First considerations on layout and alignment options

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for the TBM team

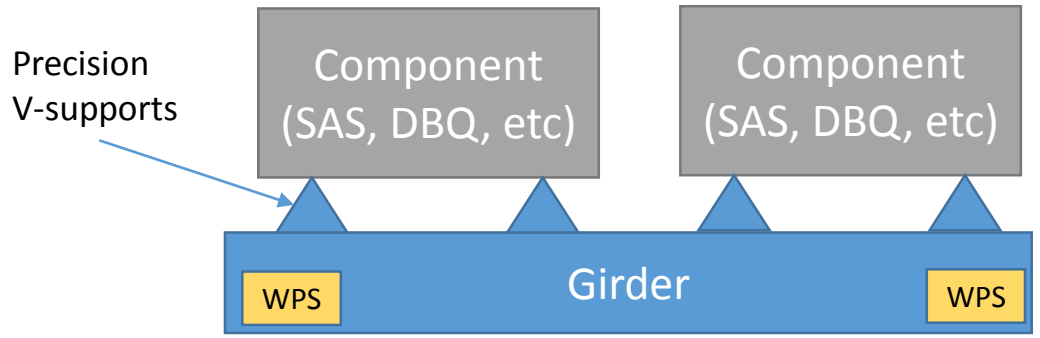
Outline

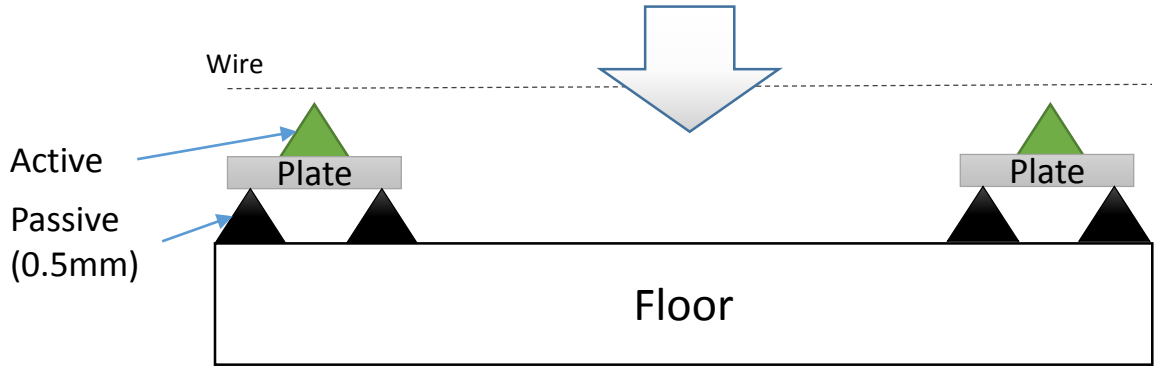
- CDR design and problems
- Systematic approach to define all possible configurations
- This presentation will concentrate on granularity
- Open questions

CDR design

A redesign of the components support is needed

- Manufacturing tolerances have not been reliably achieved
- Weak link for transportation
- Relies on extremely expensive girder
- Snake configuration requires adjustable articulation point





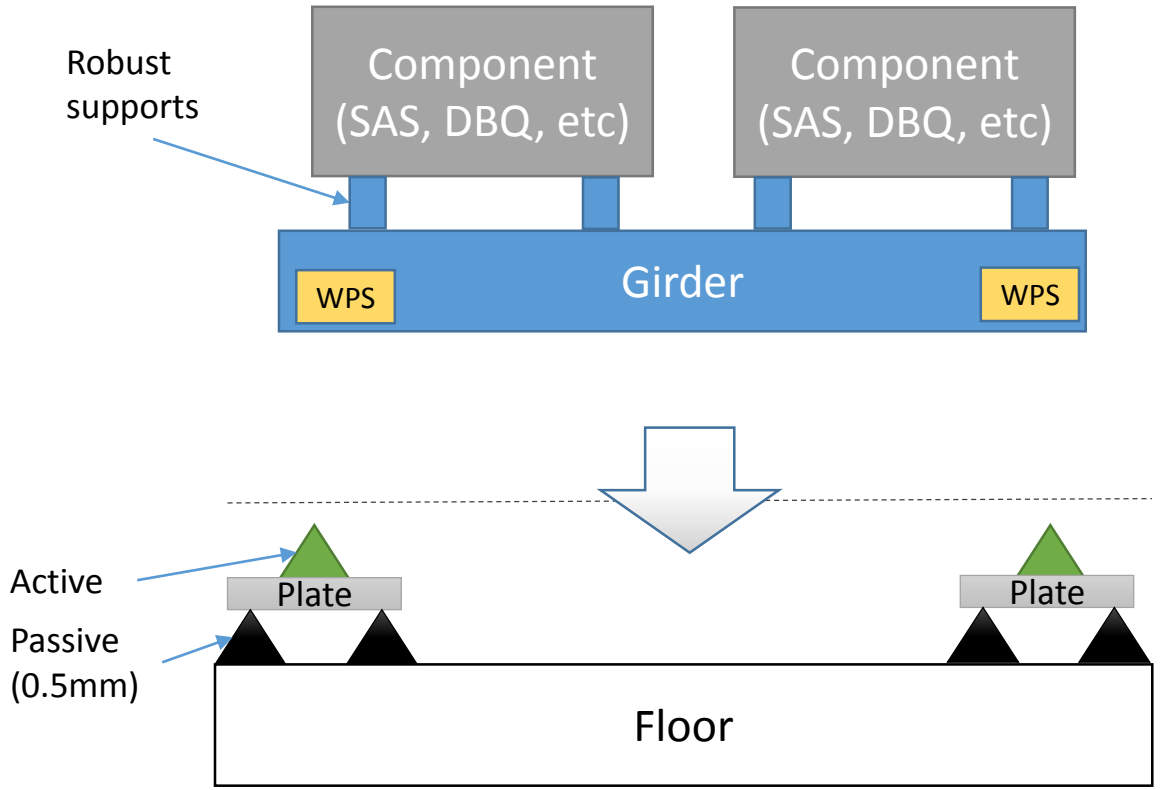
Thought process

- Key ingredients
  - Module length: multiple of «RF-Unit» length
  - Common Girder: Yes or No
  - DBQs on girder: Yes or No
  - Components on adj. supports: better not, only as last resort
  - Definition of «RF-Unit»: input from RF and production team

- Exhaustive list of possible combinations, based on first principles (~10)
- Main parameter to be defined: **Granularity**

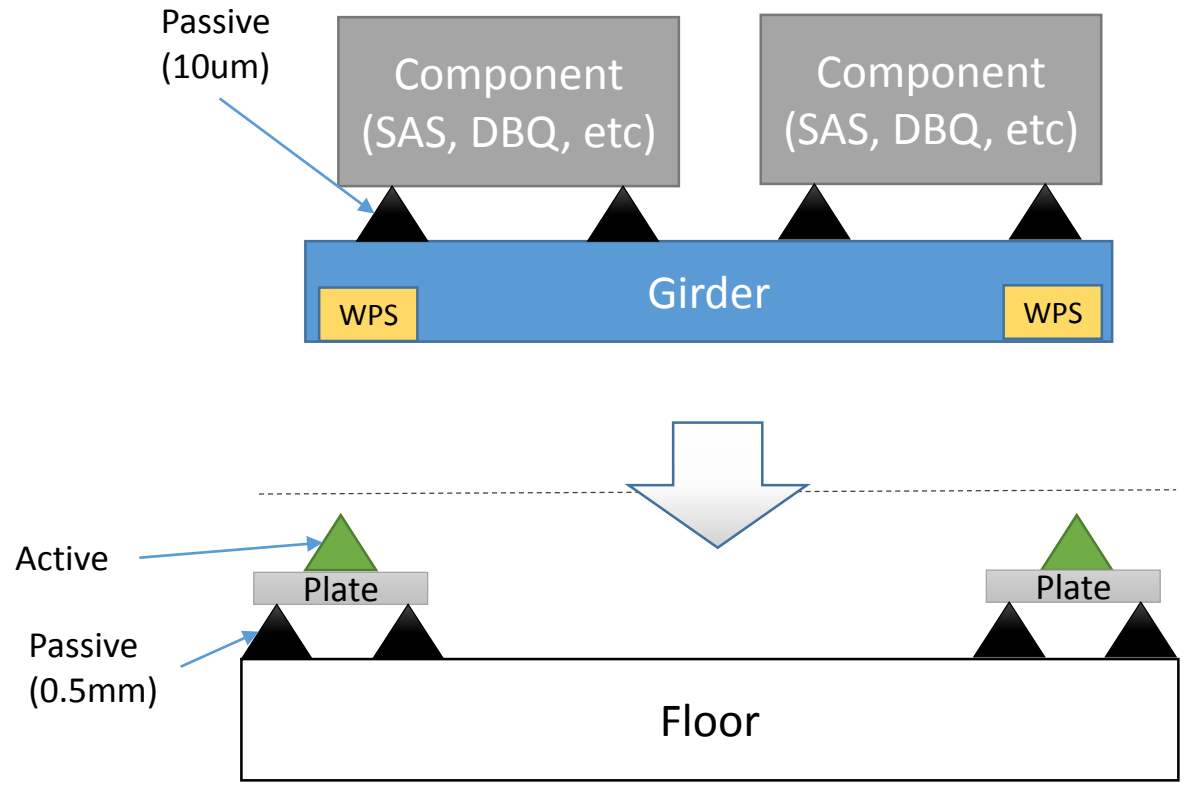
1st approach – Robust AND precise supports

- Improved version of CDR design
- Long girder with fixed components on it
- Withstands transportation with no re-alignment needed
- Examples:
  - Brazed
  - EB welded
  - Adjustable but robust
  - Deformable
  - etc…



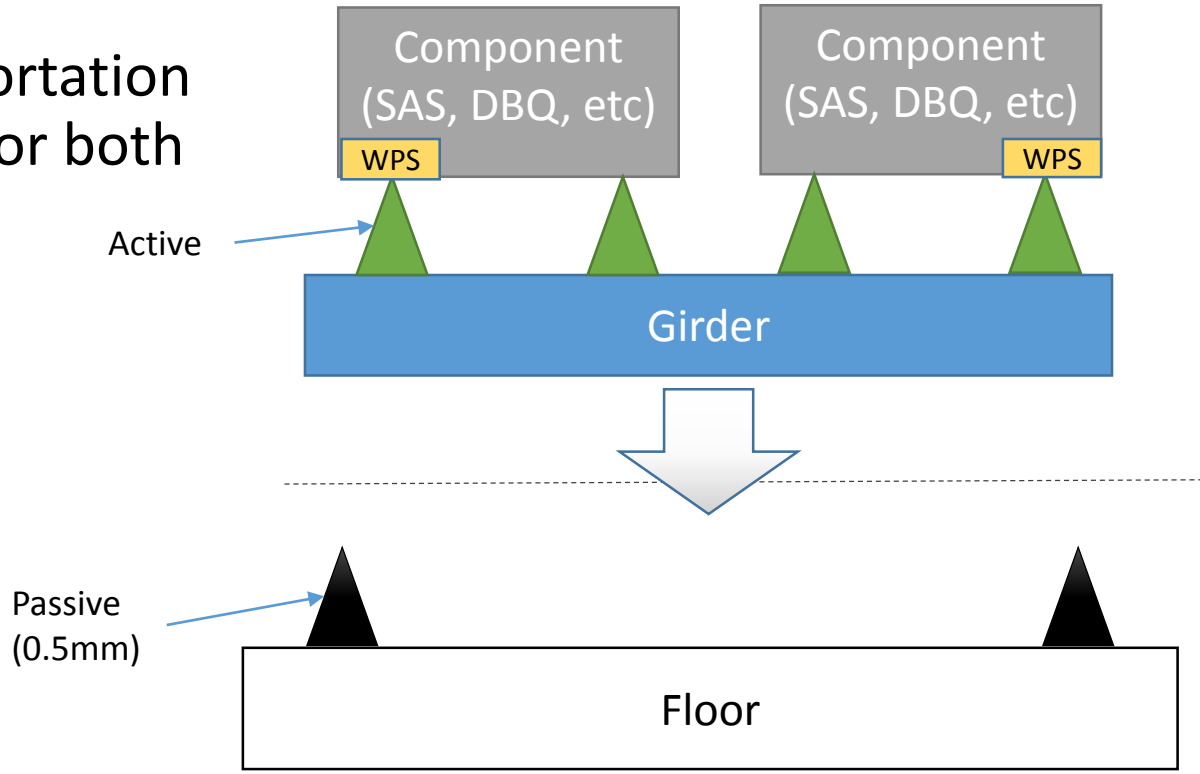
2nd approach – Passive re-alignment

- Girder with adjustable supports
- Assembled on surface
- Re-aligned in tunnel
  - Portable motorised alignment tool



3rd approach – Active adjustable supports

- Individual components get aligned
- Very quick and easy installation/replacement
- WPS sensors needed on every component
- Girder is not actuated, acts only as transportation tool. Can be as long as necessary, and/or for both beams. Conditioning can be done on it.



Actuators - Sensors

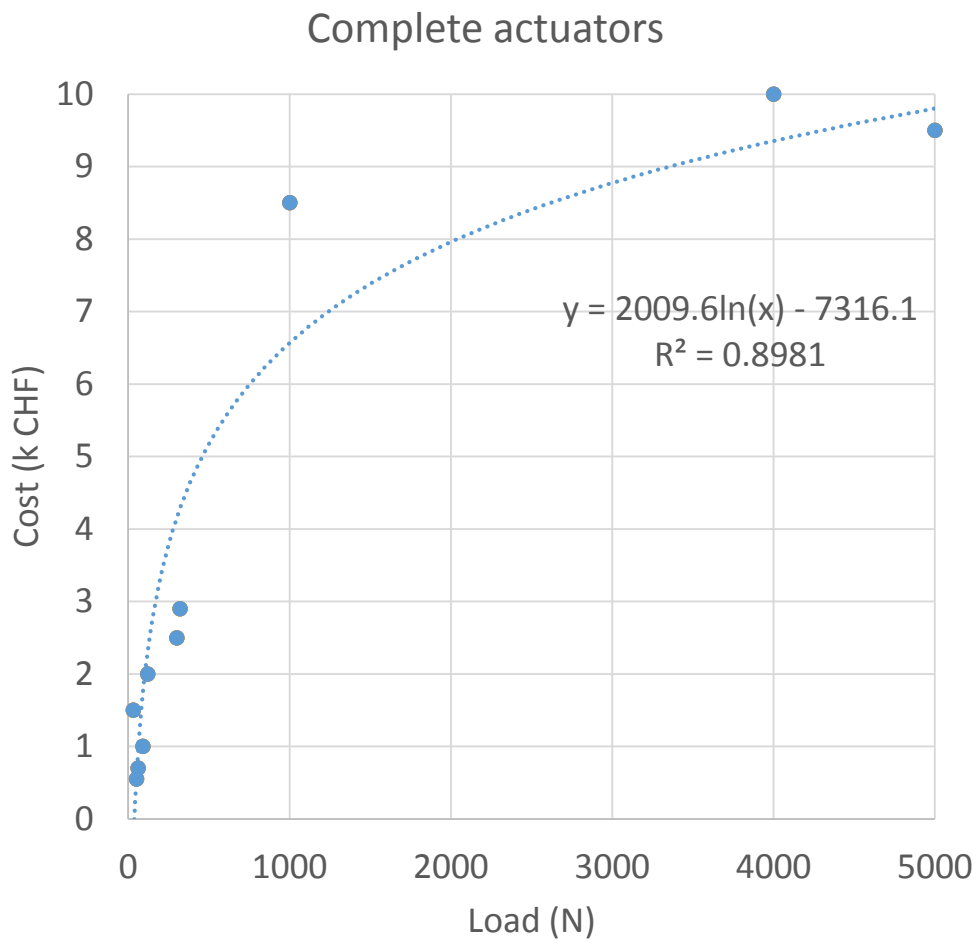
- Screw based
  - ~10mm of range minimum
  - low load (30-300N)
  - No constant power
  - Work well with leverage
- Piezo
  - ~0.1mm range
  - Relatively high load
  - Constant power
- Cam movers
  - Not enough data

- Capacitive WPS
  - 5k per piece (series)
- Optical WPS
  - 3k currently (prototype)
  - Hint for 500 CHF cost in series production

Linear Actuators

- Very difficult to estimate price
  - Need more data points
- Very difficult to find off the shelf ‘big’ actuators
  - Gear reduction necessary
- Custom made actuators could be cheaper

name	load (N)	price
standa 8CMA42	320	2900
standa 8CMA06	30	1500
PI L-239.50	300	2500
M-229.26S	50	550
PI custom	4000	10000
current TBM VLA	5000	9500
current TBM VLA	1000	8500
RS UK	60	700
RS UK	90	1000
RS UK	120	2000



Some scenarios (AS)

- 50kg/SAS
- 100kg/m for girder material (mineral cast for pricing)
- Clever design (5x leverage, minimising active DoFs)
- Excluding controller costs (multiplexing)
- Excluding passive elements alignment effort
- No redundancy

	actuators				girder	sensors			TOTAL
	load/act. (N)	act. Cost	act/mt	cost/m	cost/m	cost/pc	pc/m	cost/m	cost/m
ind. SAS (2 DoF)	100	1936	4	7743	0	500	2	1000	8743
ind. UAS (2 DoF)	200	3328	2	6657	0	500	1	500	7157
ind. SAS (4 DoF)	50	543	8	4346	0	500	4	2000	**6346**
ind. UAS (4 DoF)	100	1936	4	7743	0	500	2	1000	8743
SAS snake (on girder)	100	1936	4	7743	0	500	2	1000	8743
UAS snake (on girder)	200	3328	2	6657	0	500	1	500	7157
2m girder	400	4721	2	9442	2000	500	1	500	11942
4m girder	800	6113	1	6113	2000	500	0.5	250	8363
ind. SAS (2 DoF)	100	1936	4	7743	0	3000	2	6000	13743
ind. UAS (2 DoF)	200	3328	2	6657	0	3000	1	3000	**9657**
ind. SAS (4 DoF)	50	543	8	4346	0	3000	4	12000	16346
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2m girder	400	4721	2	9442	2000	3000	1	3000	14442
4m girder	800	6113	1	6113	2000	3000	0.5	1500	**9613**

For 500 CHF WPS:
Range: 6k – 12k

For 3000 CHF WPS:
Range: 9k – 16k

Keep in mind:
Main components cost ~150k /m

*UAS=ULTRA AS, 4x AS (1m long)

Discussion over individual supports

- Pros:
  - Quick and easy installation and replacement
  - Relaxed tolerances
  - Immunity to temperature changes
  - Deletion of expensive & heavy girder
- Cons:
  - Increased controls cost (?)

Note: Common girder interbeam distance limitations (very optimistically):

Epucret/steel (15um/K*m)	-> 2.6 K
SiC (4um/K*m)	-> 10 K

Questions to help design choices

- ✓ Permanent Magnet DBQs requirements?
  - Mechanically similar to electric magnets
  - Minus the power!!
- ✓ Rotation tolerances of components (how many DOF need be actuated)?
  - Rotation is more relaxed than position
- ✓ Benefit of better granularity (more precision has gain)?
  - Easier to achieve proper alignment
- ✓ Numbers for 380 GeV and K- based machine
  - T1 very dominant in first sector

1. Static DBQs with corrector coils <-> movable DBQs
2. Actuator/sensor cost modeling
3. What is the manufacturing technological limit of girder length?
   - Tolerances
   - Vibration
   - Transportation

Summary

- Main questions left:
  - Max girder length for precision and transportation robustness
  - Actual cost of actuating every component
- Next steps:
  - Transportation test
  - Narrow down possible designs

THANKS!!