Design considerations for LCGT's seismic isolation

LCGT の設計上の考慮事項震だ

Riccardo DeSalvo

Discussion:

Comparative seismic attenuation, vacuum tank and optical element configurations

JGW-G1000255

What am I doing?
私は何をしているのですか？

- I am here to assist Ryutaro Takahashi in designing, building and implementing the seismic attenuation for LCGT

- 私は高橋龍太郎を支援するためにここにいる
- 設計、構築および地震波の減衰を実装する LCGT

First step

- Need to define the interface between
  - General interferometer configuration
  - Optics
  - Mirror suspension (cryo and room temp.)
  - Seismic isolation
  - Vacuum tanks
  - Tunnel and cavern configuration
- I have been bugging everybody
- I apologize for the inconvenience I caused

- In the way

  I have freely given comments and suggestions

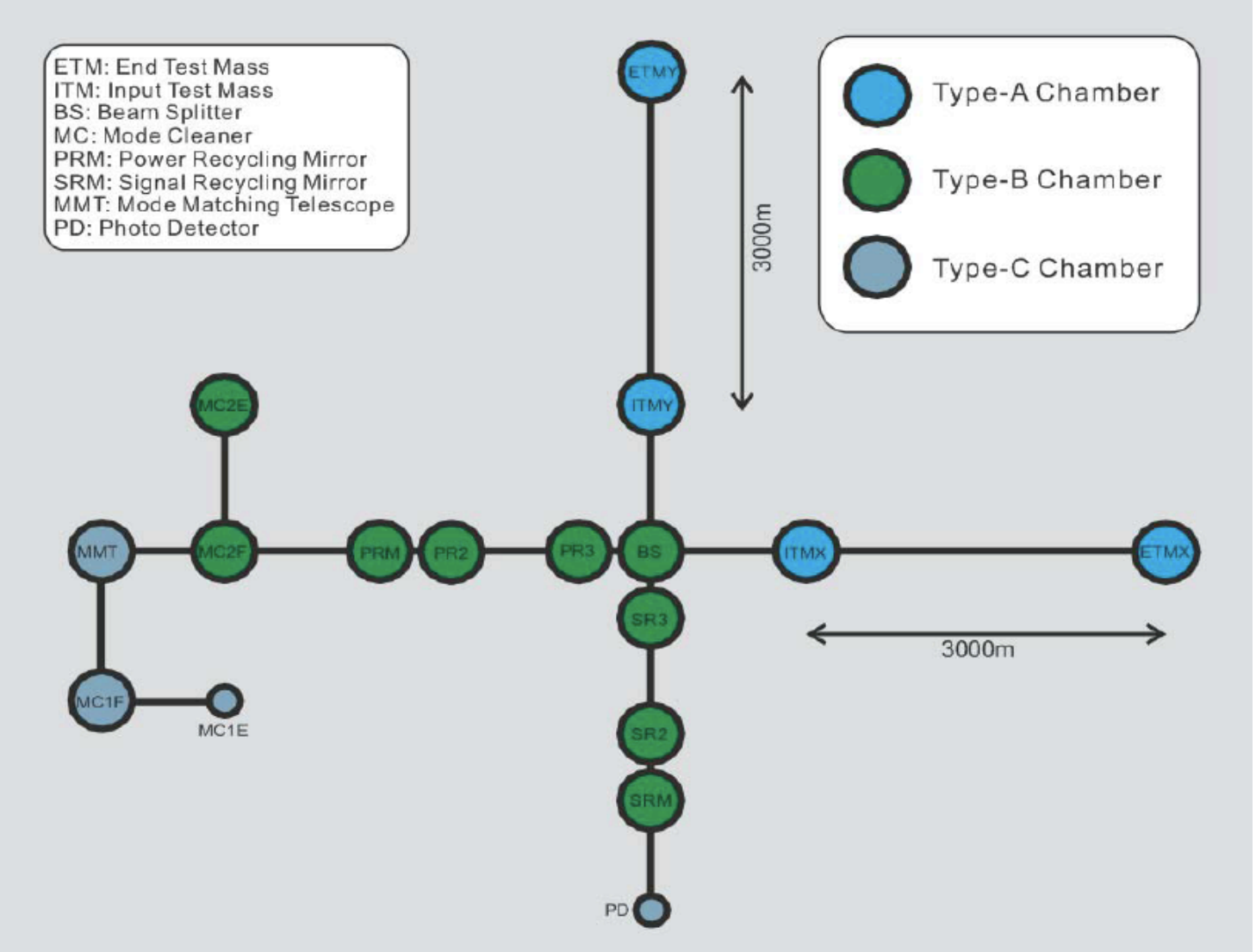
- Please feel free to take them or ignore them

- but please considere them !

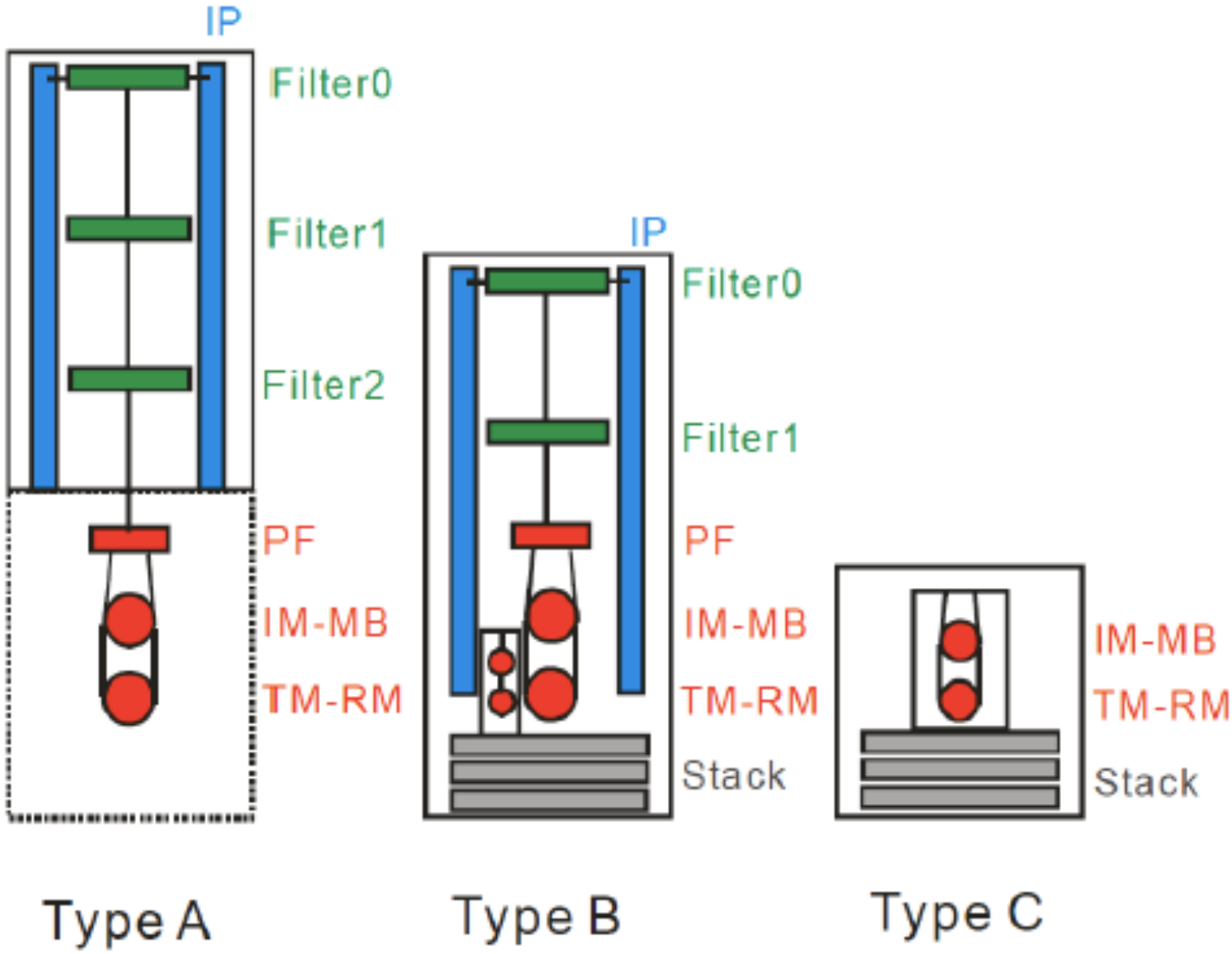
Premise

- I make specific proposition and design hypothesis
- What I present is just a "proposal"
- Need discussion and negotiation between subsystems
- Please interrupt me often !

Starting point: configuration



Starting point: attenuator types



Thinking threads

- Seismic configuration
- Access type
- Vacuum tanks

- Modularity of design

Seismic configuration

- Passive attenuation similar to Virgo's
- SAS type, based on Geometric Anti Springs (GAS) not magnetic (Virgo SA)
- Underground location
  - need less attenuation than Virgo

- Start at room temperature
- Future cryogenic

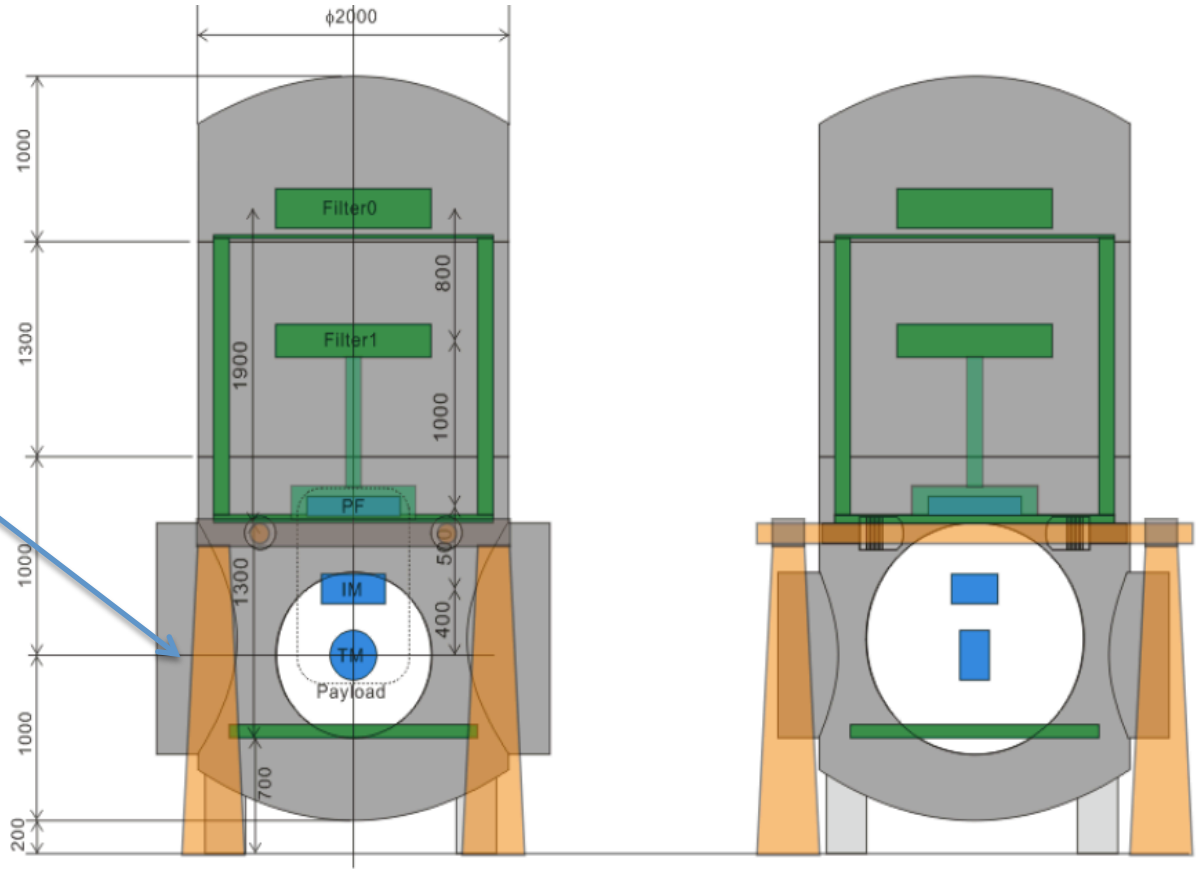
Physics advantages

- Underground location
  - Less Newtonian noise
- Can potentially detect GW at lower frequency
  - * * * Exclusive physics for LCGT ! ! !
- Future cryogenic interferometer
  - Problem with high power
  - Lower Frequency requires less power
- Want to preserve potentialities
  - Need to produce attenuation at lower frequency

Constraints

- Need very stable basement for seismic chains
  - Virgo and LIGO had problem with stilts

This is a problem that must be avoided



Constraints from low frequency

- Horizontal attenuation
- Pendulum attenuation frequency √g/l
  - Need elevation l for low frequency attenuation

- Vertical attenuation
- GAS filters OK at low frequency
- No dilution, full metal noise present
  - Will need horizontally level interferometer to preserve capability to detect GW (Back to this later)

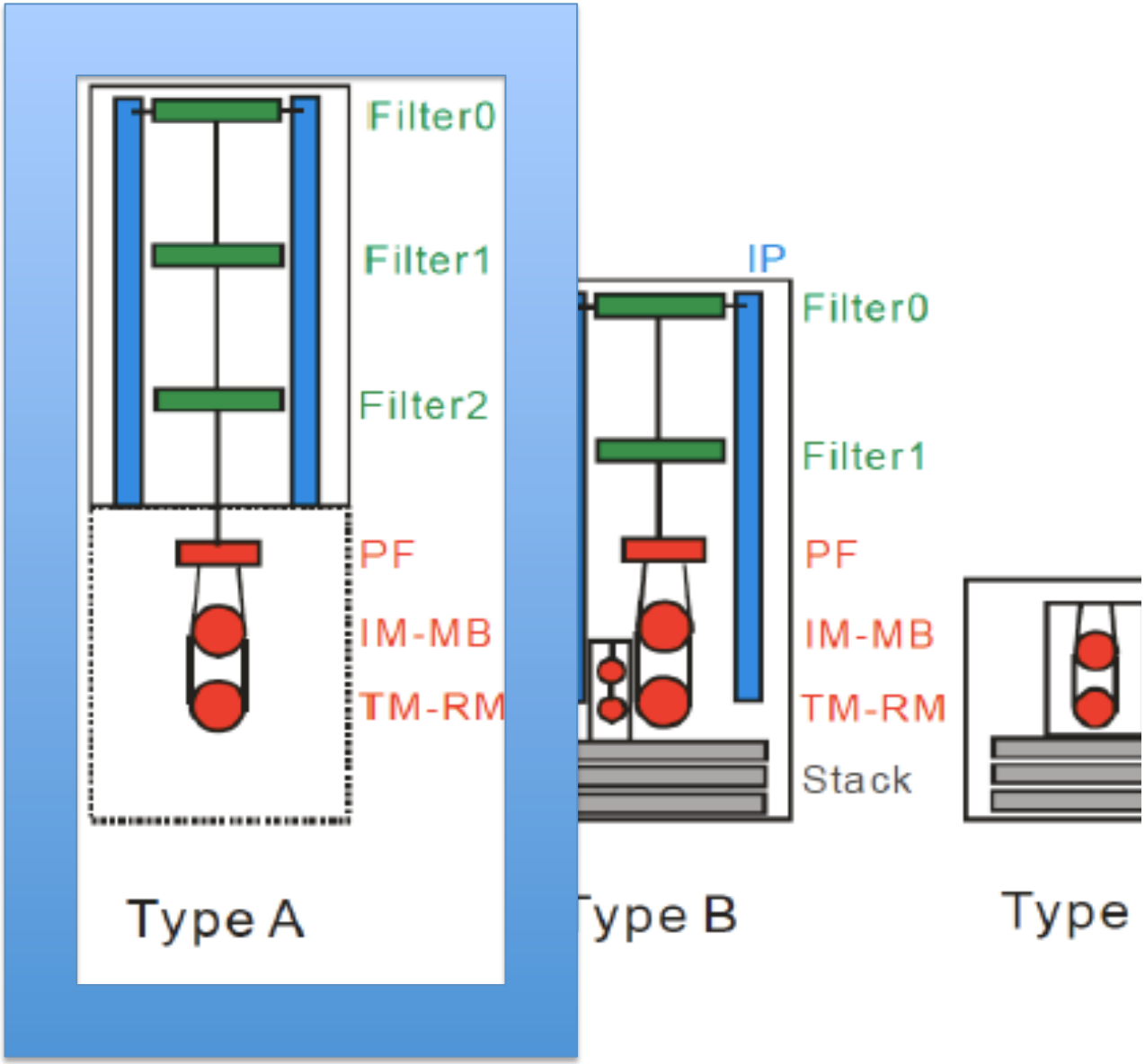
Factual constraints

- Design seismic attenuation

- For unknown suspensions => flexibility
- Design of seismic attenuation is important
- Access is also important for implementation,
- Seismic must be designed together with detector configuration, vacuum, suspension, ...

Type A proposed solution

- Attenuation chains for test masses and possibly beam splitter

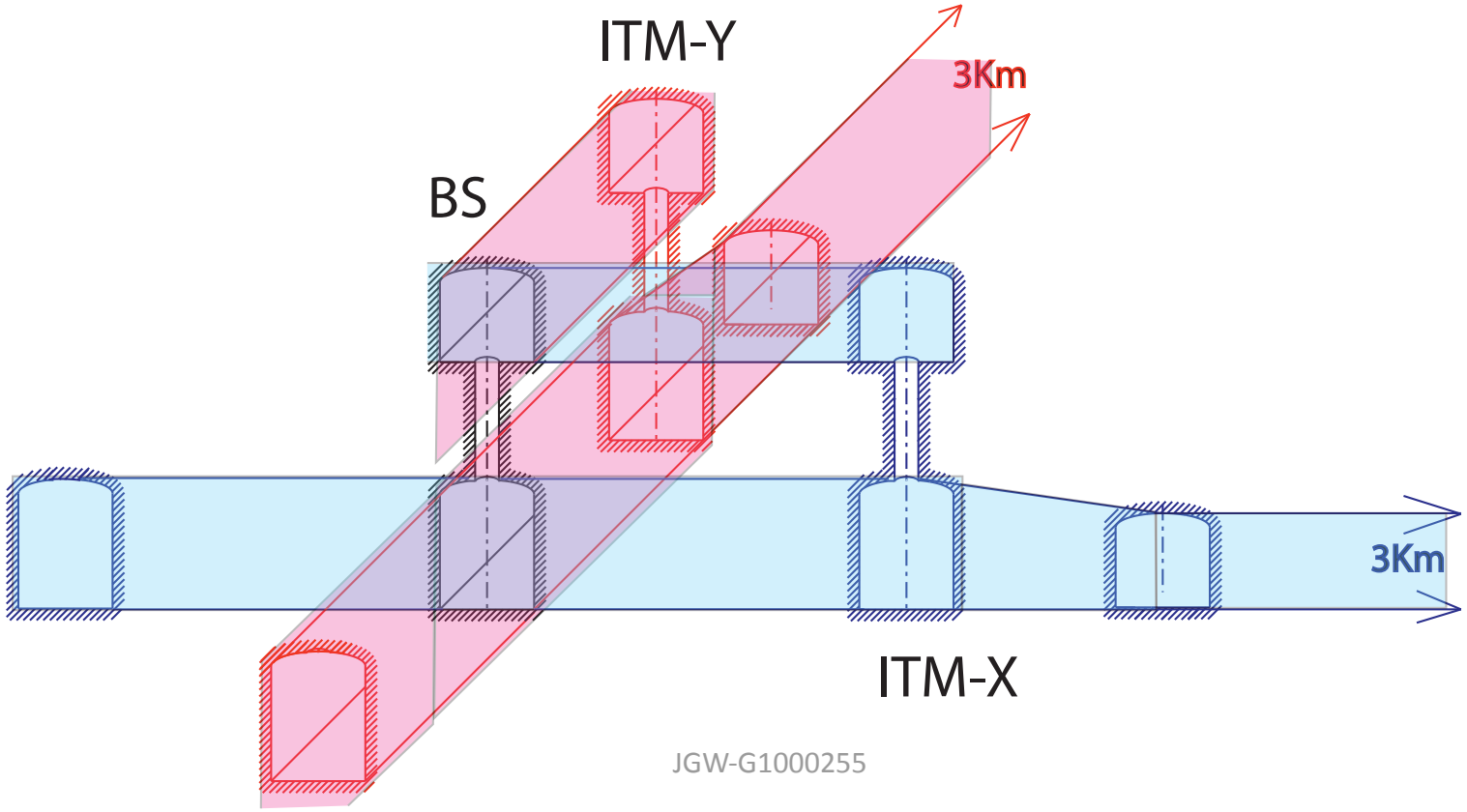


Design key point

- Need height for low frequency
- Need foundation stability
- Need to preserve the advantage of stable rock
- Need not to occupy space to allow later installation of cryogenic suspensions

Dual tunnel - general description

- Eliminate the large experimental Hall
- Replace with two superimposed tunnels



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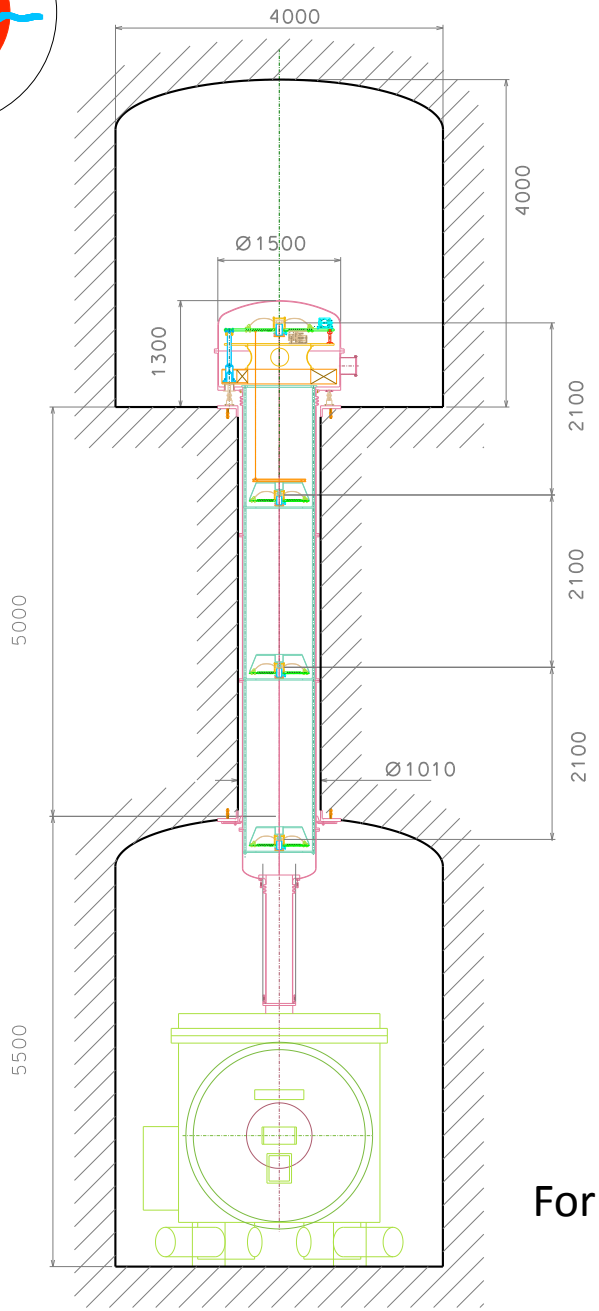
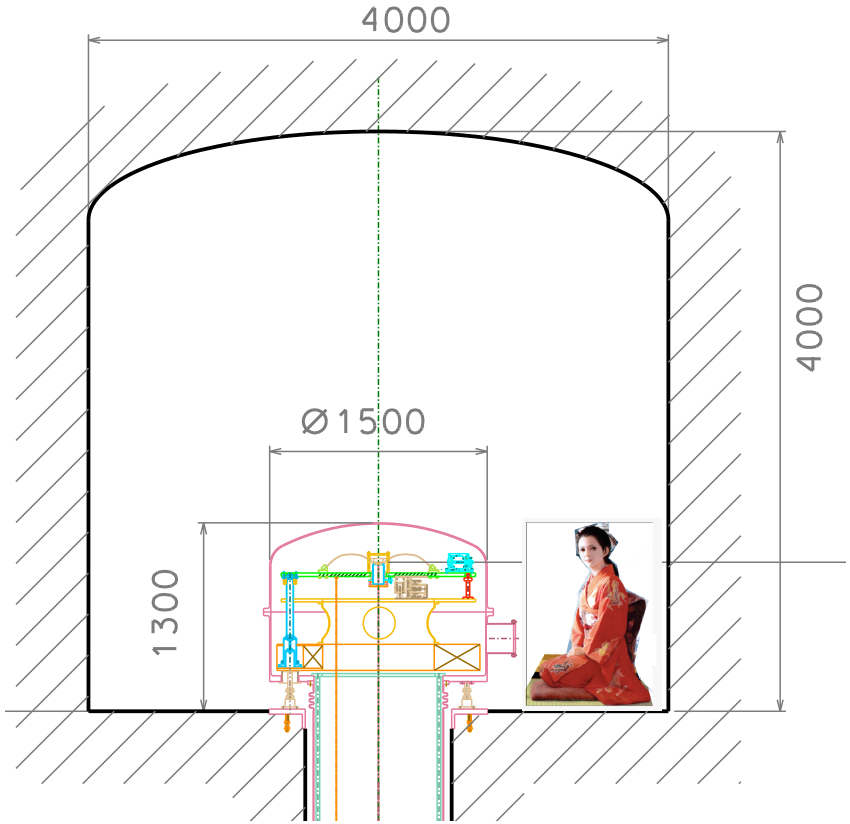


Generalities

- ≥4m x ≥4m upper tunnel containing pre-attenuator
- 1 m diameter ≥5 m tall bore-hole with SAS chain
- 5.5 m tall containing main beam and cryostat

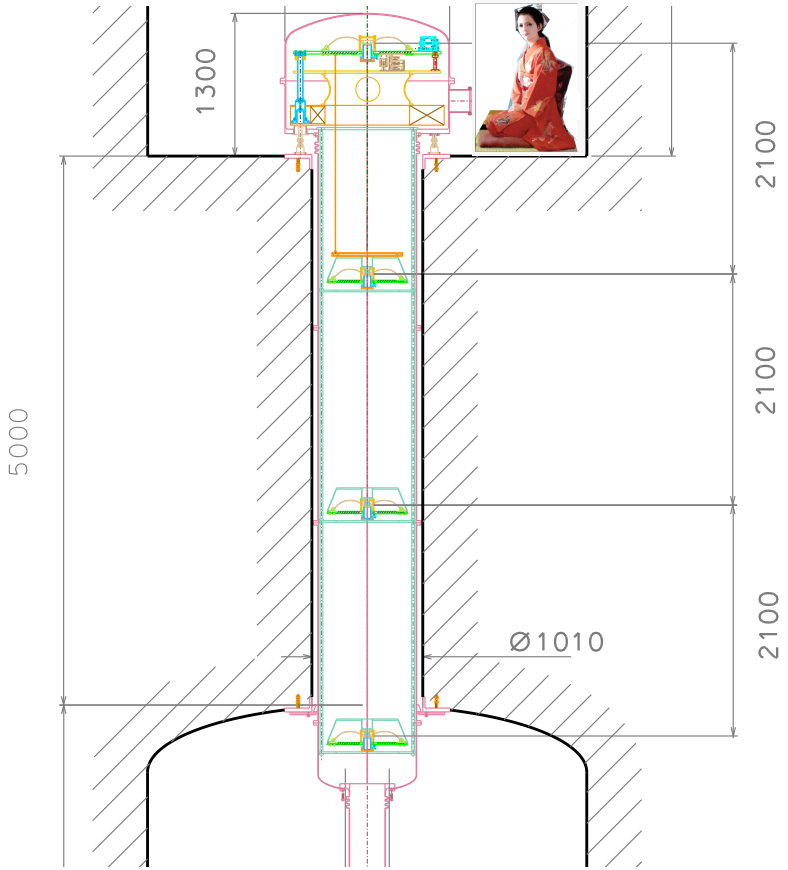
For more detailed discussion, please see JGW-T1000249

Physical advantages



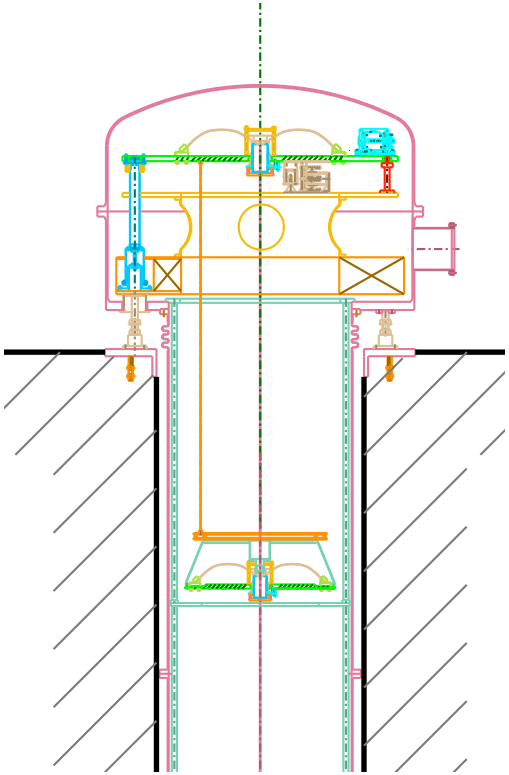
- Pre-isolator footed on solid rock
- Inverted Pendulum table short
  - It was found that small size = better performance
- Easy of access for pre-isolator tuning

Physical advantages



- Naturally longer pendulum length between filters
- Lower frequency performance
- Opens door to possible physics underground from lower Newtonian Noise

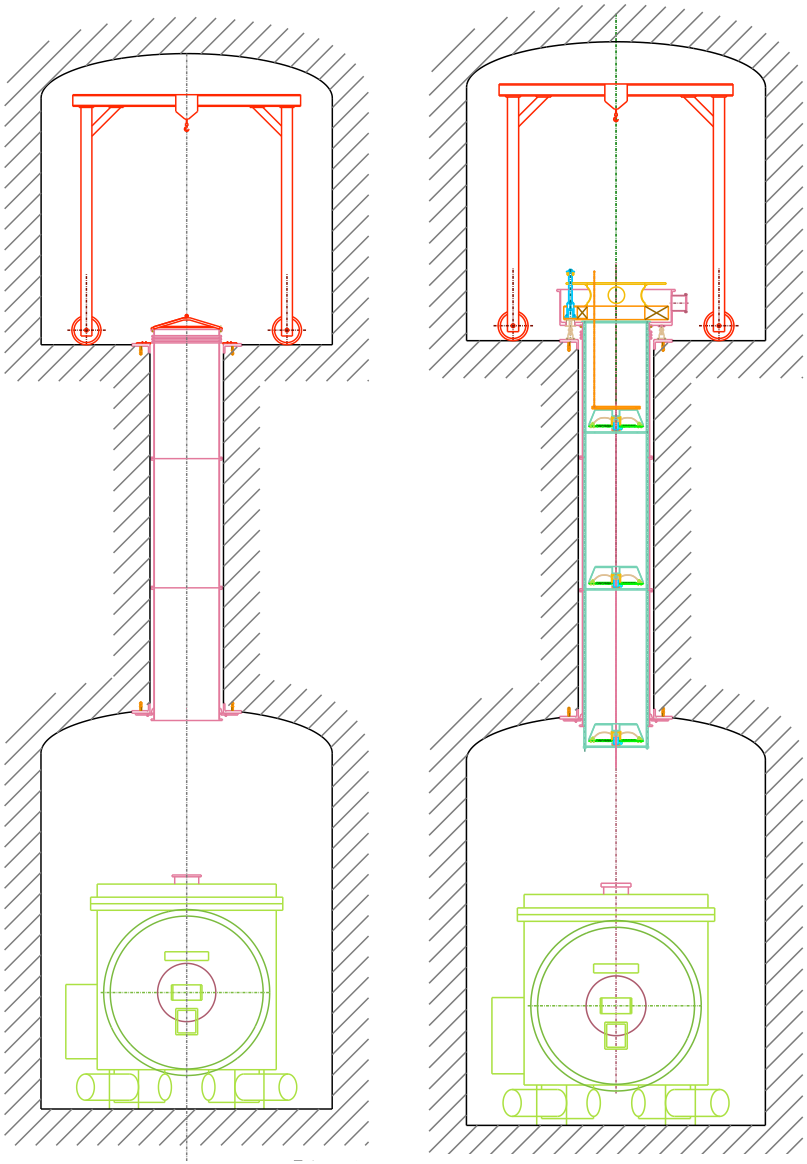
Controls advantages



- 3 standard filters instead of 2
- Reserve in attenuation power
- Additional filter to implement Eddy current damping
- Effective chain mode damping
- Easier and more reliable Interferometer locking

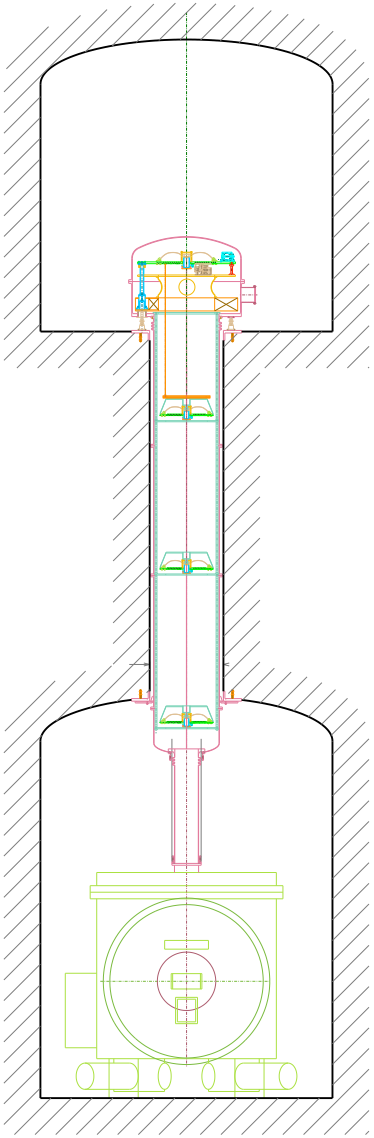
- Need simulations to confirm design

Technical advantages



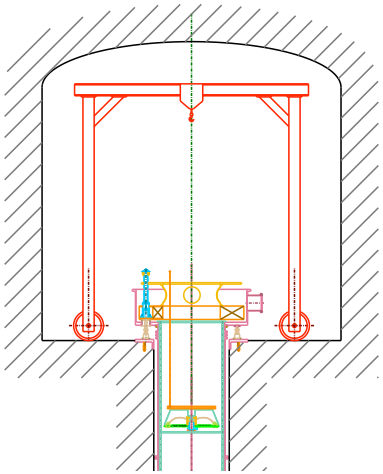
- Ease of installation
- No need of large, expensive rigid structures

Technical advantages



- Safer installation procedures
- Large separation between suspension point and main tunnel, cryogenics, . . .
  - Longer path for noise transmission
- Ease of payload/cryostat replacement

Economical advantages

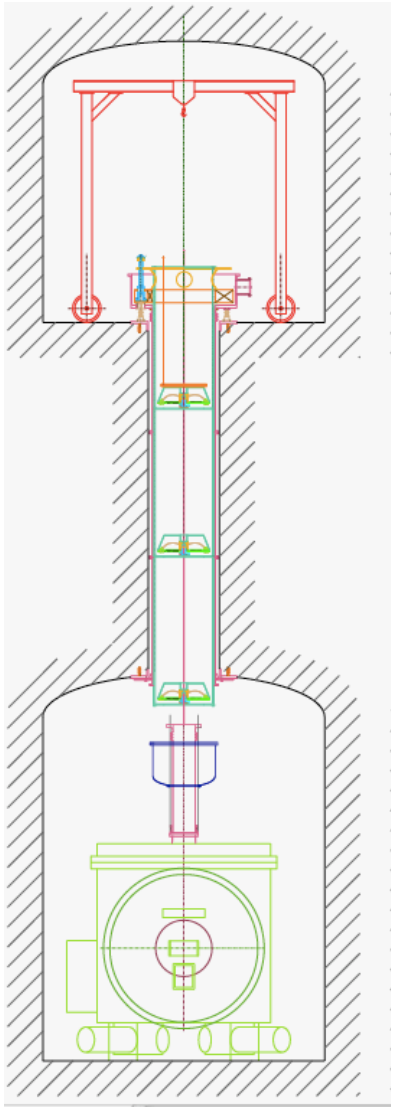


- Much smaller and cheaper vacuum structure
- Much lighter crane requirements

Mining advantages

- Smaller dug out volume
  - Less stability problems
  - Less lining thickness
- Tunnel-like structures
  - No need of larger machineries to make large halls
-

Cryogenic installation



- No impediment in cryostat tunnel
- Ease of connecting-disconnecting payload
- Relative ease of payload change if needed

Disadvantages

- Need new bore-holes to re-position any optical element
- Need to know where to locate all mirrors !
- Re-boring alone ~M¥

- Need ~ 75 m (15% slope) of 4m x 4m tunnel ramp to connect floors

Disadvantages

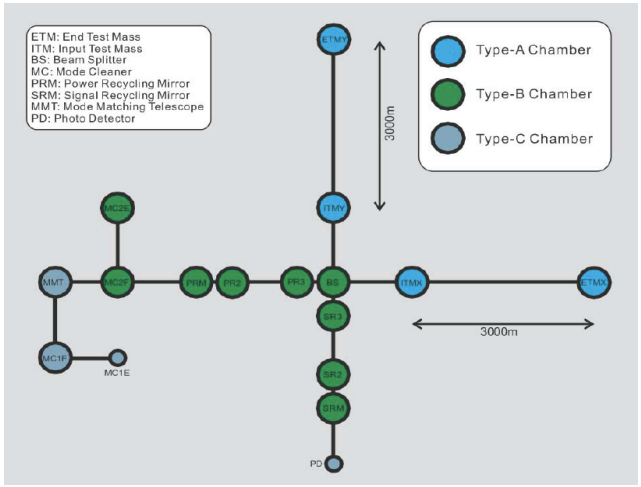
- Will need 1200 mm diameter or oval boreholes
- to allow for ±100 mm tuning of PR, SR, ITM mirrors

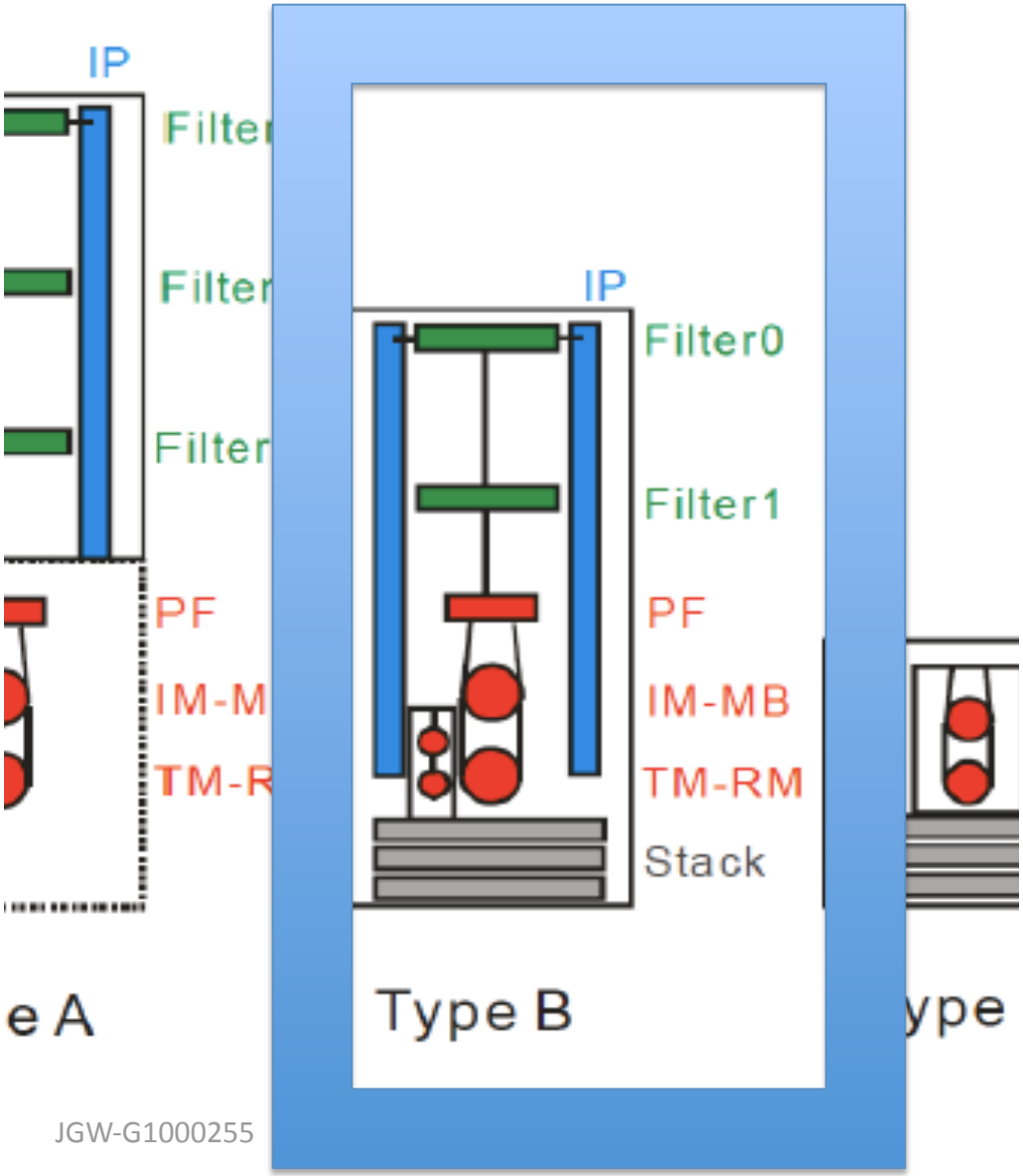
Dual tunnel type A seismic

- More stable pre-isolator footing
- Keep door open for exclusive physics
- At marginal or no additional cost

Type B proposed solution

- Attenuation chains for recycler and mode cleaner mirrors





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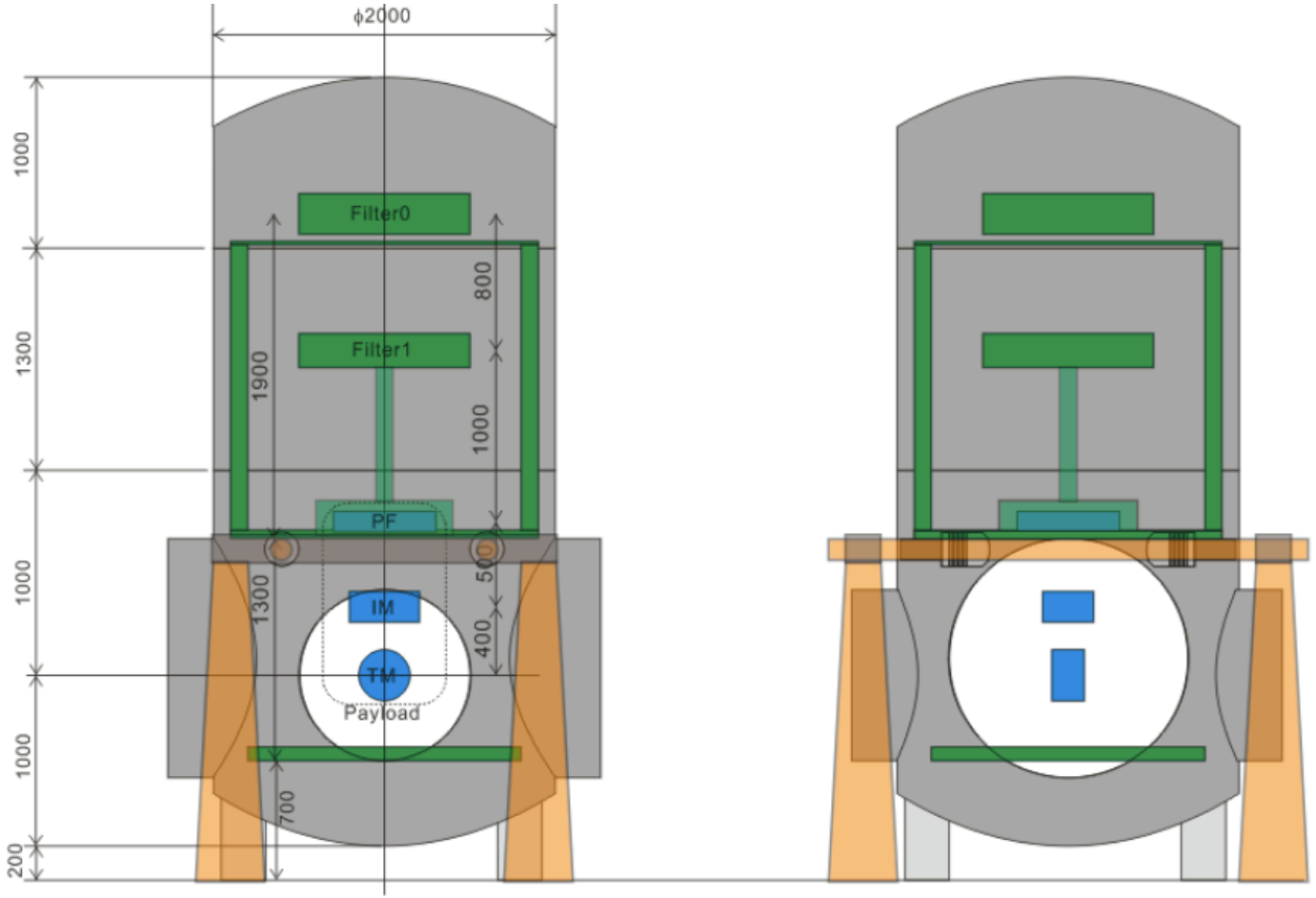
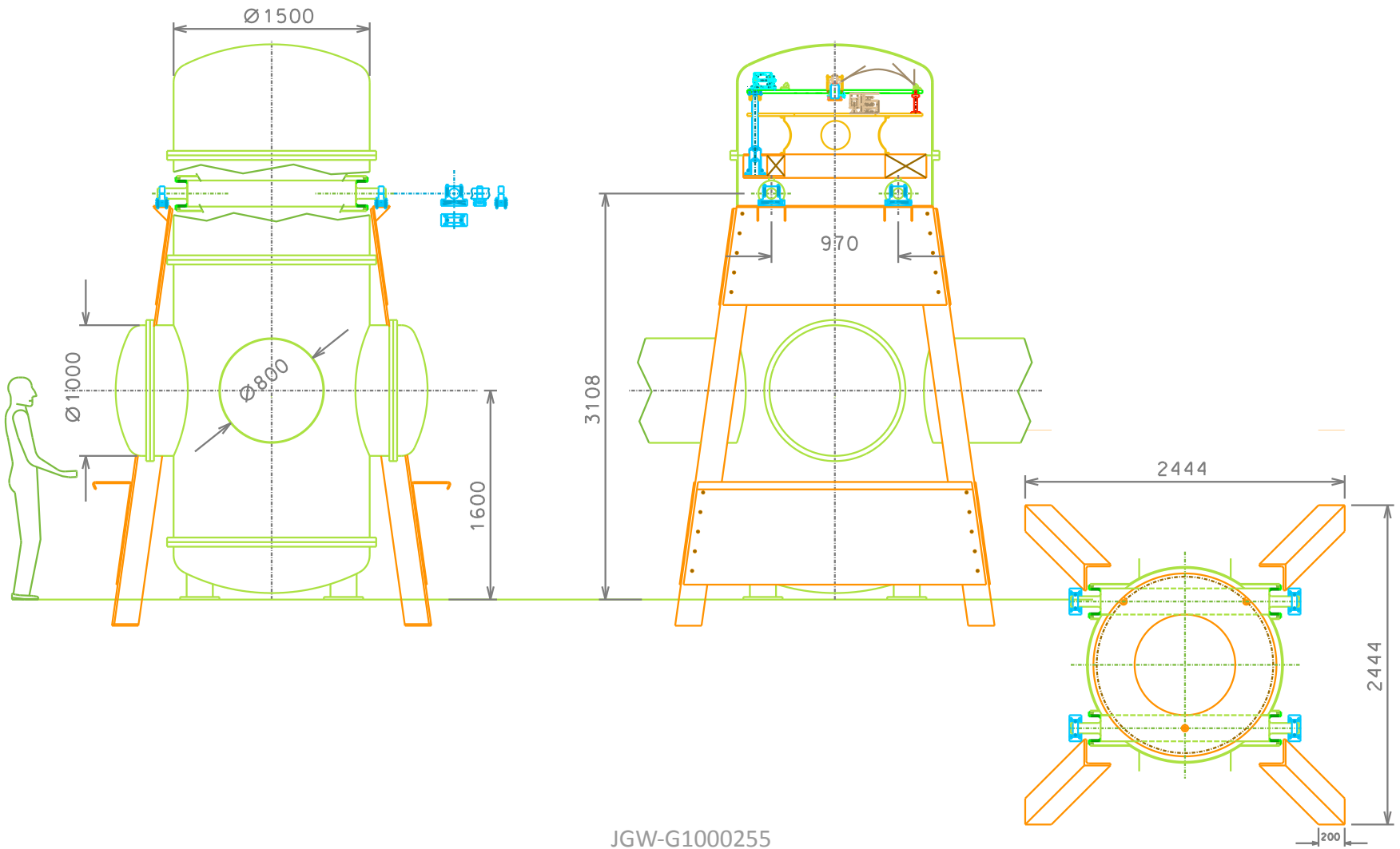
Starting point



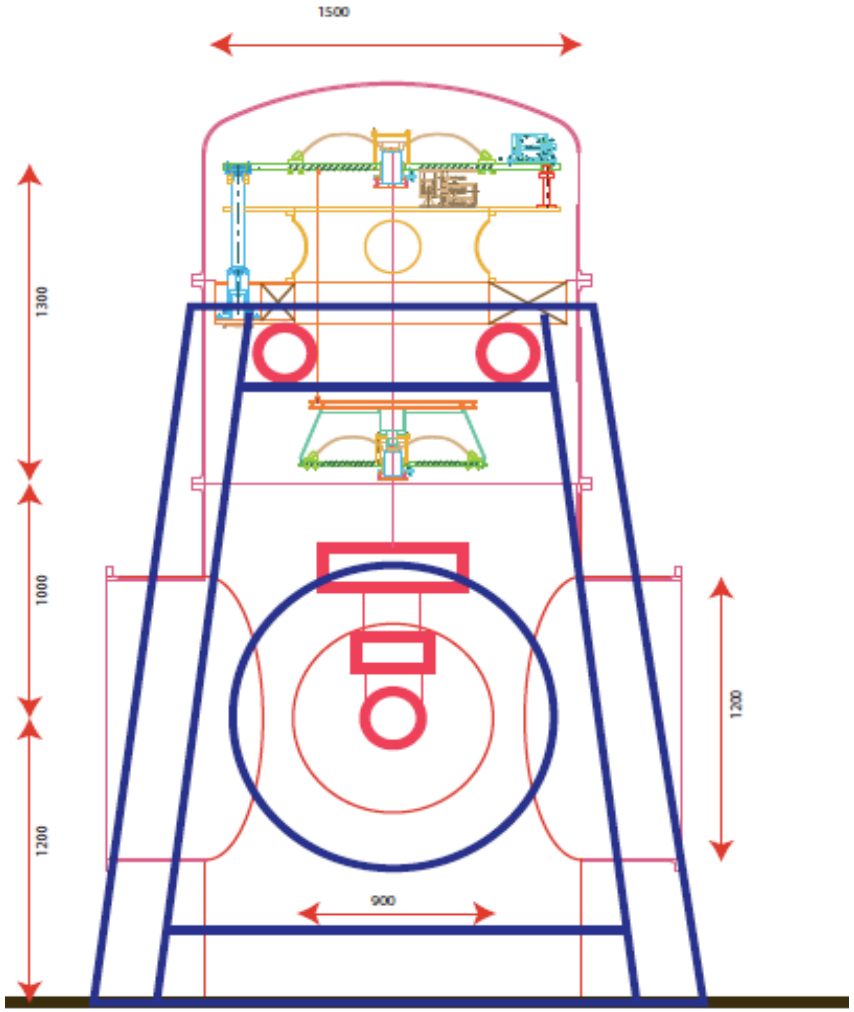
Proposed solution

- 

Proposed solution

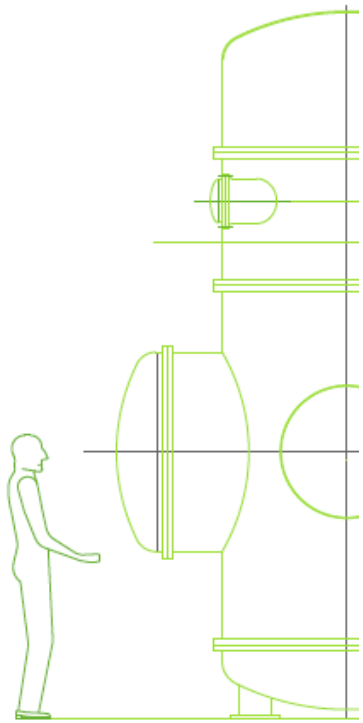
- External rigid structure
  - preserve advantage
- Same isolation elements
- Reduced size
  - Better access
  - Reduce cost

Need simulations to confirm design



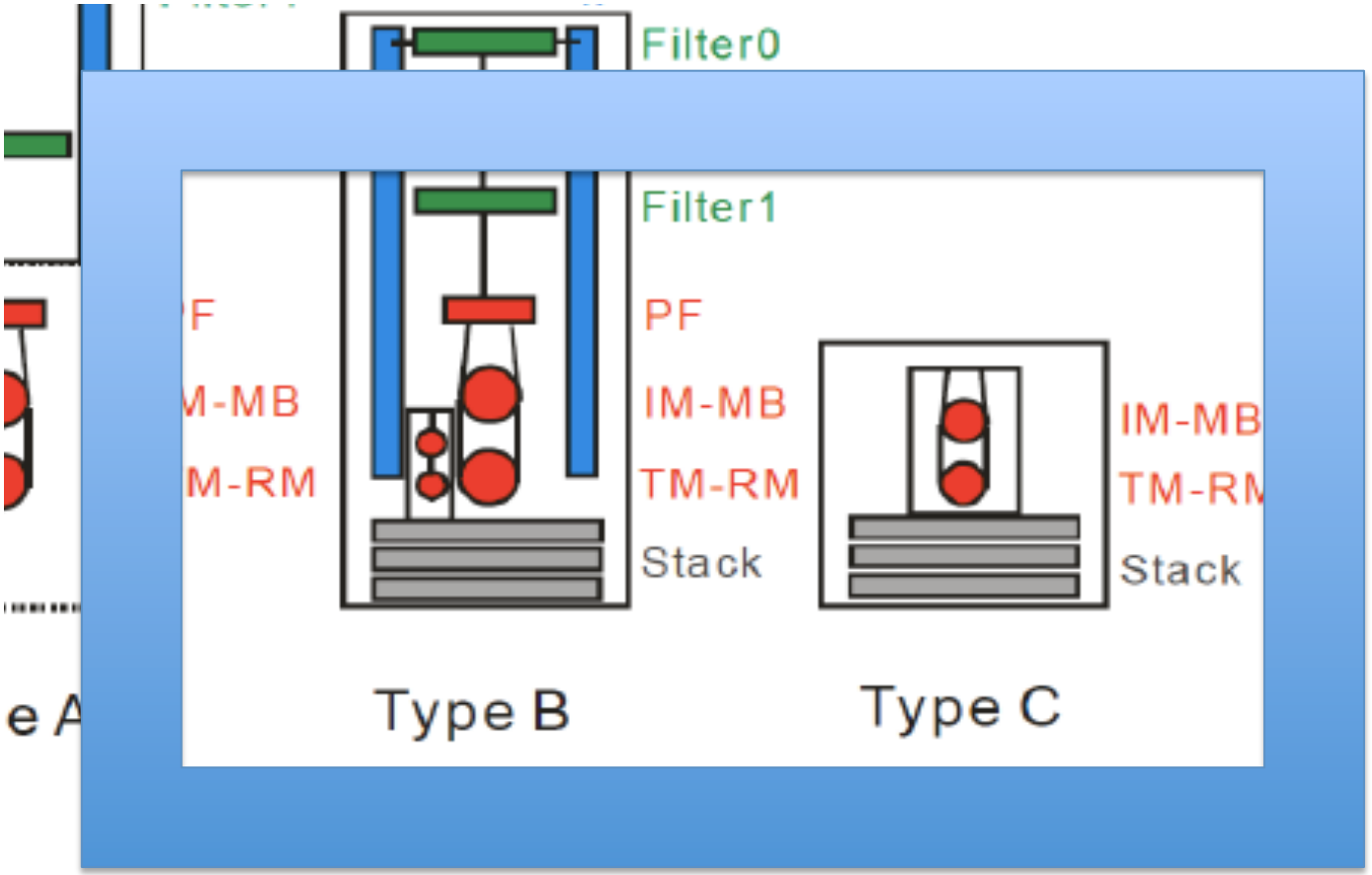
Installation access

- LIGO:
  - Enormous (very expensive) walk in chambers
  - HAM side access SR, SR1, SR2, MC mixed on same table
- Virgo:
  - Access from below
- LCGT:
- Side access
  - Separated SR, SR1, SR2, MC suspensions
    - Larger chambers unnecessary
  - Small chambers access advantage
  - Similar to cryostat configuration

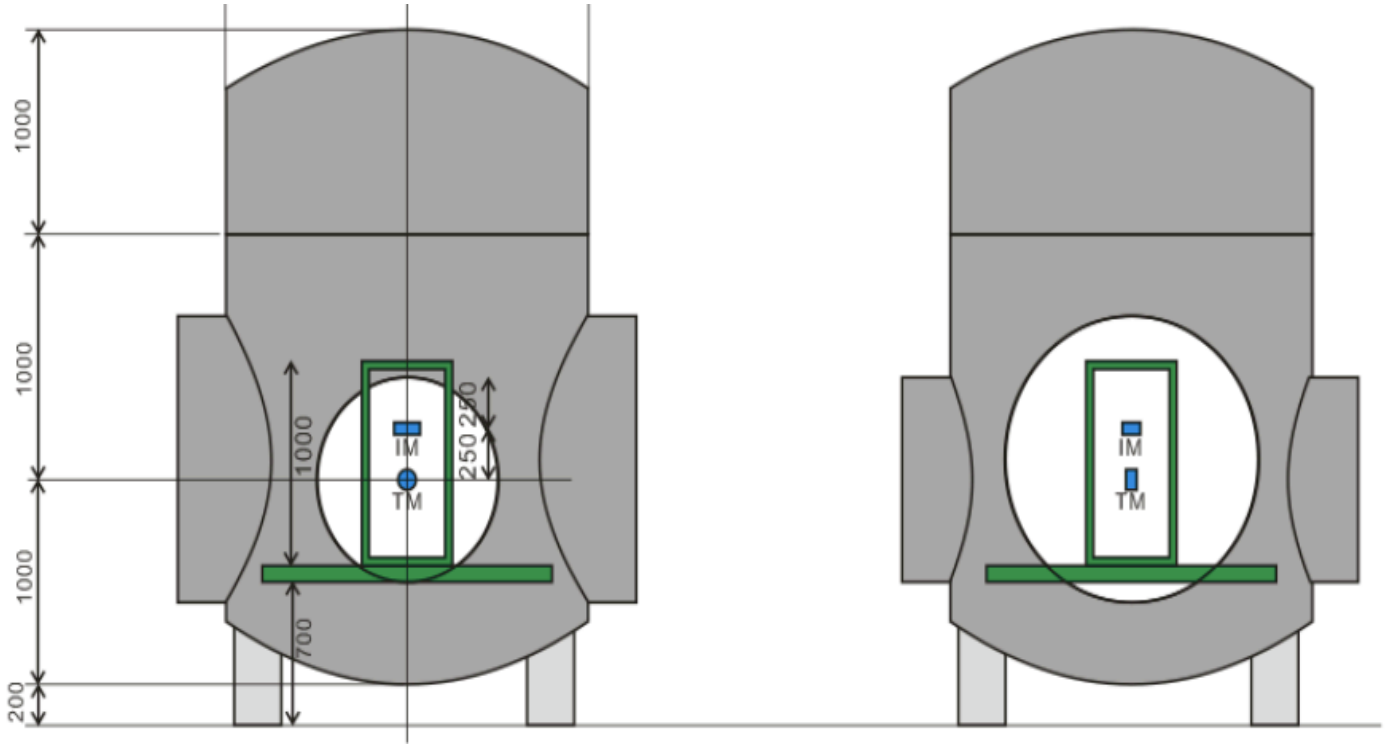


Type B and C proposed solution

- Attenuated optical benches

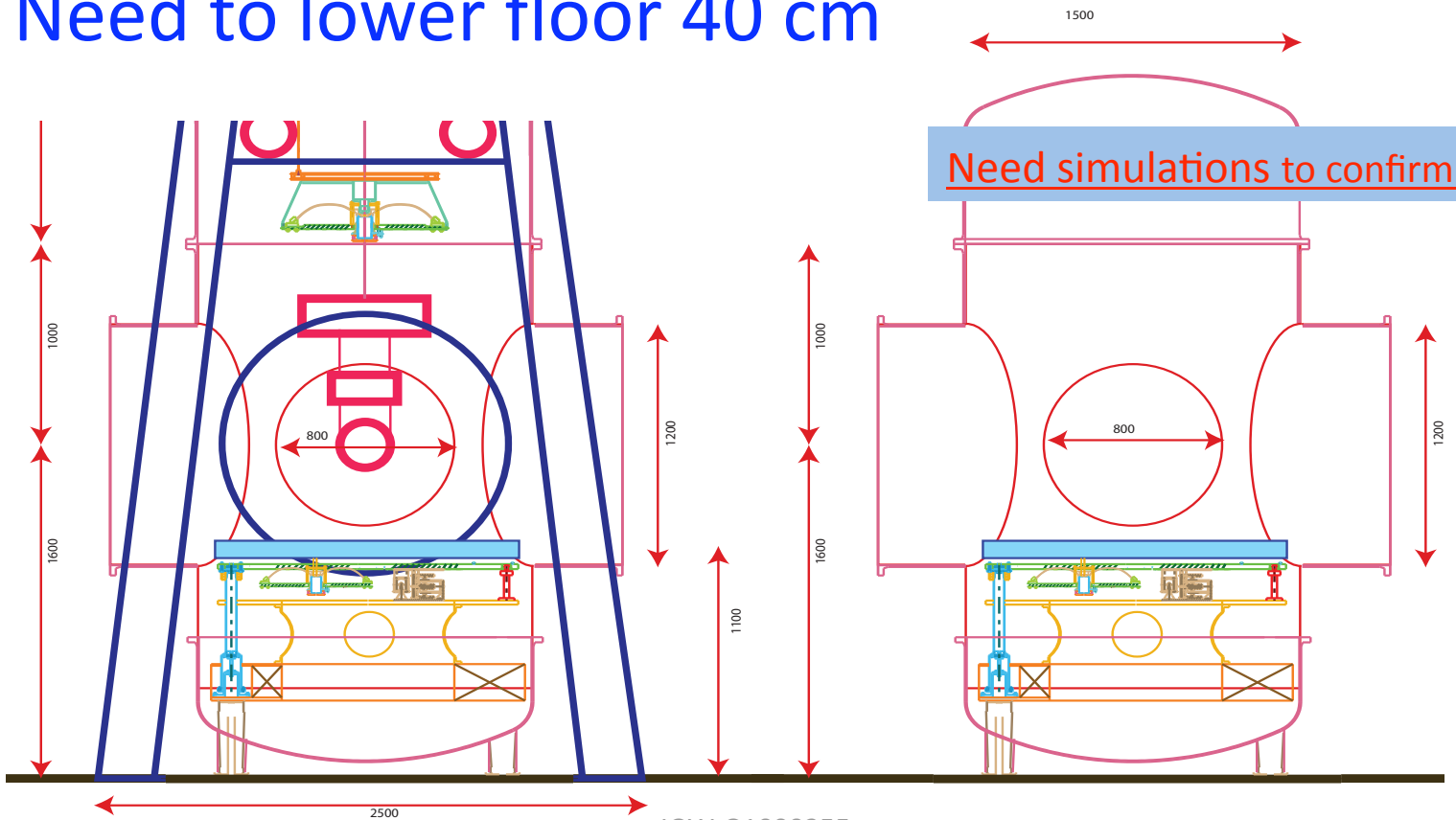


Starting point



Proposed solution

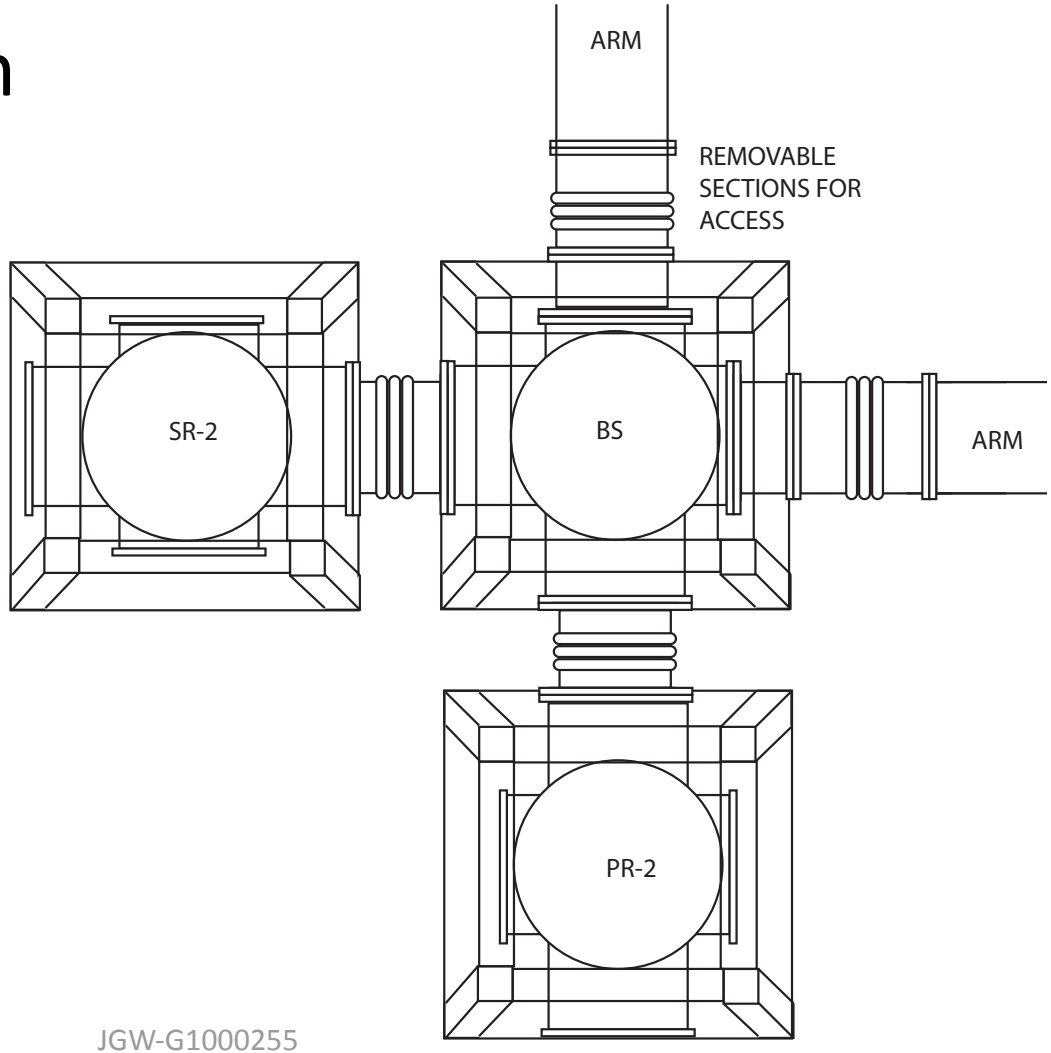
- Need space below
- Need to lower floor 40 cm



Need simulations to confirm design

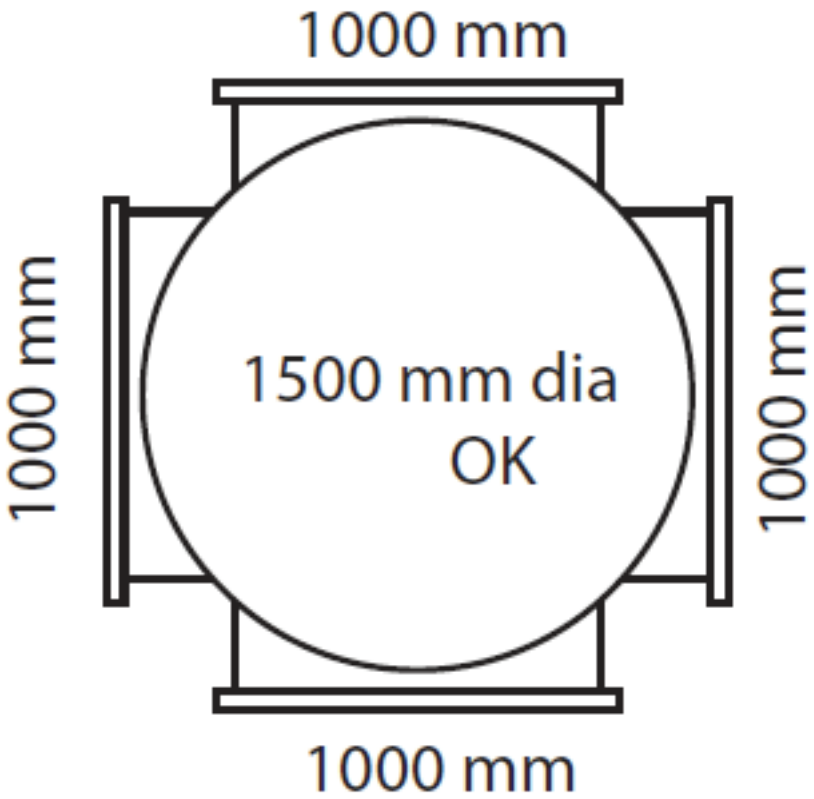
More on access

- Side access OK in most chambers
- Except in BS where 4 pipes cross
- Need to remove pipe sections for access



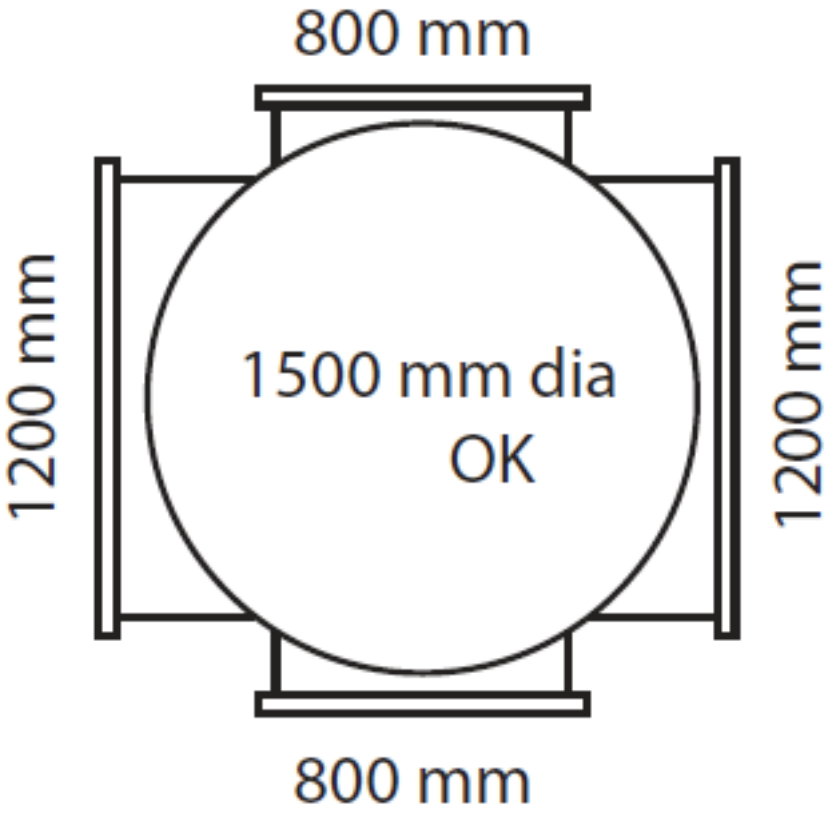
Vacuum tank questions

- Is 1500 mm the best choice?
- Are 1000 mm flanges the best compromise?
- Is it structurally OK?



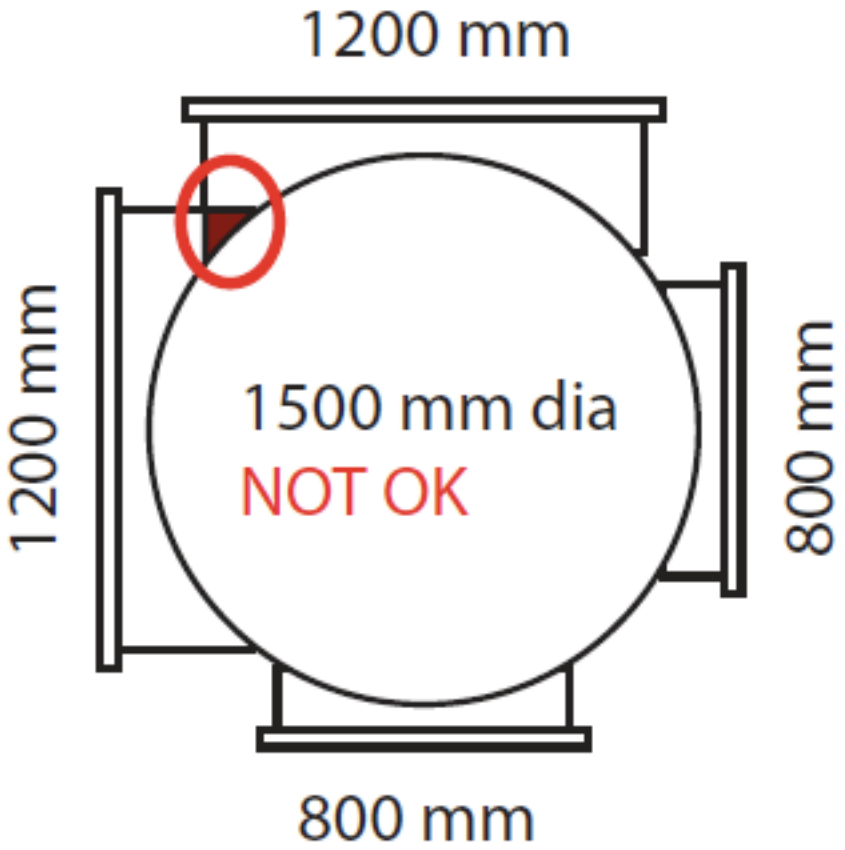
Vacuum tank questions

- 1200 mm flange best for access
- 800 mm matches pipe size
- 1000 mm may be needed to route folded recycler beams



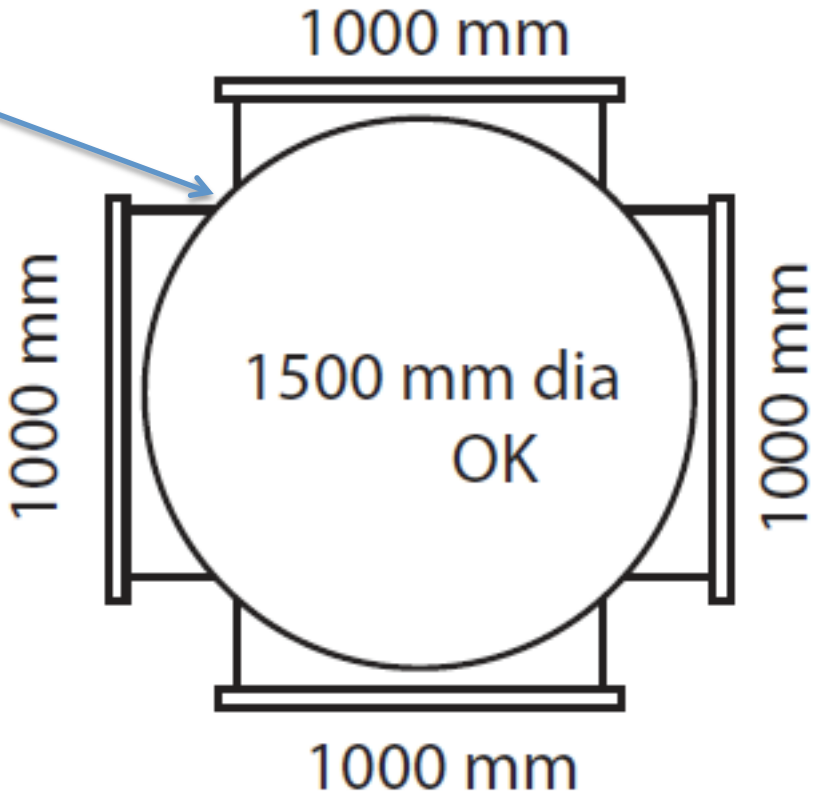
Vacuum tank questions

- 1200 mm flanges on contiguous sides certainly not a good idea ! ! !



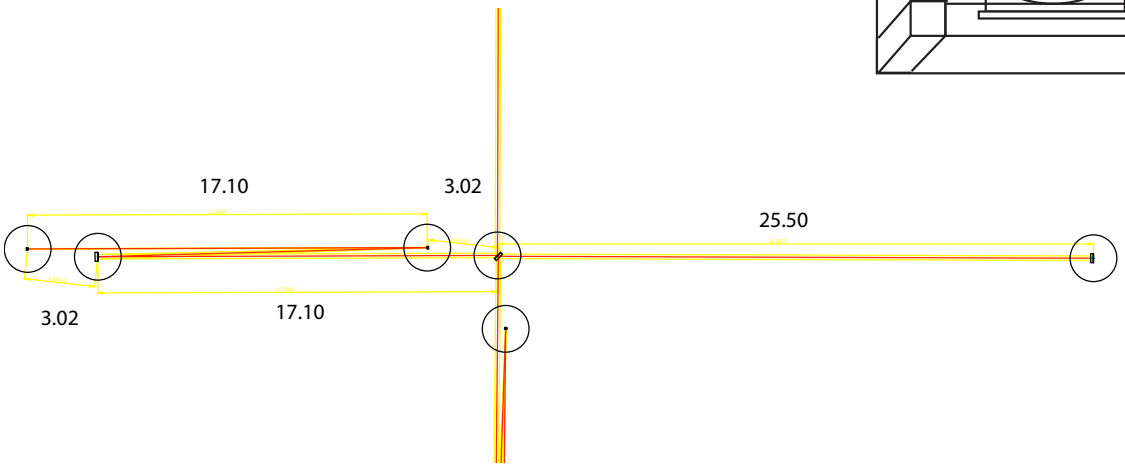
Vacuum tank questions

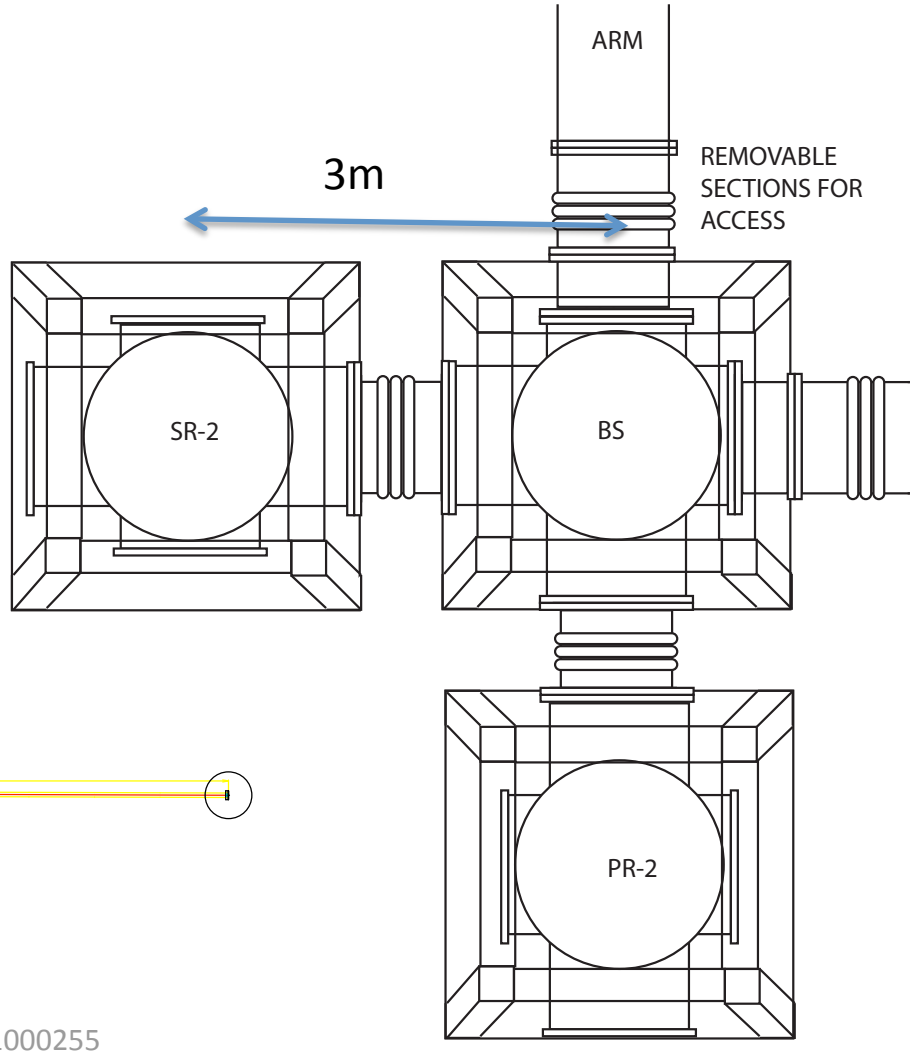
- Does 1500 mm tank with 1000 mm flanges lead to structurally sound?
- How thick needs the tank to be?
- Is 1000 mm flange sufficient for side access assembly?
- Is a 1400 mm bench sufficient for ancillary optics?



Do we need more than 3 m separation between tanks?

- 17.1+14.08+17.1+25.5 =83.78 m fixed value
- To conserve 83.78 m
- and increase 3 to 3.5m
- 17.6+14.08+17.6+24.5
- Is 24.5 m to ITM OK?





Back to non-horizontal interferometer
戻る非水平干渉計

- Earth's radius 地球の半径 = 6.4 10^6 m
- Natural tilt自然の傾き1500/6.4 10^6 = 2.3 10^{-4}
- Imposed tilt 課したの傾き1/200 = 5 10^{-2}
- sensitivity to vertical noise worse 20 x
- 垂直方向のノイズに対する感度悪い 20 x
- Metal elasticity 1/f noise in wires diluted by gravity in horizontal direction
- 金属の弾力性 1/f 配線のノイズは、水平方向の重力によって希釈
- Last stage non metallic, further filter metal noise
- 最終段以外の金属、さらにフィルタ金属ノイズ

Please read
JGW-P1000254

Problems with non-horizontal interferometer
問題 非水平干渉計

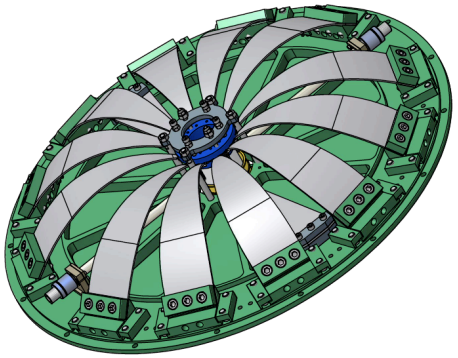
- All metal elasticity 1/f noise is transmitted completely unfiltered in vertical direction
- 金属の弾力性は1 / fノイズ完全に送信されます 垂直方向にフィルタリングされていない
- Transmitted to horizontal by tilt
- 傾斜が水平に伝わる
- We can do a good tilted interferometer
- 我々は良い傾斜干渉を行うことができます
- We cannot do a tilted GW detector !
- 我々は、傾斜重力波検出を行うことはできません

Please read
JGW-P1000254

Facility issue 施設の問題

- Tilt the tunnel may defeat the purpose
- チルトは、トンネルの目的を打ち負かすことがあります
- Is it worth building an interferometer that may not measure Gravitational Waves?
- 重力波を測定することができない干渉計を構築する価値がありますか？

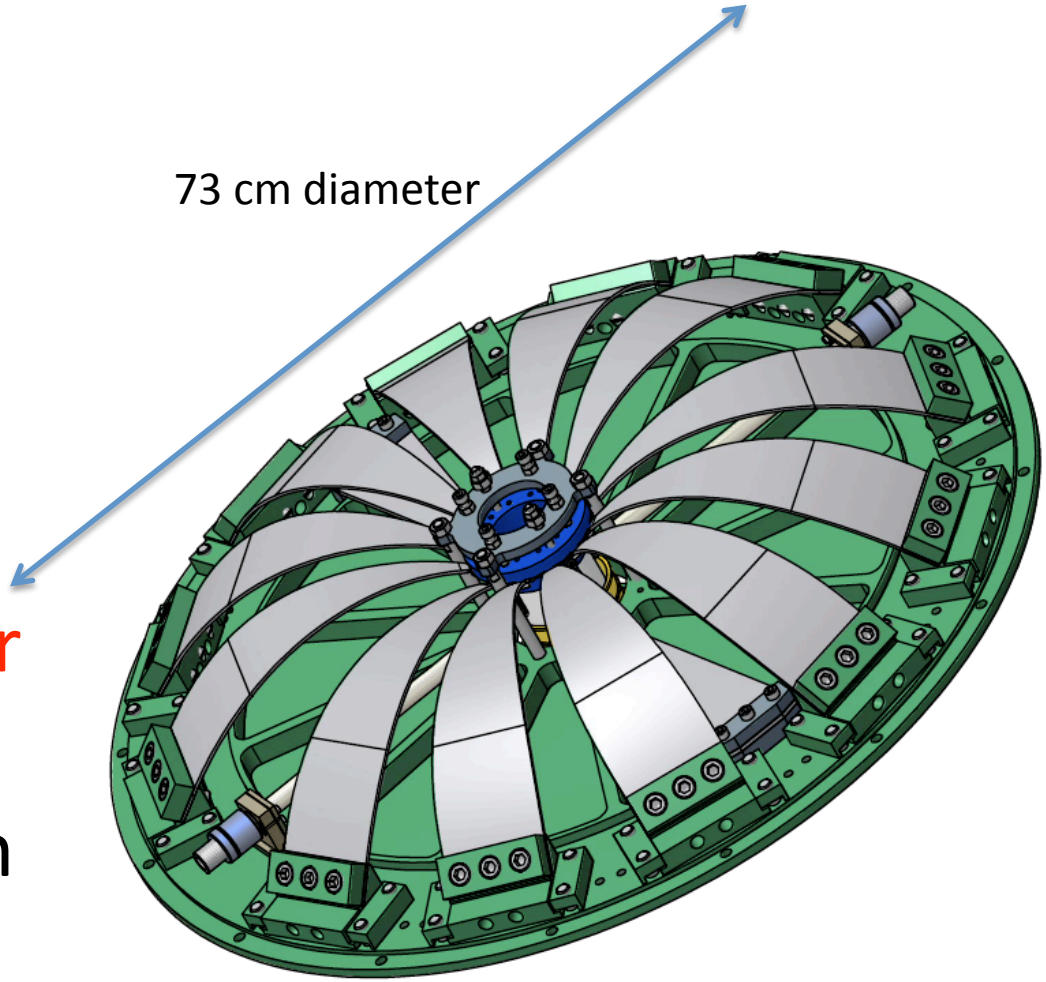
Seismic attenuation Modular design



- Standard filter with changeable load
- Standard pre-isolation with
  Inverted pendulum and
  GAS suspension
- Optical benches on same IP-GAS elements

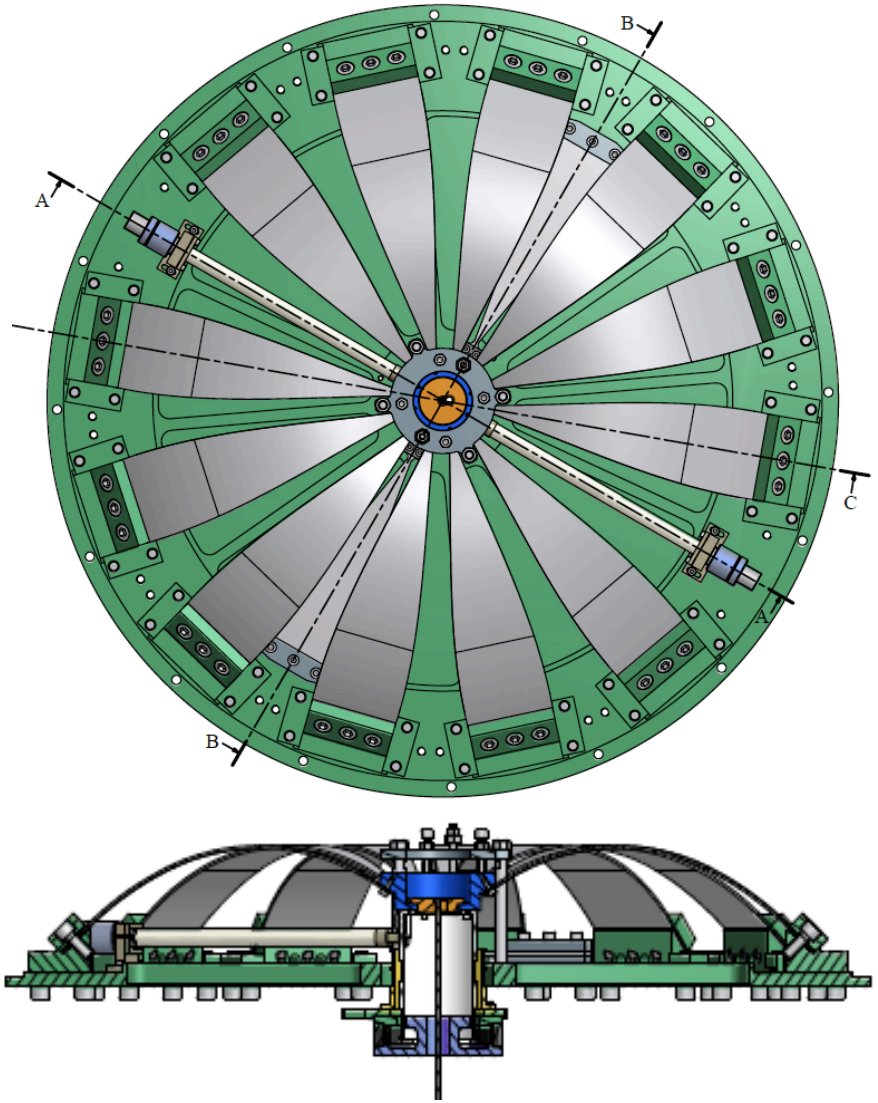
Standard modular filter

- Twelve separate blades design
- 500 kg max nominal load
- Steps of 80 kg load reduction per pair suppressed
- Smaller steps with smaller blades



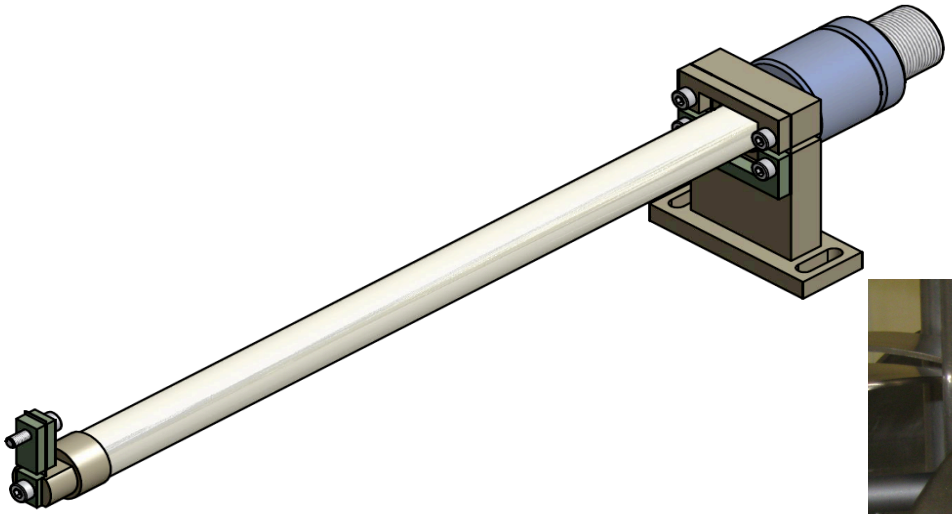
Standard filter performance

- Magic wands,
  - Peak attenuation 90 dB
- Bimetal thermal compensation
- LVDT/Actuator for frequency tuning



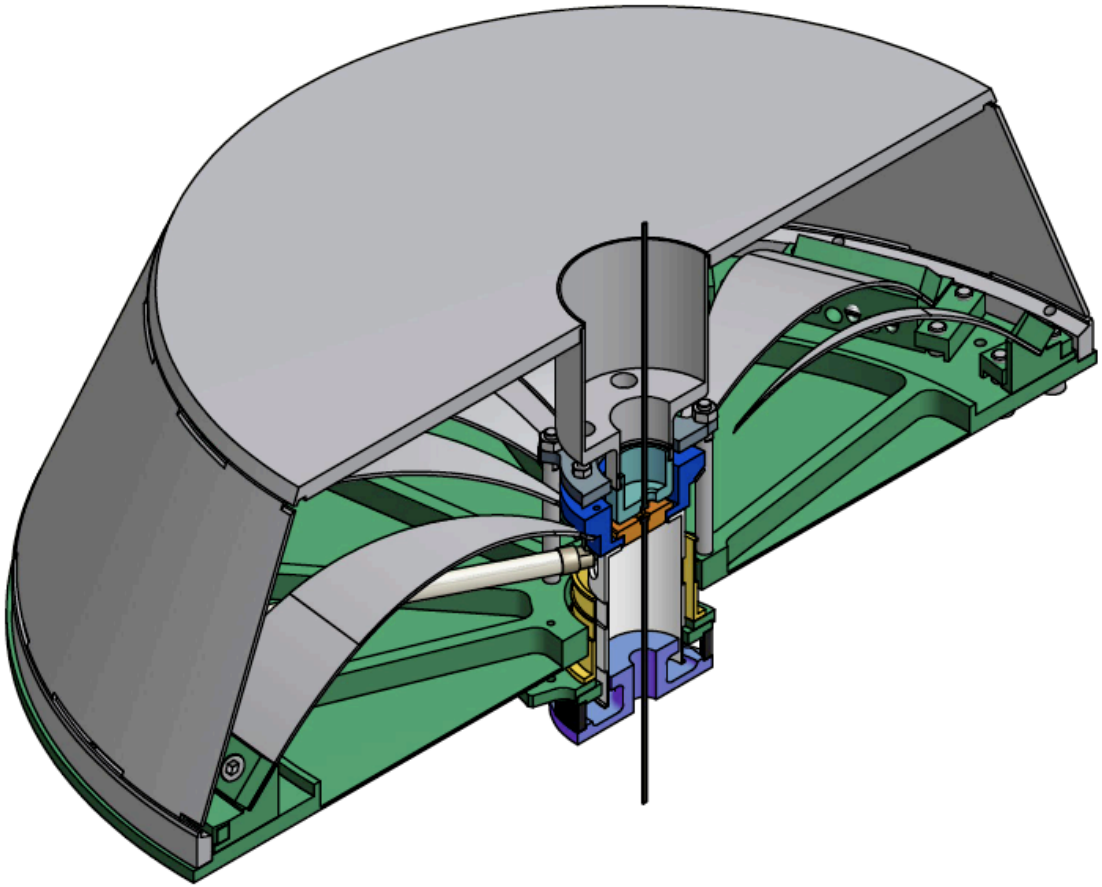
Magic wands

- Compensate center of percussion limitations



Thermal shield

- The standard filter is designed to operate near cold spots



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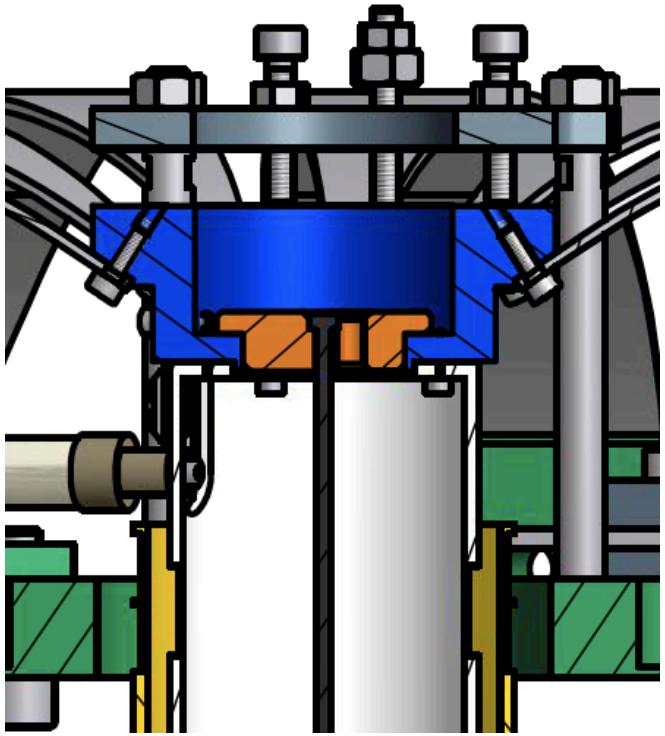
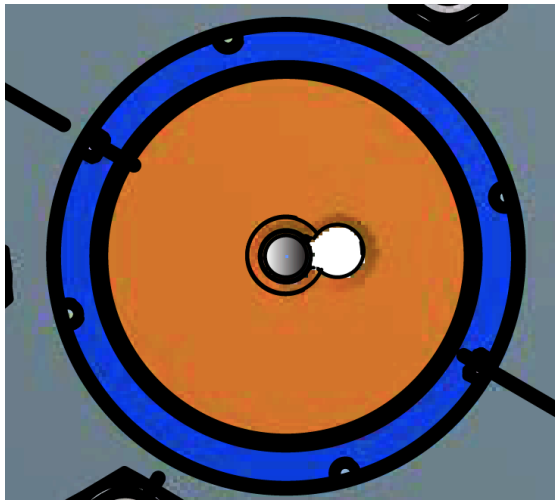
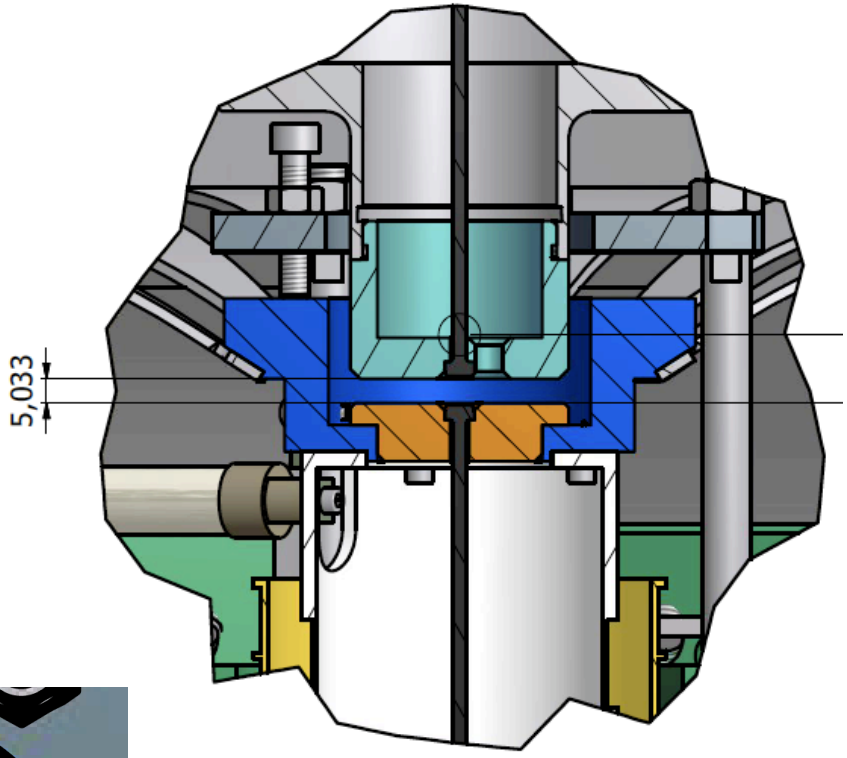
Rapid suspension wire hooking

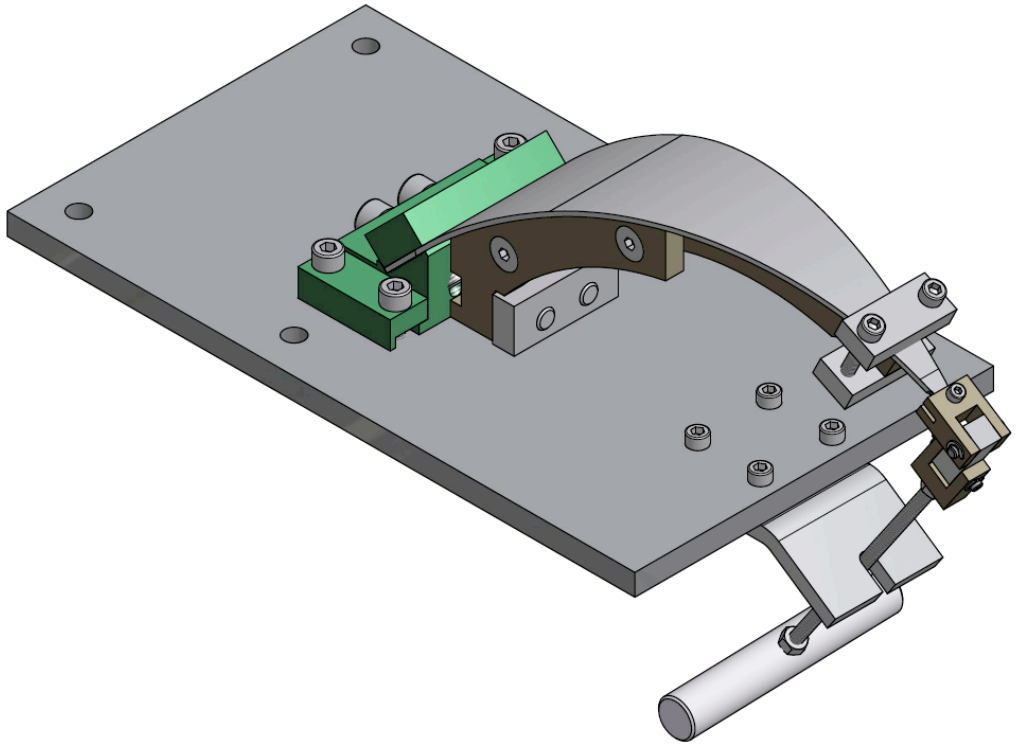




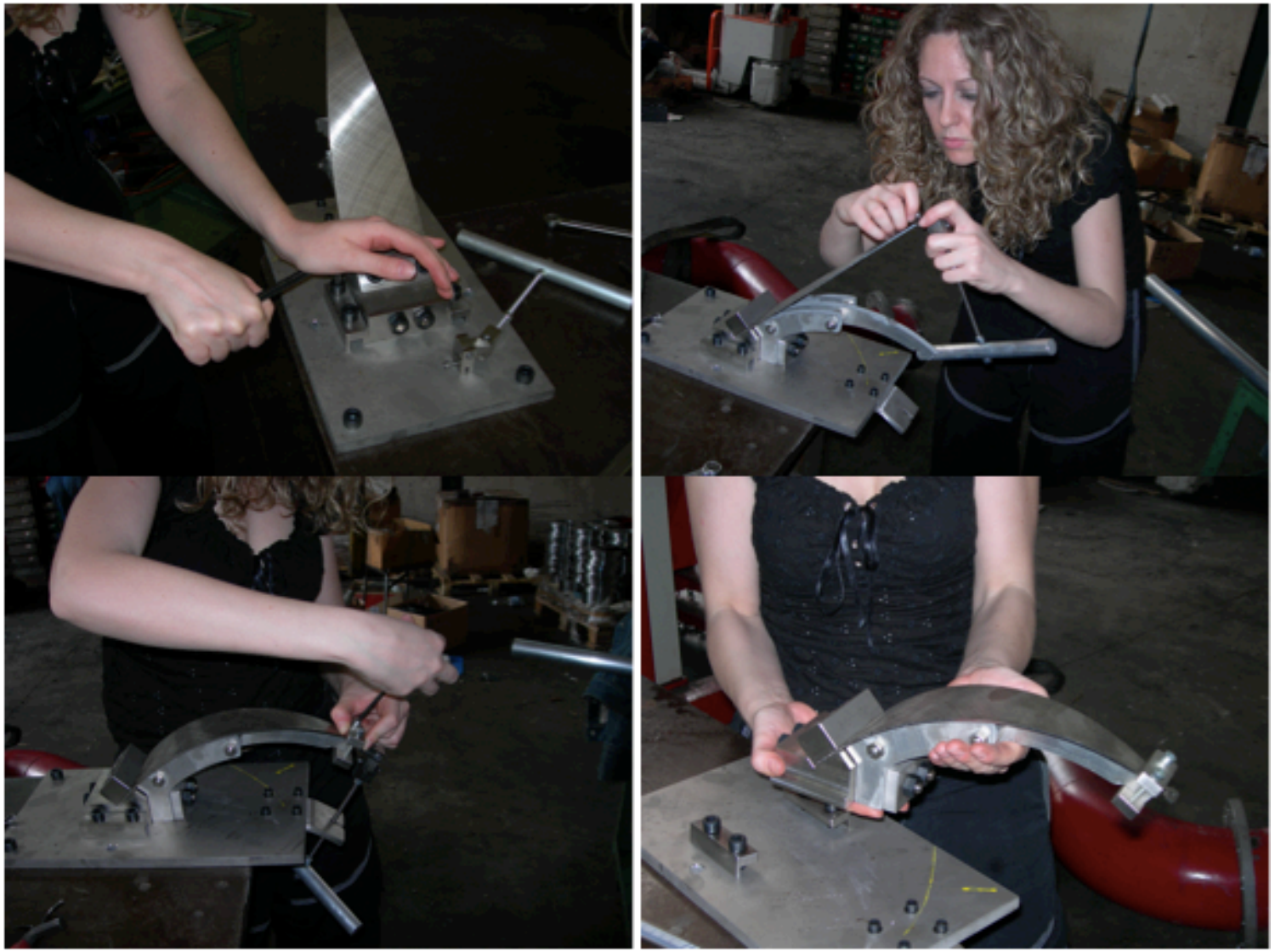


Modular-rapid blade assembly

- Specialized tooling

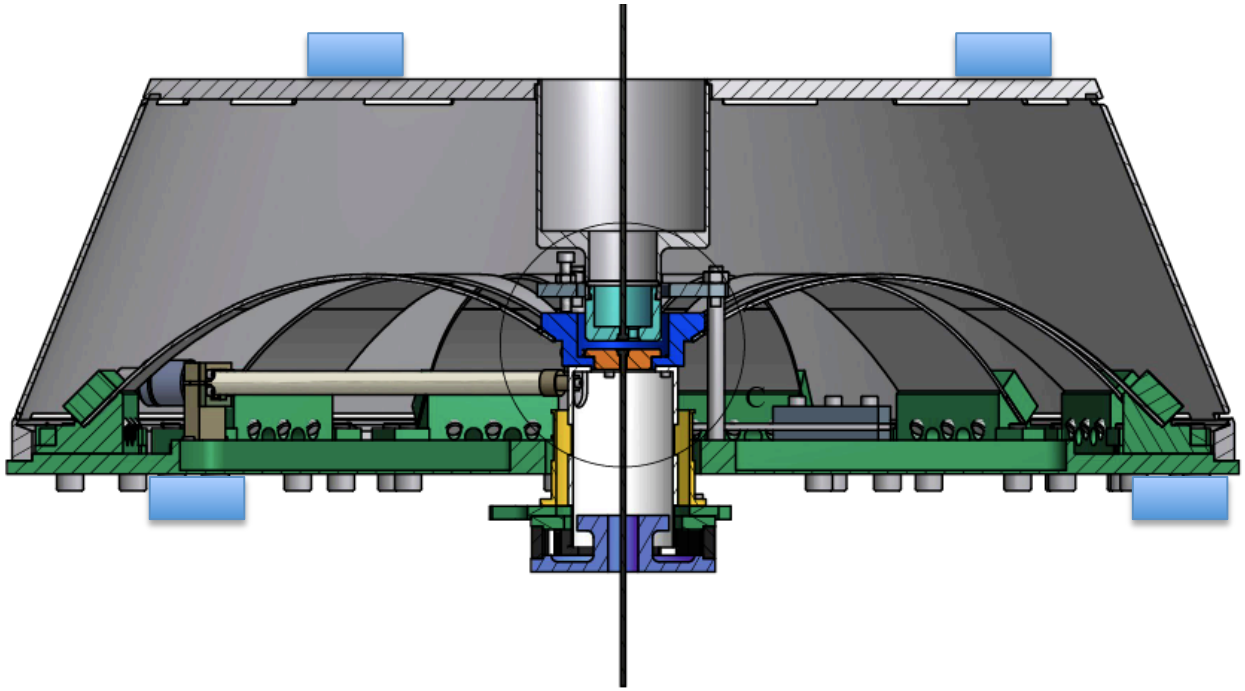


Easy to assemble



Mass/balance, tilt frequency tuning

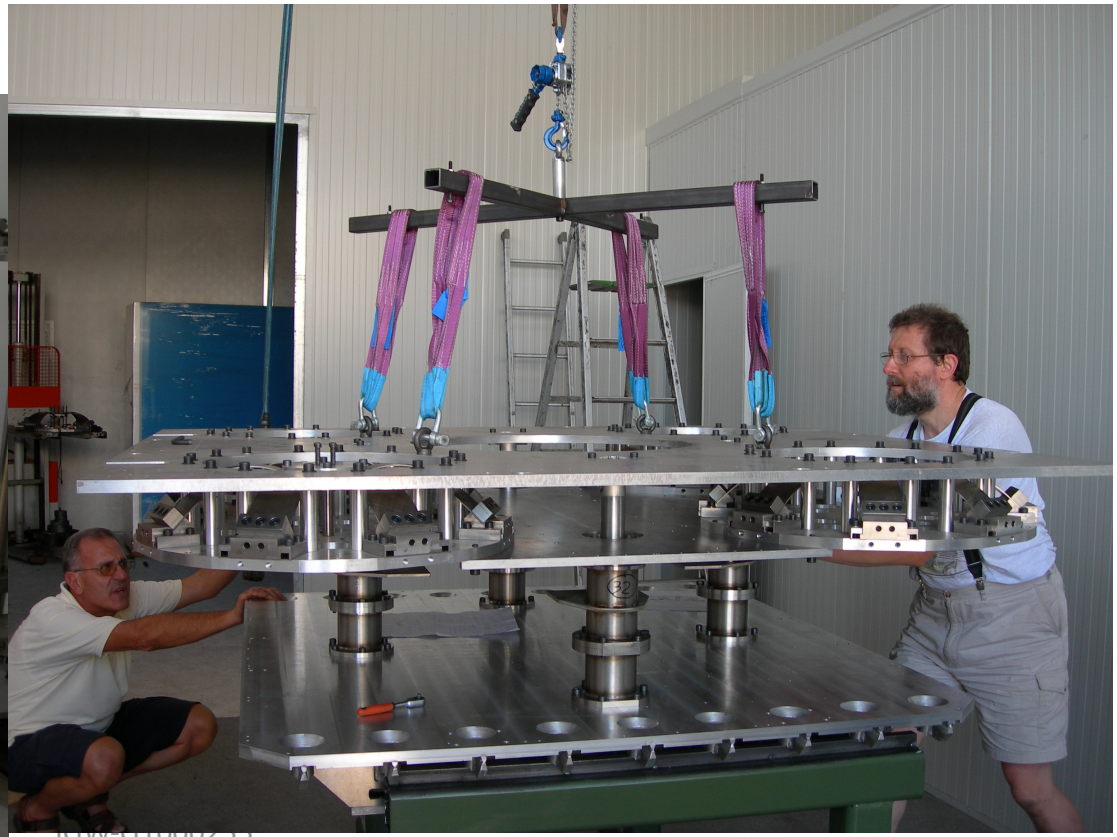
- With masses above and below the shell



Inverted pendulum

- Same as HAM SAS and AEI SAS

Please read LCGT-T1000253:
http://gw.icrr.u-tokyo.ac.jp/cgi-bin/private/DocDB/ShowDocument?docid=253



How to proceed-1
どのように進めて-1

- No time to delay design any further
- 時間がない設計遅延へのさらなる
- We need prototype delivery by March
- われわれは3月までにプロトタイプの配信を必要とする
- I will discuss with all of you today, tomorrow and Wednesday morning
- 私はあなたのすべての今日、明日、水曜日の朝に議論する
- Then I will assume that the suggested design parameters are correct and approved
- それから私は提案設計パラメータが正しいと承認されていると仮定します

How to proceed-2

どのように進めて-2

- I will proceed with the design of type A seismic attenuation chain and vacuum tank
- 私のタイプの設計地震波減衰チェーンと真空槽を進めていく
- I will modify the design if and when I receive complaints from you
- 私はあなたから苦情を受けるとき場合、私はデザインが変更されます
- Flexibility will reduce rapidly with time
- 柔軟性は時間の経過とともに急速に減少します