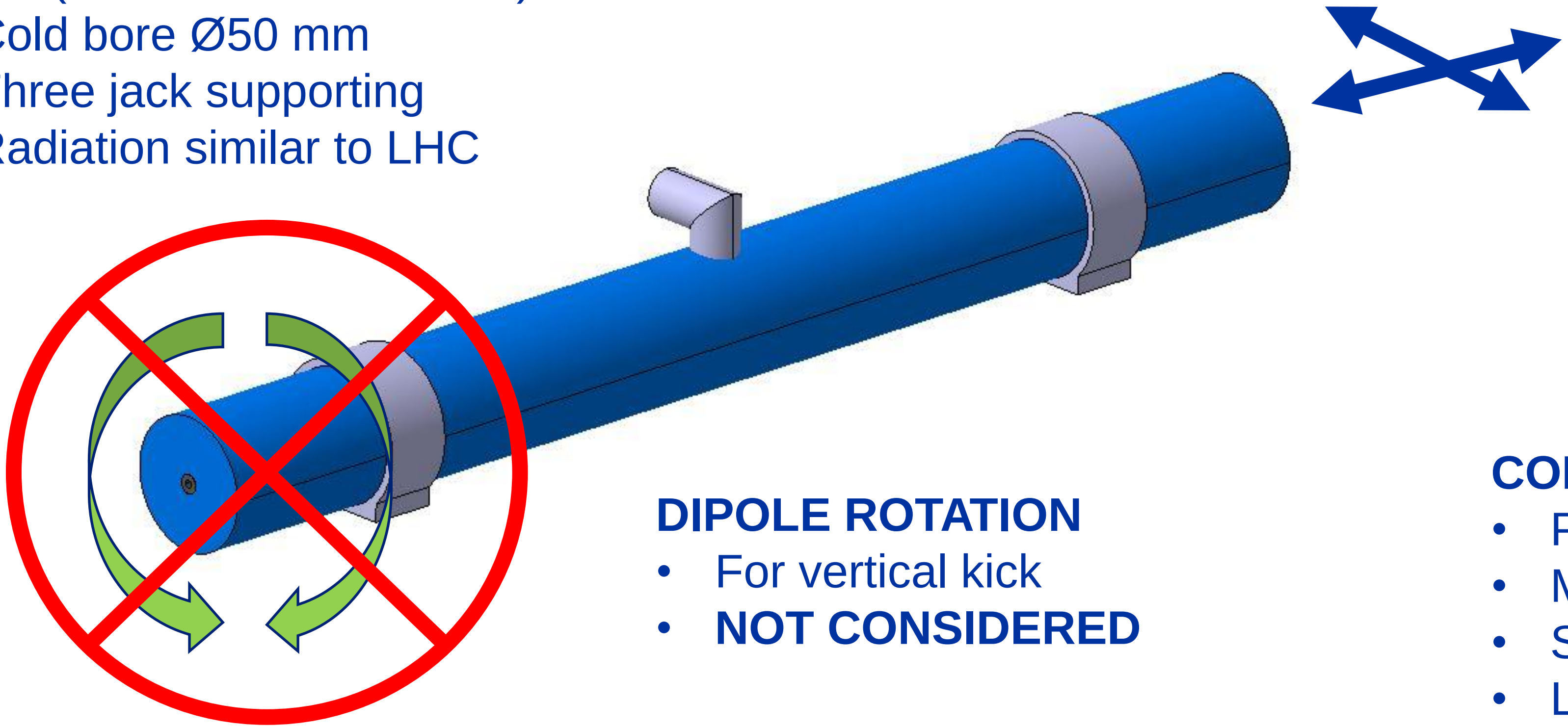
ASSUMPTIONS

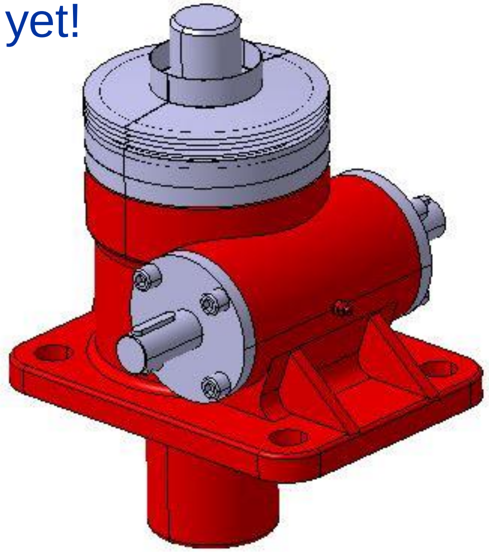
DIPOLE MAGNET MODEL

- 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

LATERAL FORCES:

- On dipole only from gravity(LHC tunnel angle of 1.4%)
- On quadrupole also from vacuum barrier and He lines as well – not studied yet!





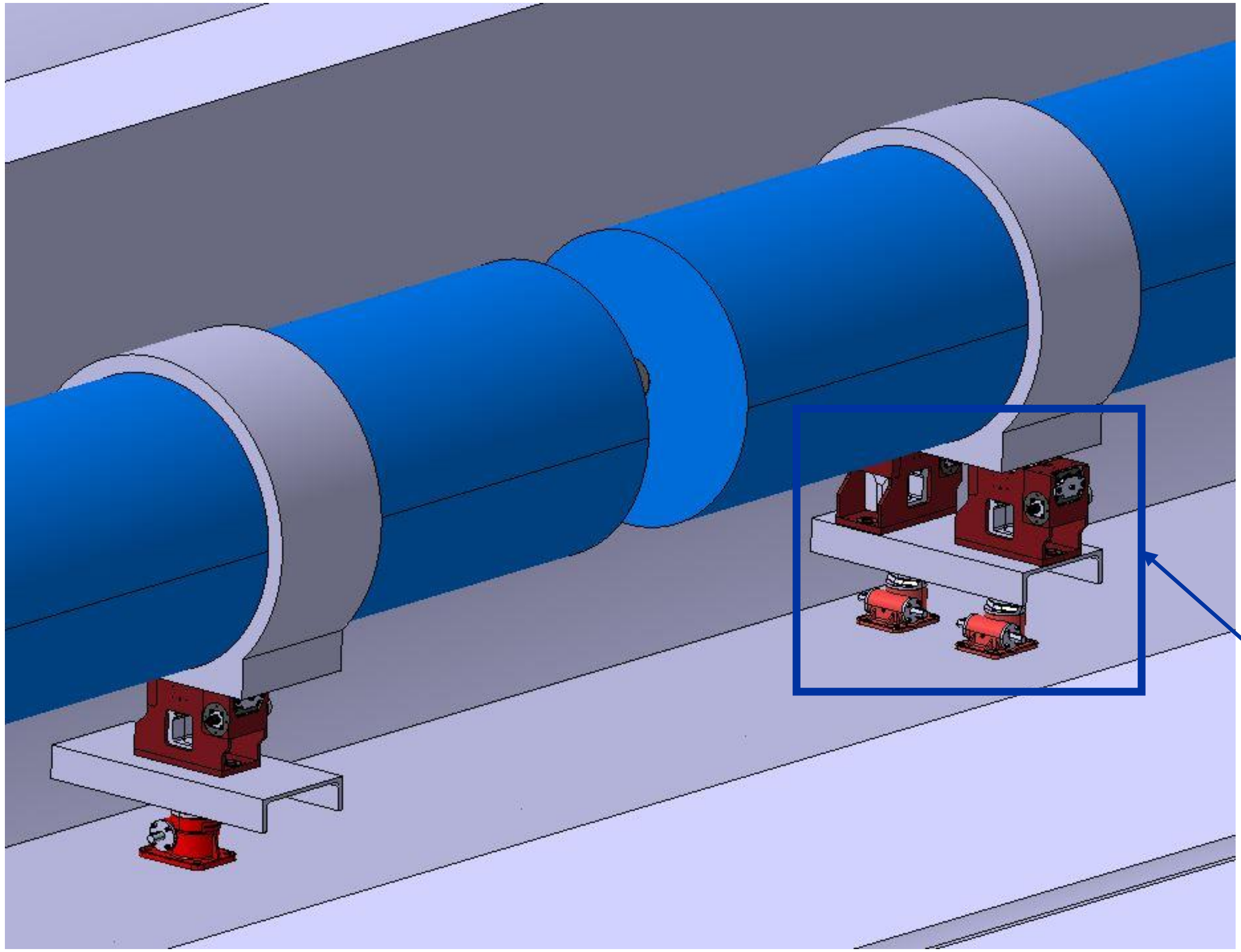
DIPOLE ROTATION

- For vertical kick
- **NOT CONSIDERED**

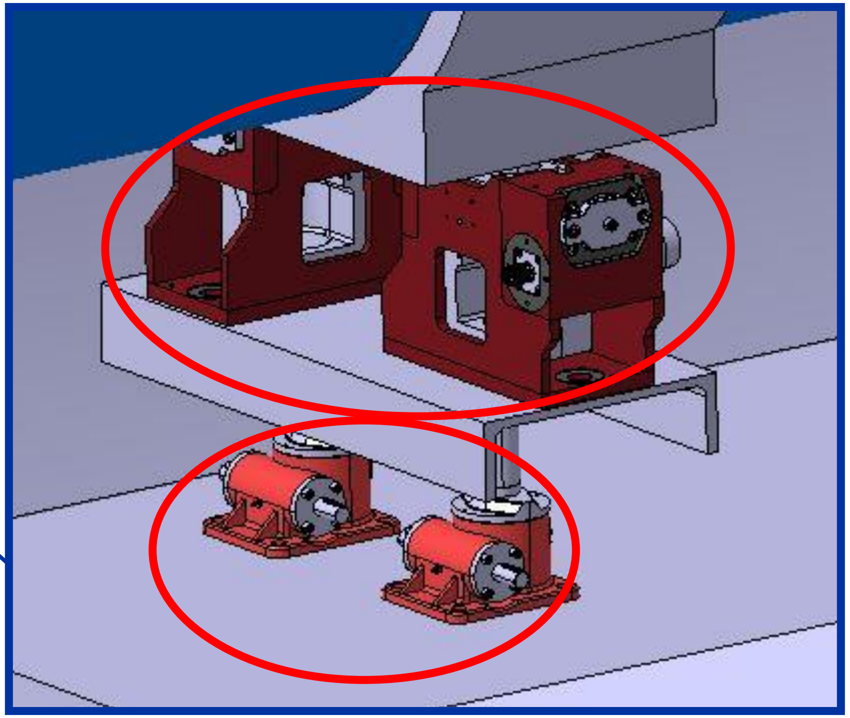
COMMERCIAL JACK

- Precision: ± 0.5 mm
- Mechanically driven
- Self-locking mechanism
- Lateral forces appr. 3-5%

TWO JACKING SYSTEMS – SOLUTION 1



ALIGNMENT JACKS
- Magnet alignment
- HL-LHC Jack

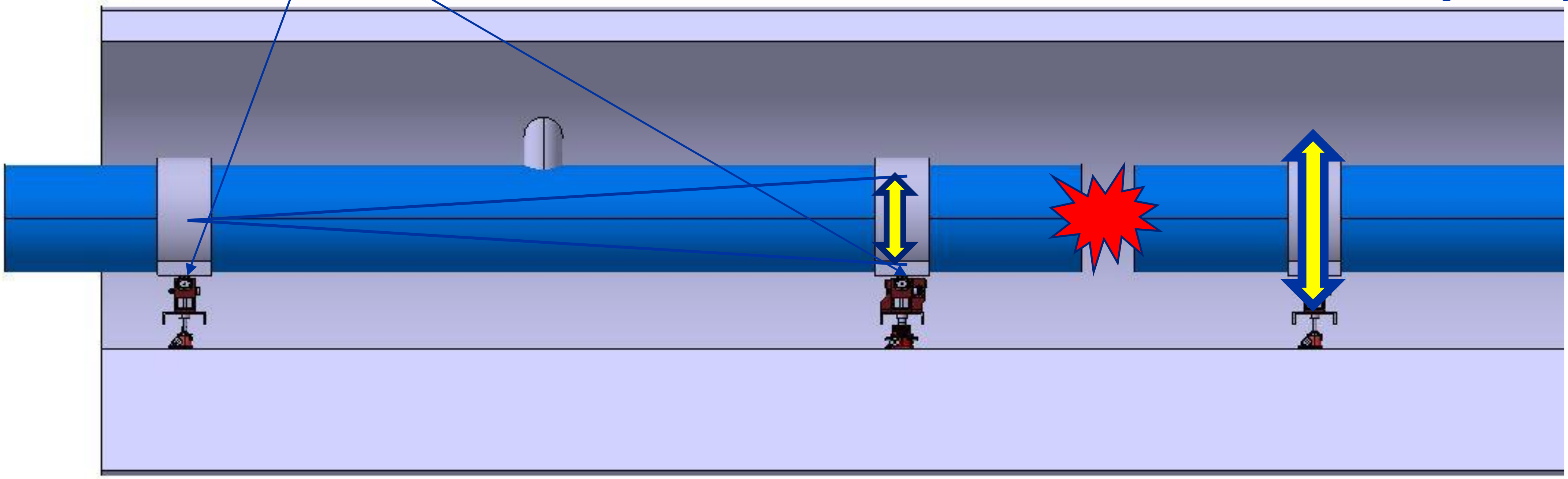


MOTORIZED JACKS
- Only vertical movement
- Commercial jack

ALIGNMENT AND LAY-OUT CHANGE

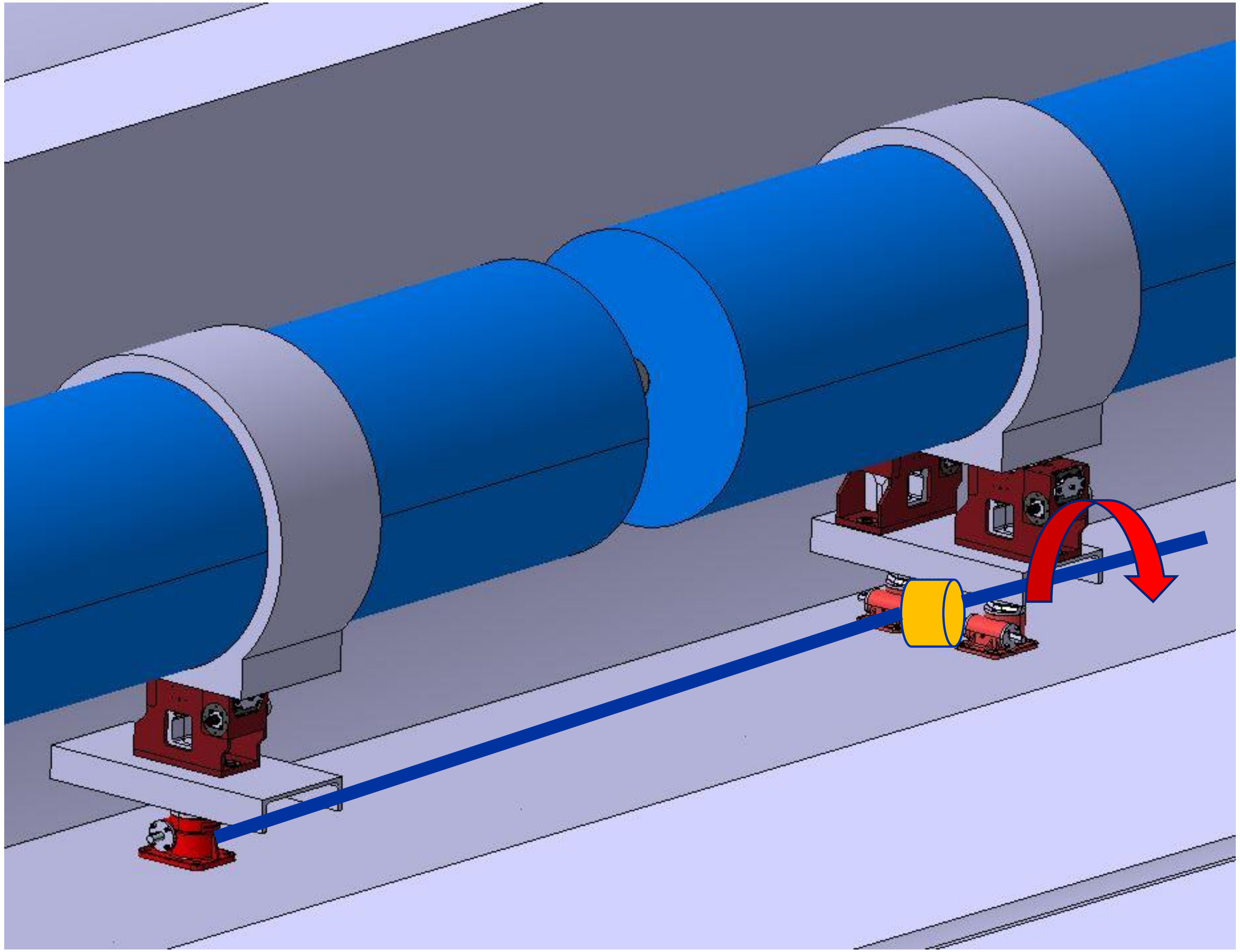
ALIGNMENT JACKS
- Magnet alignment

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



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

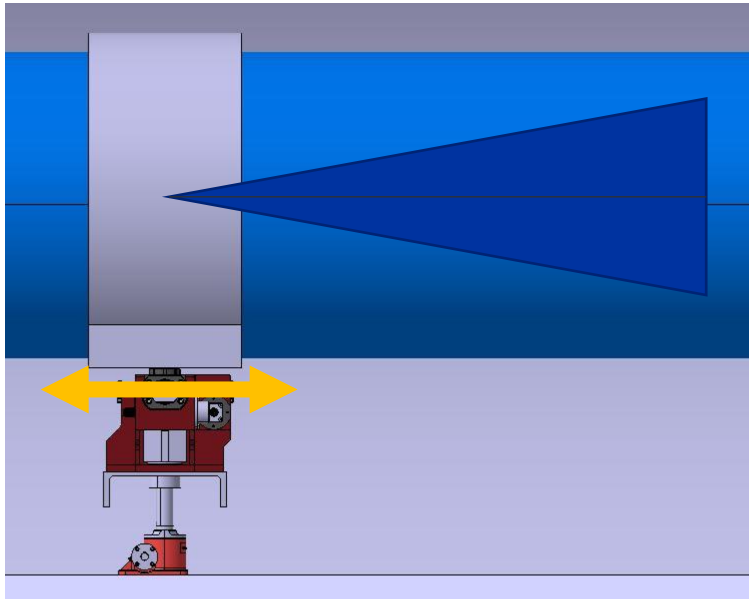
- Connect jacks mechanically
- 4-way gearbox
- Shafts
- Single motor on the gearbox
- IN STUDY – redundant system with two motors, requires two gearboxes

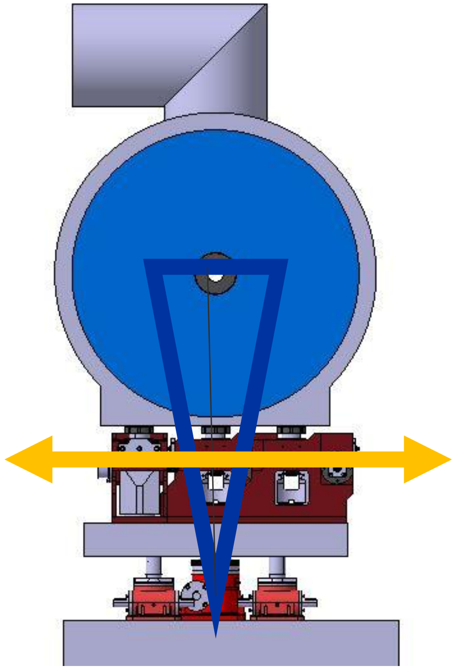
- **BELLOWS OFFSET BLOCKED**
- **ANGLE BETWEEN MAGNETS ALLOWED**

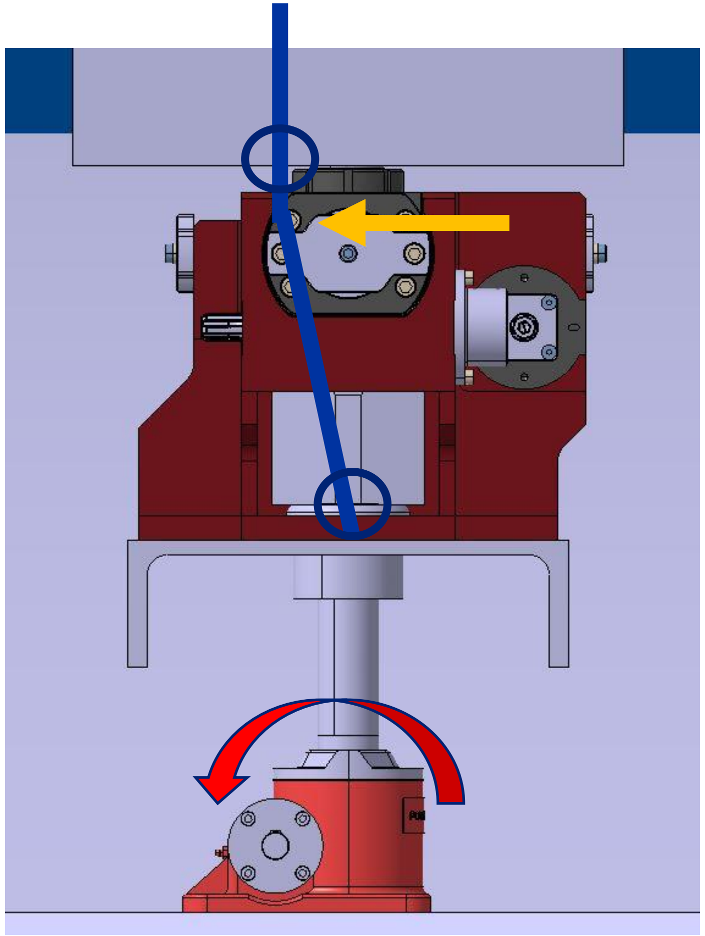
SUPPORTING OF MOTORIZED JACKS

BENDING MOMENT ON THE MOTORIZED JACK

- From magnet tilt or roll due to the tunnel
- 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

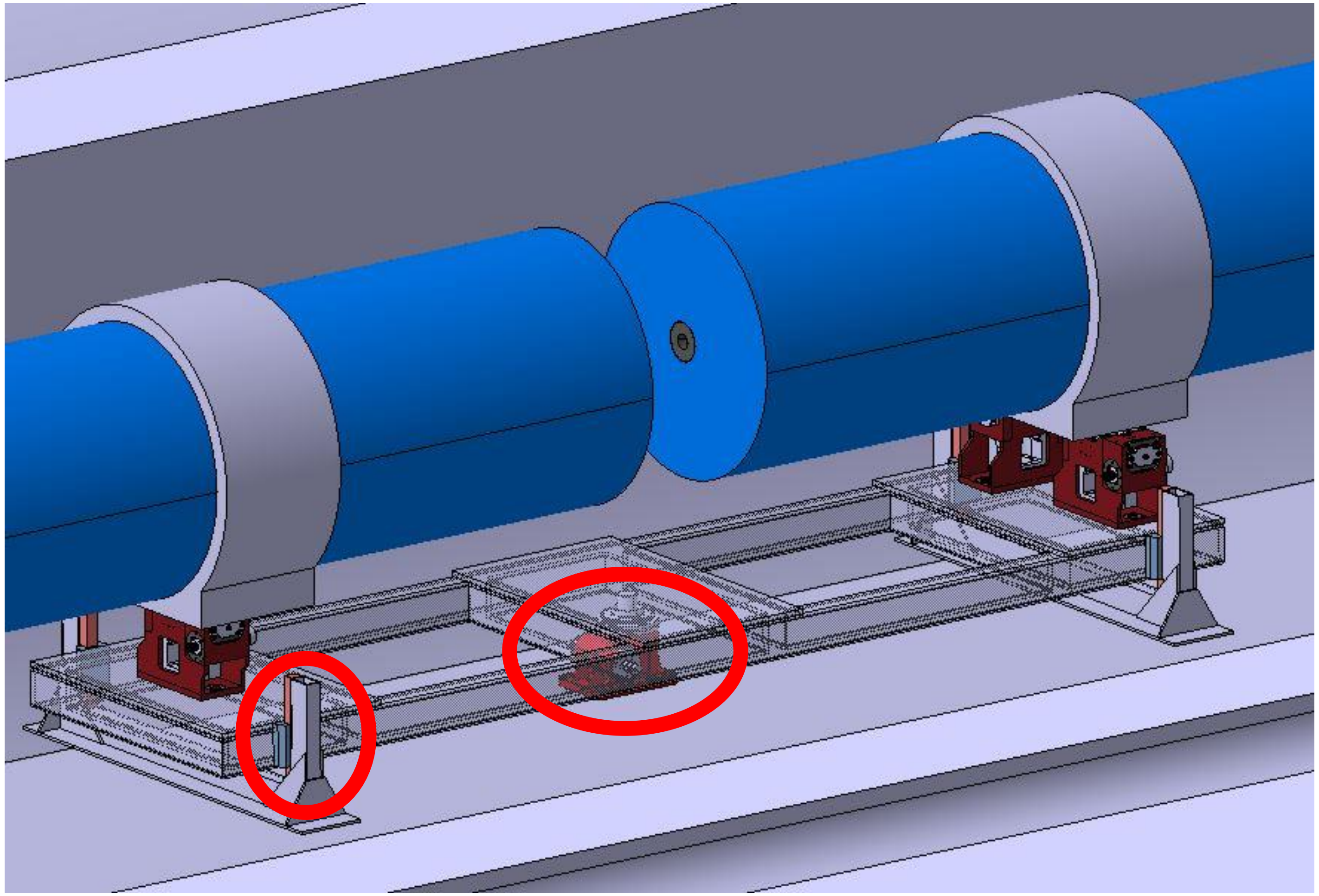






MOTORIZED JACKS MAY NEED SUPPORTING GUIDES TO PROTECT THEM FROM BENDING MOMENTS!

TWO JACKING SYSTEMS – SOLUTION 1b



ALIGNMENT JACKS ACROSS THE INTERCONNECTION ON COMMON PLATFORM

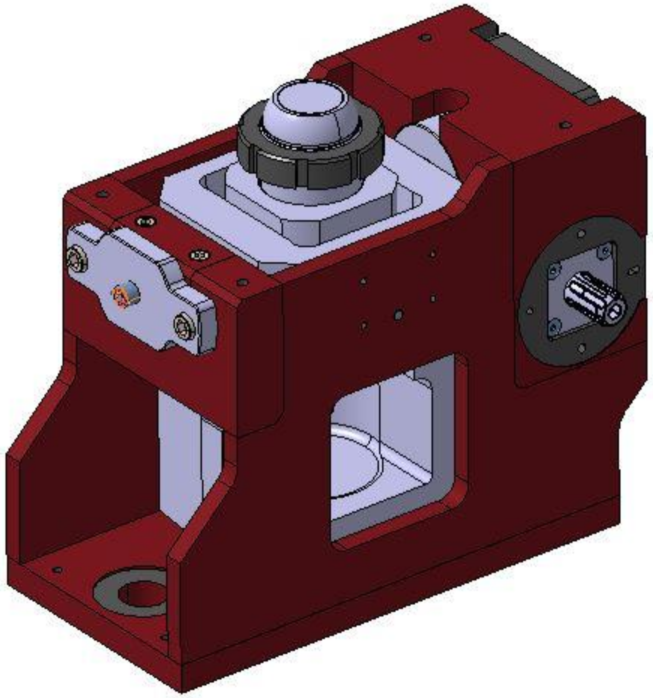
- One central jack for the height change
- Platform must have linear guides to avoid bending moment on the jack
- One motor per interconnection = magnet
- Motor for redundancy required?

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

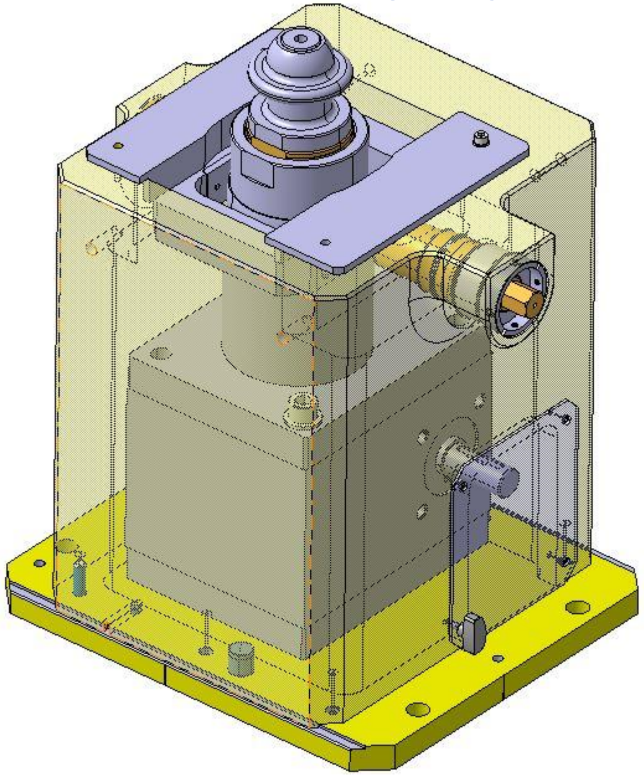
COMBINED JACK - SOLUTION 2

Combine the functions of the two jacks – alignment and lay-out change!

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



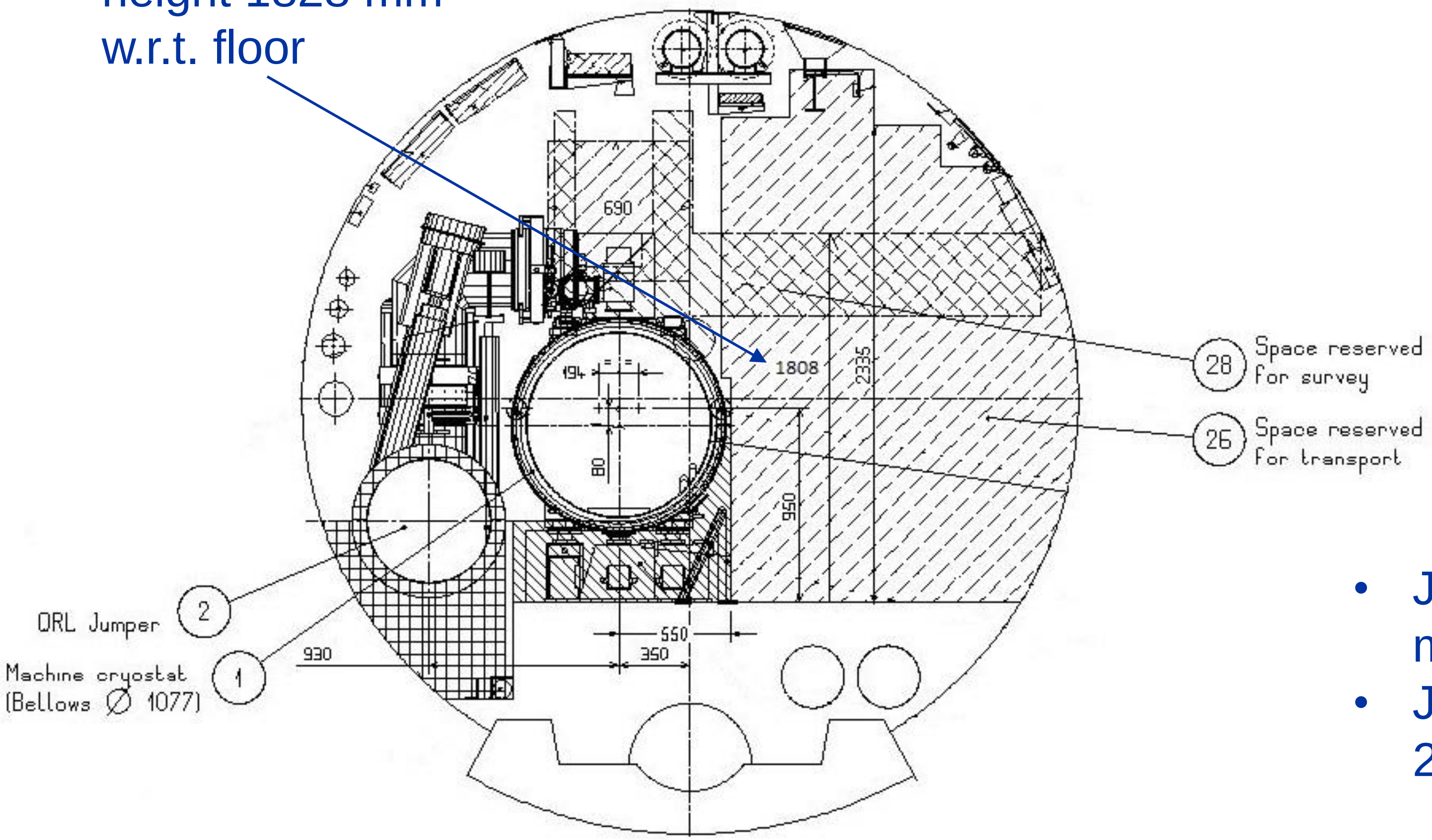
Both require three jacks together to create an isostatic support system!

Muon Collider specification requires a new design – concept work initiated with a jack supplier

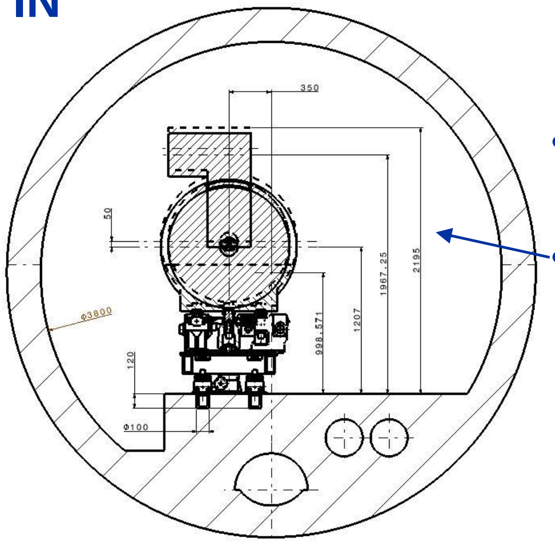
TUNNEL SPACE

LHC

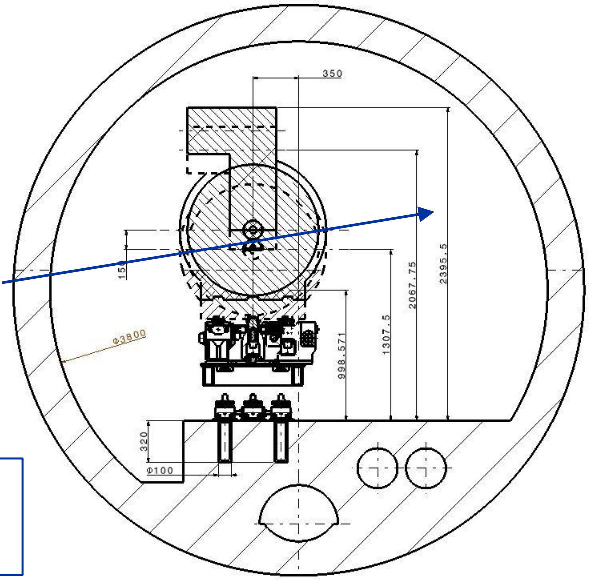
- Jumper max height 1828 mm w.r.t. floor



MUON COLLIDER IN LHC TUNNEL



- Jacks with ±50 mm movement
- Jumper max height 2215 mm w.r.t. floor



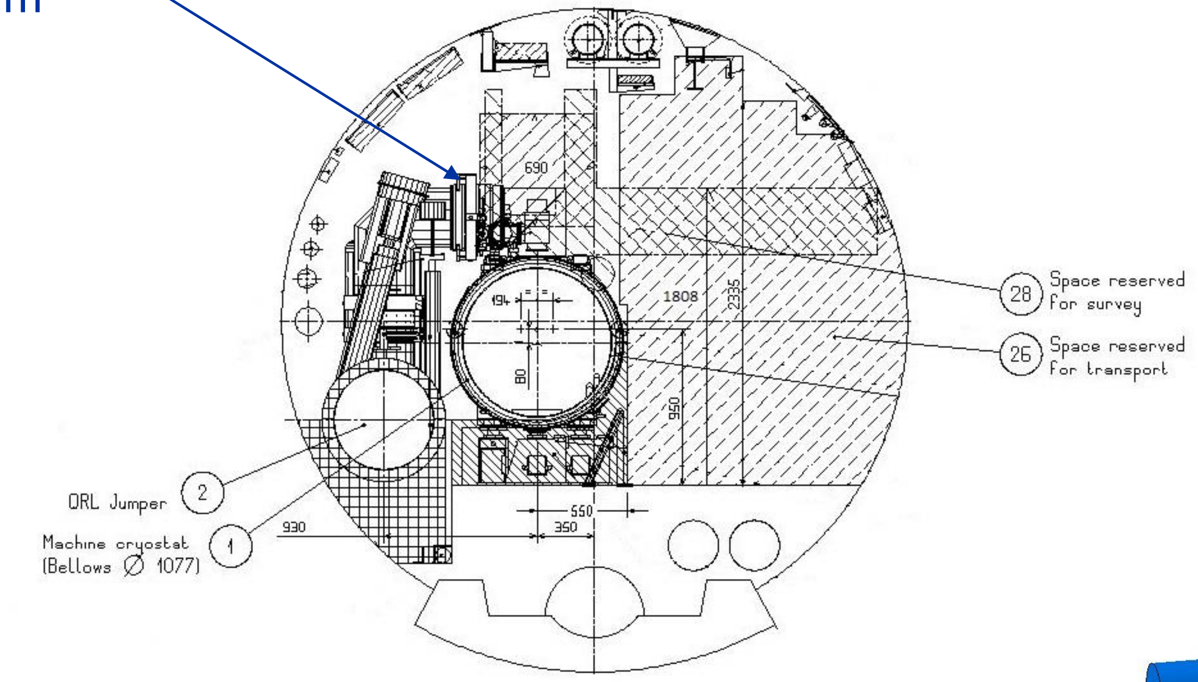
- Jacks with ±150 mm movement
- Jumper max height 2415 mm w.r.t. floor

NOTE: This assumes part of the jack frame sits in a cavity!

He SUPPLY

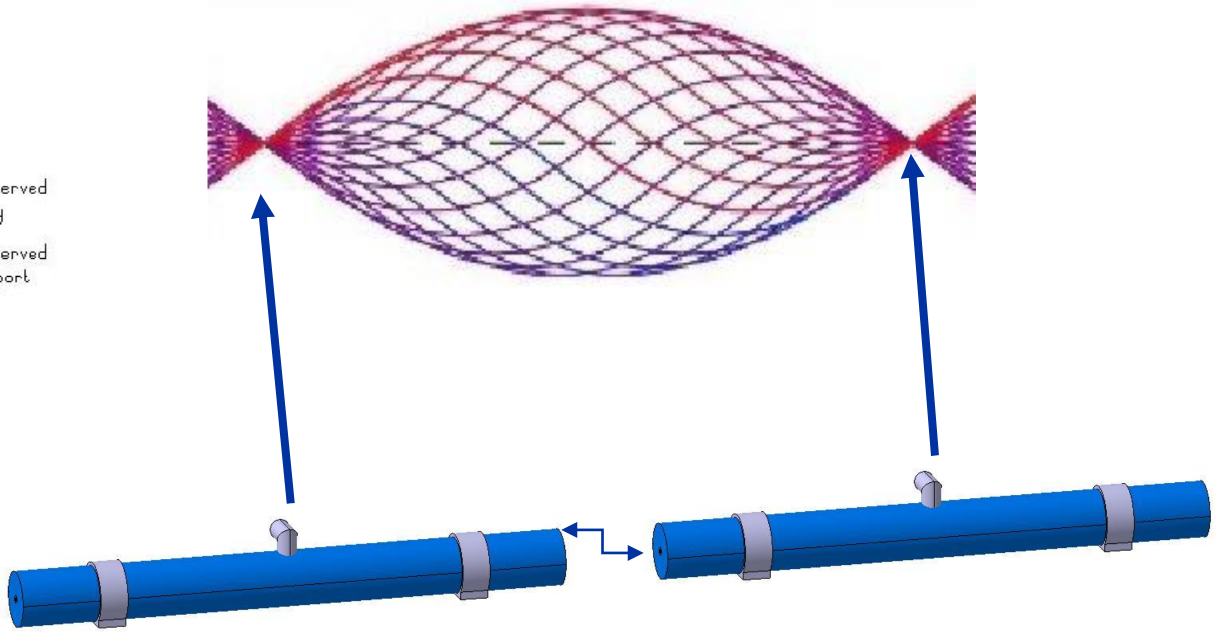
LHC

- Jumper connection to He supply every 110 m



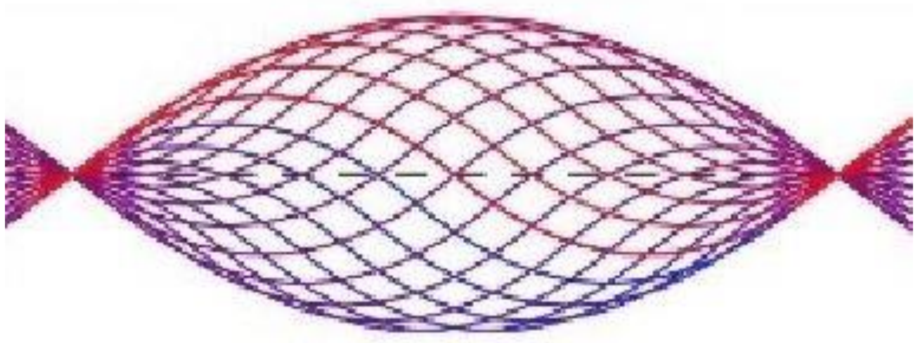
He SUPPLY CONNECTIONS FOR MUON COLLIDER

- 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

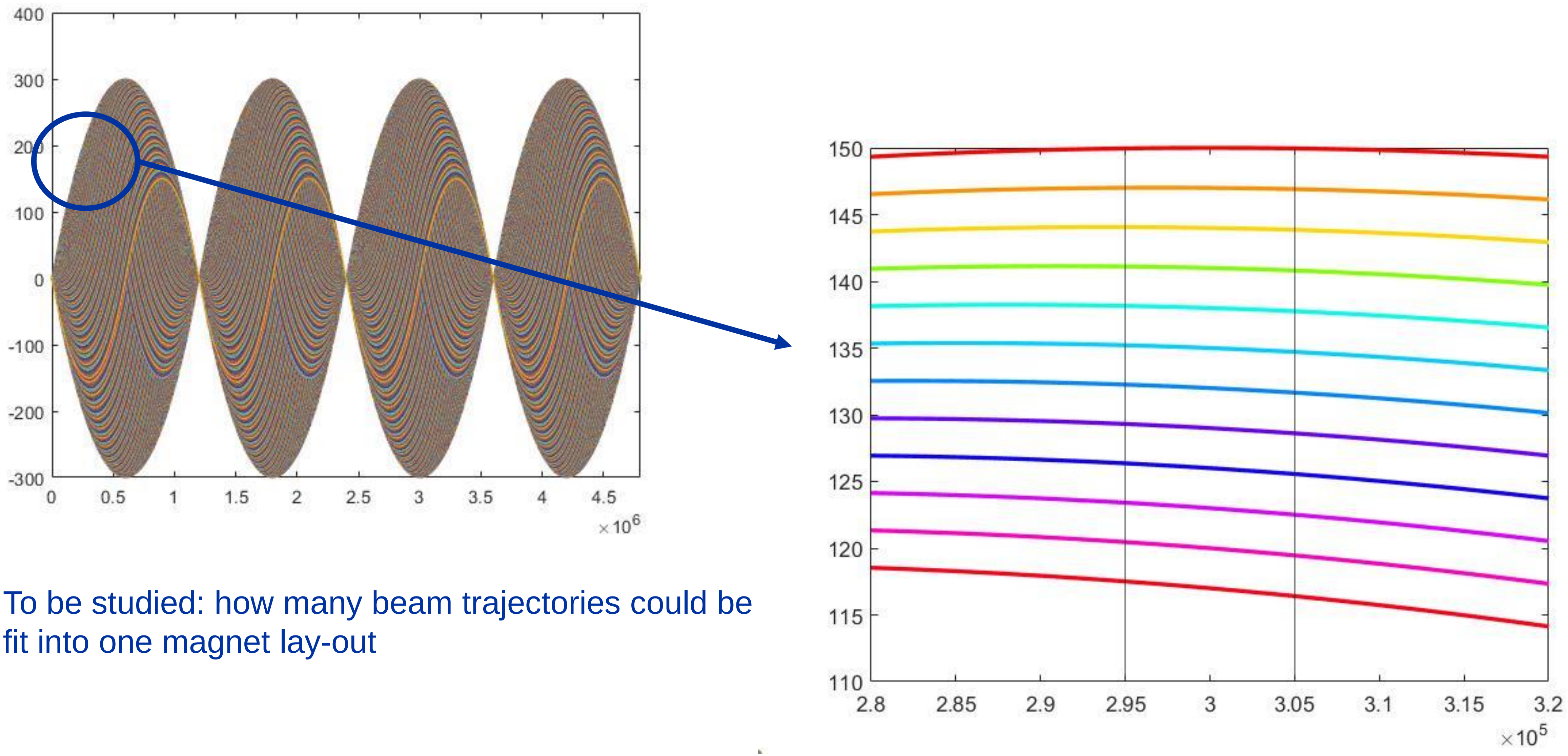


POWER

- **200 days of physics annually(55%) leads to 400 trajectory changes**
  - LHC 2023 – 2038 planning is 43%
  - 20 years 8000 changes
  - How many physical lay-out changes w.r.t. Beam trajectory change? – more on the next slide
- **Powering lay-out changes**
  - $Power_{total} = N_{magnets} \times N_{jacks} \times Power_{motor}$,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



To be studied: how many beam trajectories could be fit into one magnet lay-out

CONCLUSIONS

- **Two solutions to move the magnets presented**
- **Information required**
  - Aperture confirmation
  - Period confirmation
- **Concept selection and design engineering**

THANK YOU FOR YOUR ATTENTION

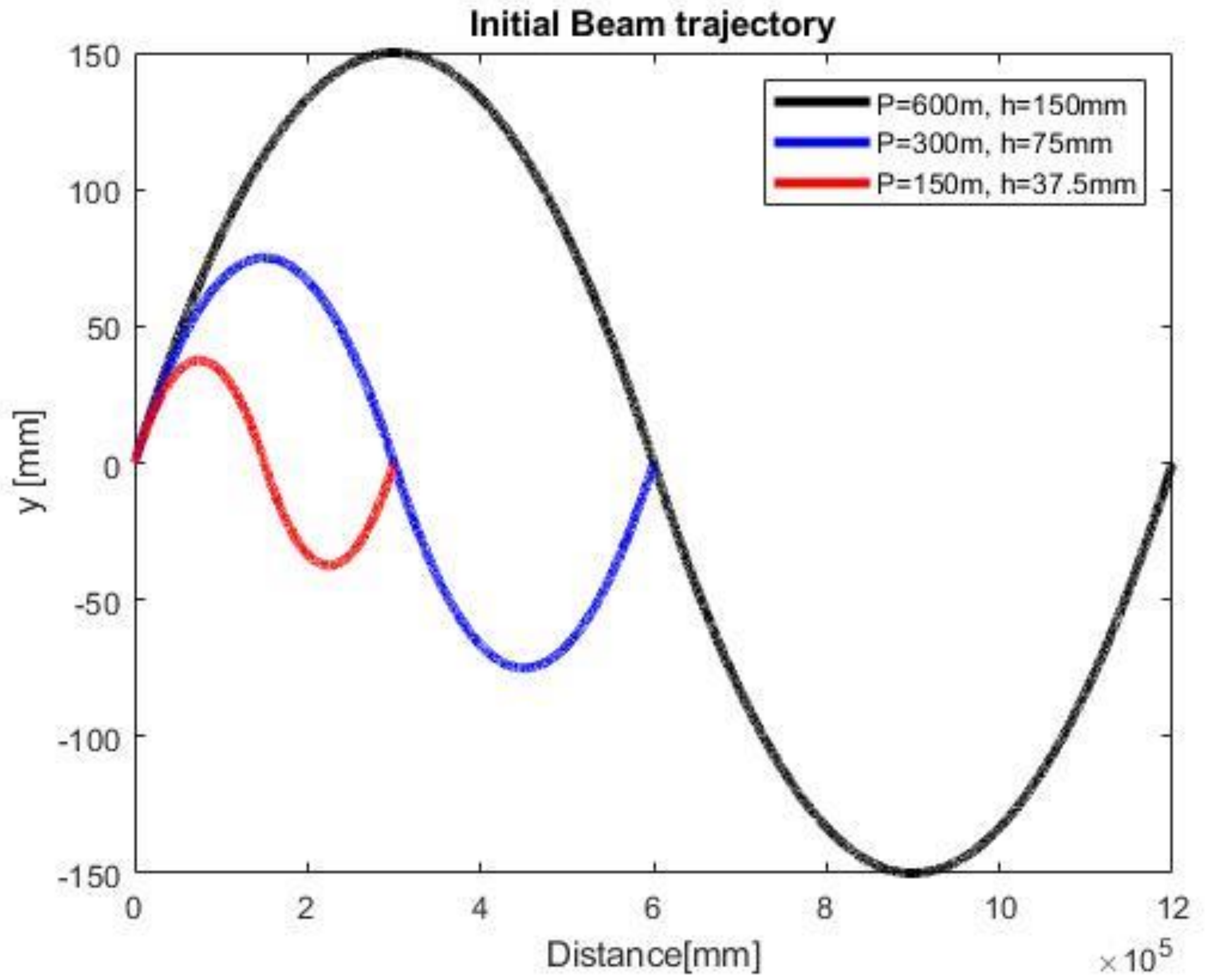
YOUR QUESTIONS PLEASE

!/?

CERN

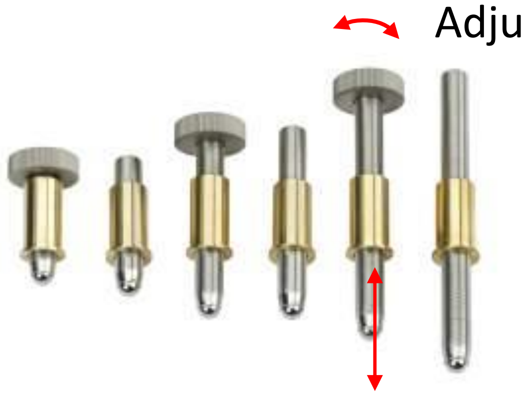
ENGINEERING DEPARTMENT

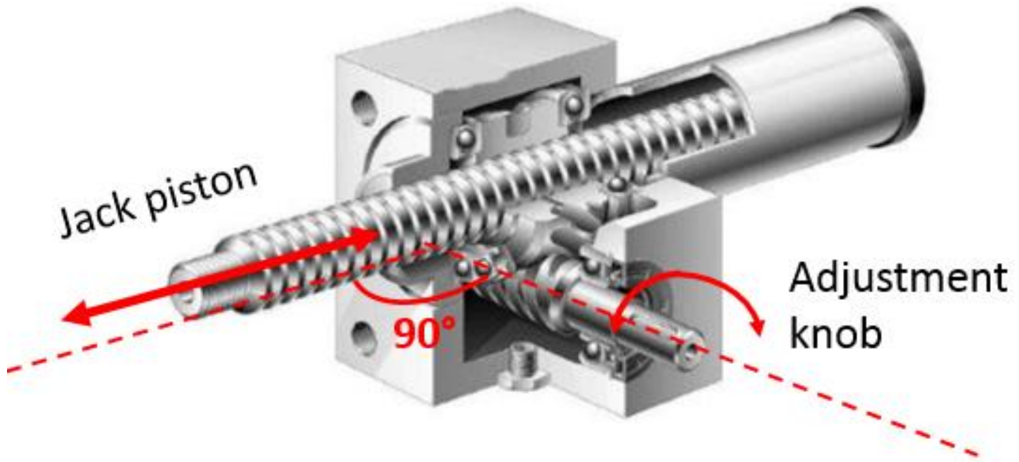
PERIODS



Initial Beam trajectory
150
100
50
0
-50
-100
-150
y [mm]
0
2
4
6
8
10
12
Distance[mm]
× 10^5
P=600m, h=150mm
P=300m, h=75mm
P=150m, h=37.5mm

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





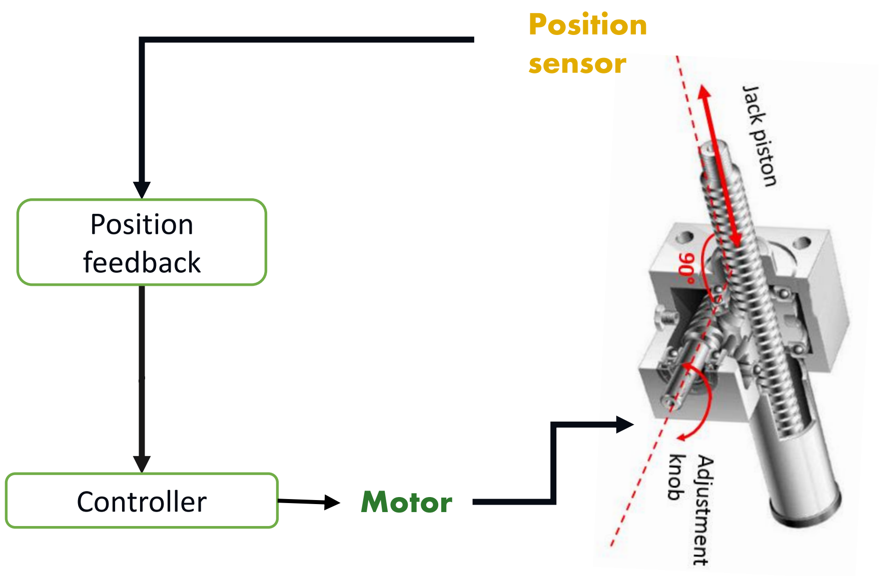
- **<u>Simple screw adjustment</u>**
  - Play (seen on *screw end*) depends on quality of the thread machining
    - For typical machined threads (M x, Tr x, etc …) – play at *screw end* can vary from tenths um-s to even mm for bigger screws
    - For ball screws play depends on fitting quality – it 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

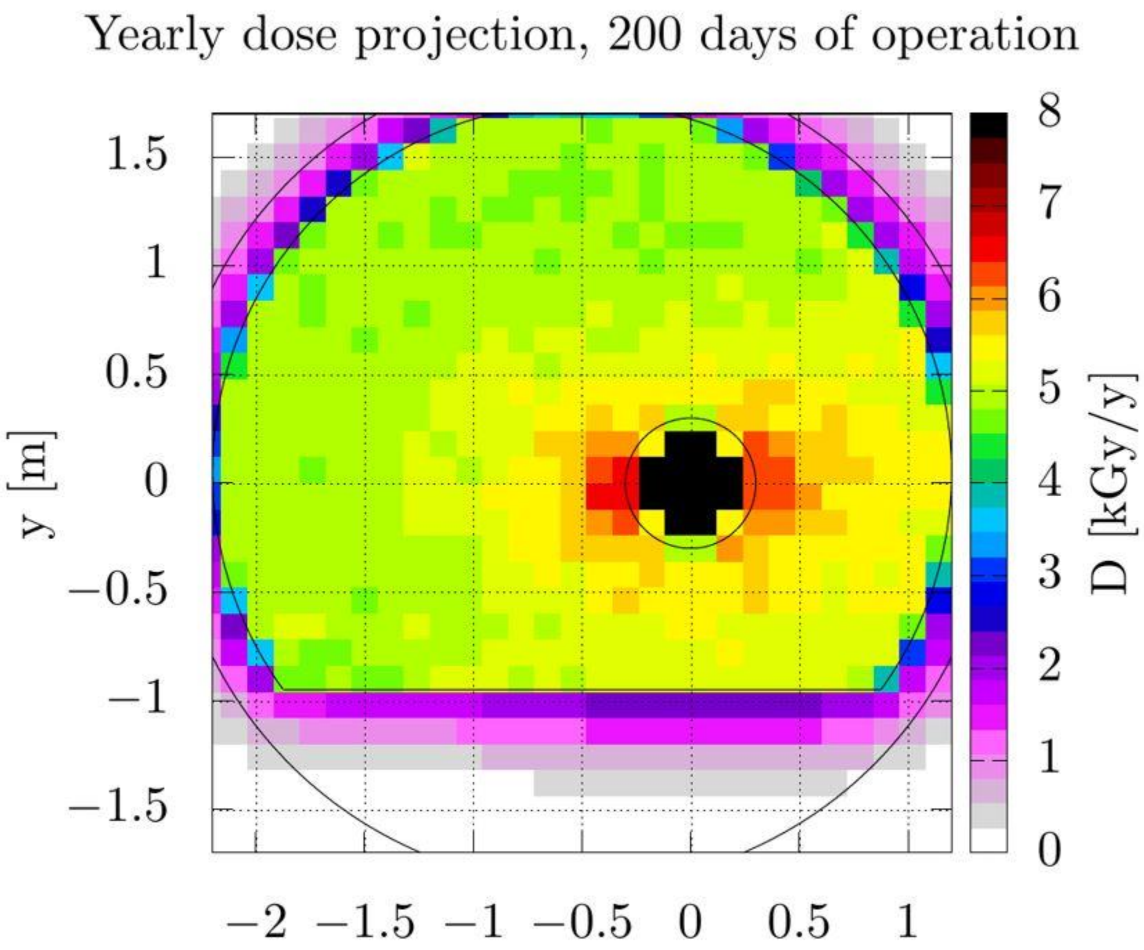
Real impact of play in adjustment jigs (screw mechanisms, jacks) on adjustment performance

- **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..)



RADIATION



Courtesy of Daniele Calzolari