High Resolution and Stability Beam Position Measurements

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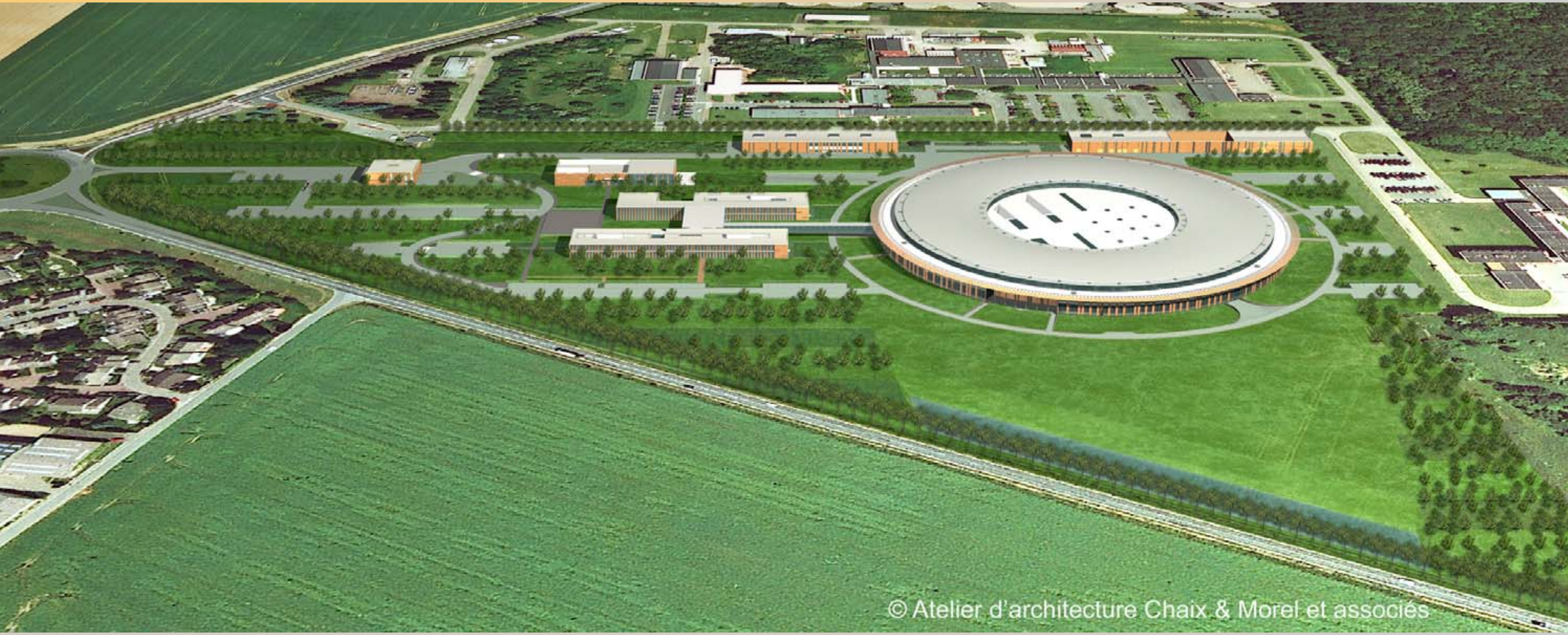
Outline

- Why stable BPMs ?
- BPM requirements
- Multiplexed electrodes BPM system
- New Digital BPM system
- Mechanical issues
- Girder design issues for submicron beam stability
- Conclusion

Artist's view of SOLEIL in 2006



As it is today

Why Stable BPMs ?
Beam Stability Strategy for Soleil

- Reduce drifts and vibrations as much as possible (air & water temperature regulation, feedforward reduces ID effect to few μm)
- The two closed orbit feedback systems are based on machine BPMs
  - Slow closed orbit feedback (0 to ~ 0.1 Hz)
  - Fast orbit feedback (0.1 to 100 Hz)
- Beam is locked to the BPM centers by correction algorithms
- With good feedback systems:

  Beam stability (0 to 100 Hz) ≈ BPM stability
- Check beam stability with Photon BPMs (no feedback on them)

What Needs to be Stable?

Soleil type of strategy requires:

- Stable ground (see building foundation, part of M.-P. Level talk)
- Stable BPM mechanical center with respect to ground
  - BPM attached to girder
  - Need stable girder (M.-P. Level talk)
  - Need stable BPM support on girder
- Stable BPM and vacuum chamber design
- Feedback accuracy to lock beam on BPM centers (IDs between 2 BPMs)
  - Quadrupole movements should not cause any beam movement if the orbit correction is perfectly done to the BPM centers
- Possible beam spectrum components at 100 and 150 Hz can be suppressed with specific harmonic locks on these frequencies

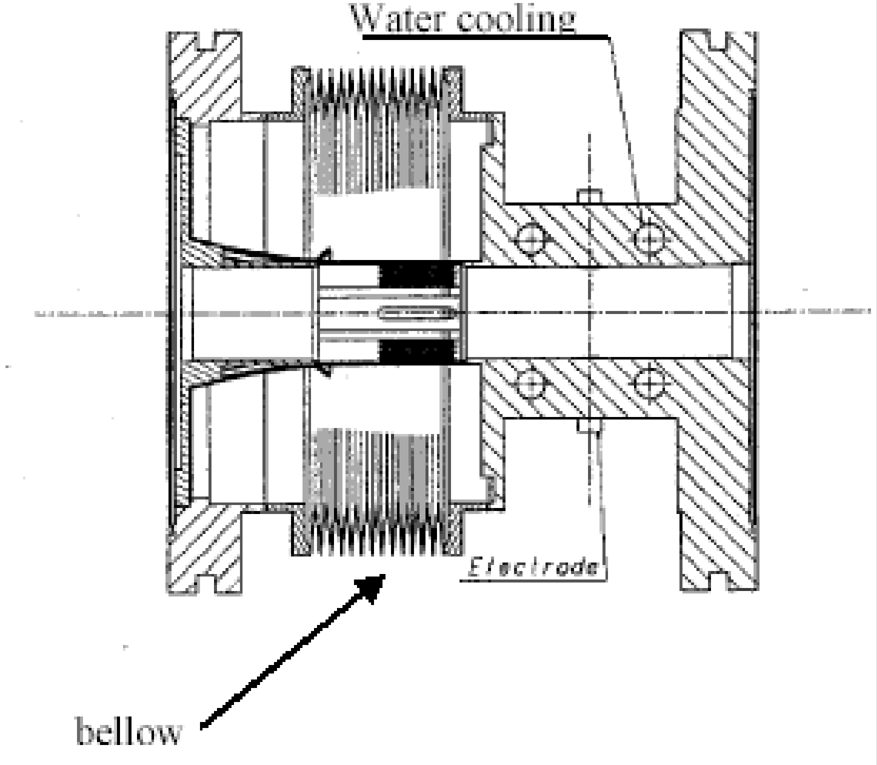
Additional BPM functions

- Required
  - First turns
  - Turn-by-turn for machine studies
- Useful (not absolutely required)
  - Post-mortem position data buffer
  - Analog output signal for beam position interlock

BPM Mechanical Design

- BPMs fixed on Girders
- BPM is the only fixed point of its vacuum chamber section
- Bellow relieves stress on BPM
- Water cooling channels keep BPM temperature constant

BPM side cross section



BPM Requirements for SOLEIL

	Closed orbit correction	Global Feedback	First turns	Turn-by-turn for machine studies
Number of BPMs	120	48	120	120
measurement resolution (rms)	< 0.2 µm in 1 second	< 0.2 µm (residual on beam with 100 Hz feedback BW)	< 500 µm in a single measurement	< 1 µm in 60 seconds
Absolute accuracy with respect to quad	< 200 µm	✕	< 500 µm	< 200 µm
Absolute accuracy after beam based alignment	< 50 µm	✕	✕	✕
Measurement rate	> 1 per second	~ 1 KHz for 100 Hz feedback BW	1 per second	every 60s
Dynamic range	M: 200 - 600 mA T: 20 - 120 mA	M: 200 - 600 mA T: 20 - 120 mA	0.4 - 4 mA	4 - 100 mA
Current dependence within a 10 dB range	< 5 µm (< 1µm after calibration)	< 5 µm (< 1µm after calibration)	< 500 µm	✕
8-h and 1-month drift at constant current	< 1 µm in 8 h < 3 µm in 1 month	< 1 µm in 8 h < 3 µm in 1 month	< 500 µm	✕
Reproducibility versus bunch pattern	< 10 µm (< 1µm after calibration)	< 10 µm (< 1µm after calibration)	< 500 µm	< 500 µm

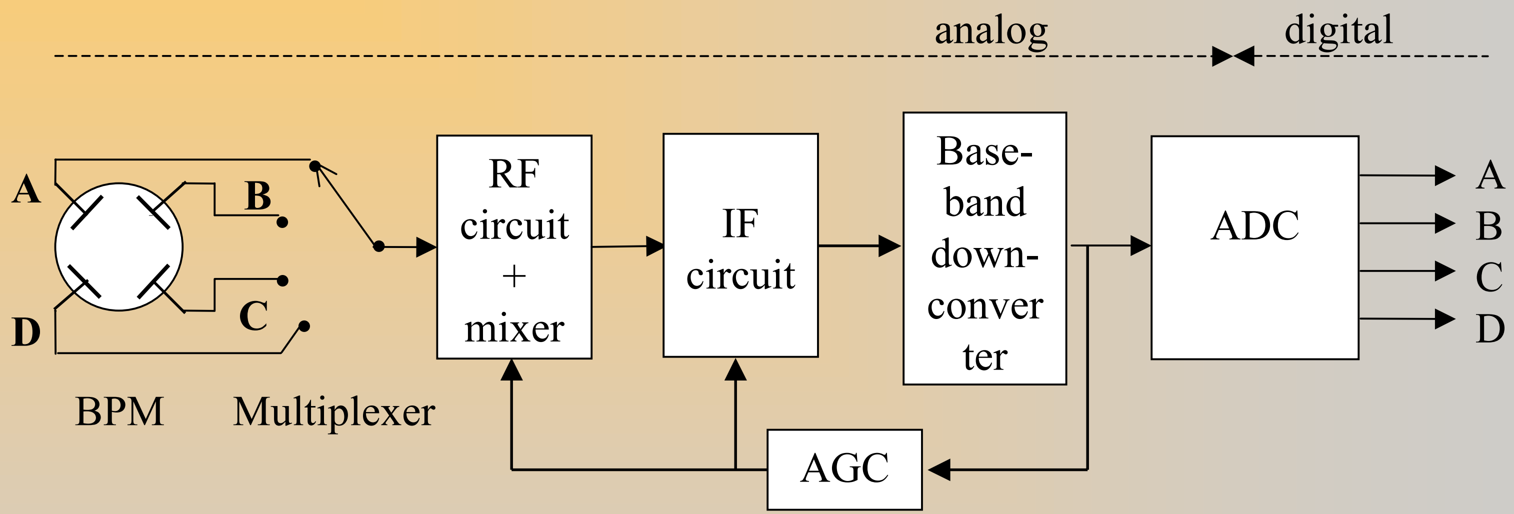
High Accuracy BPM Electronics

At this time, only two concepts have proved to function at the micron level and are improving at the submicron level

- Multiplexed electrodes system
- Digital BPM system

Good tutorial on BPM systems by G. Vismara in AIP conference proceedings #546 (9th Beam Instrumentqtion Workshop)

Multiplexed Electrodes BPM system



Simplified Block Diagram

Multiplexed Electrodes BPM system: pros and cons

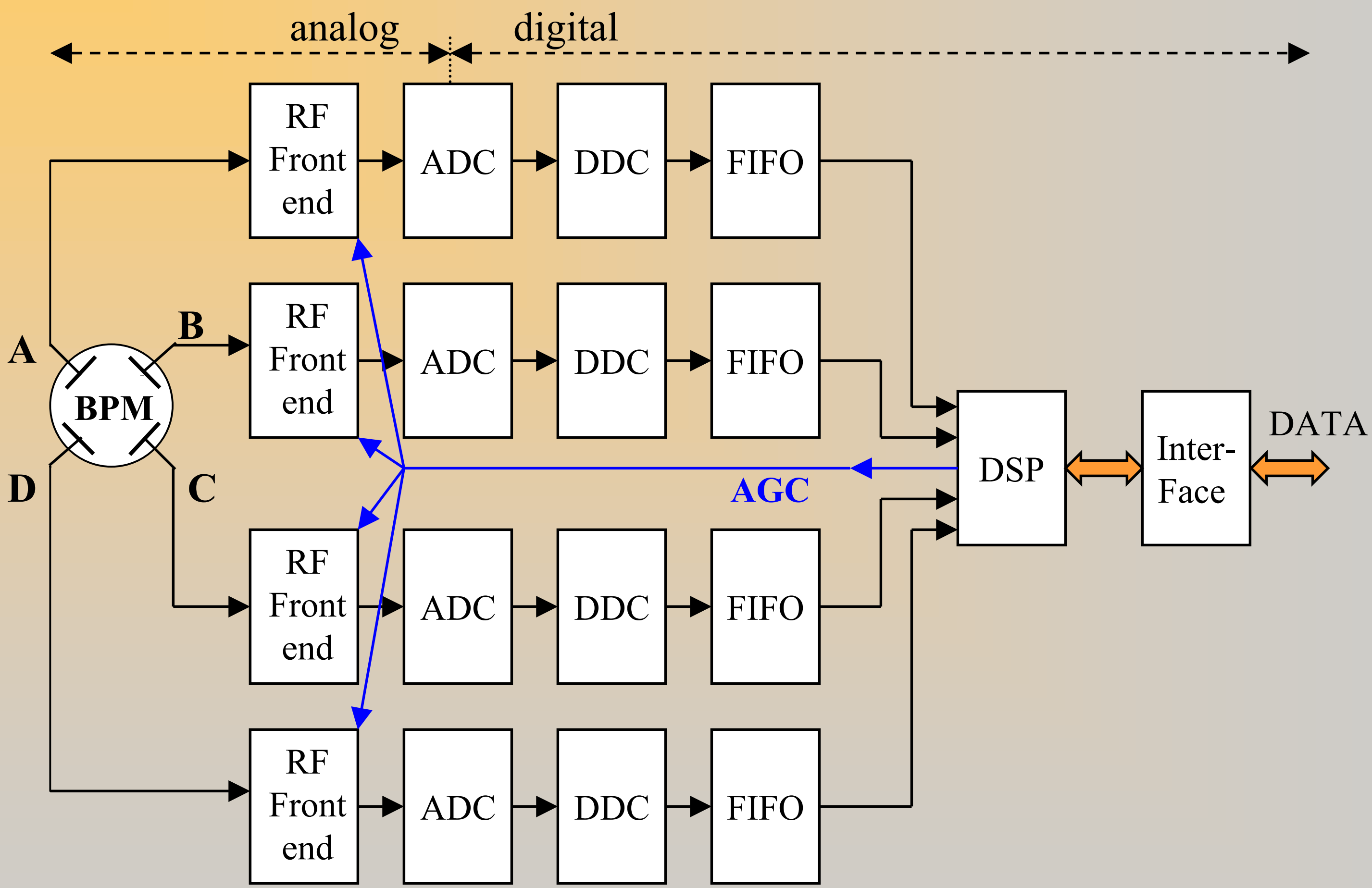
Pros

- Single electronics → single gain & offset for the 4 electrodes
- Excellent position stability
- Excellent current dependence
- Commercially available from Bergoz company

Cons

- Resolution issues
  - Synchrotron oscillations → noise increase due to aliasing
  - Difficulty to get low noise
    - Signal available ¼ of the time
    - Front end matching for low current dependence
    - Preamplifier with AGC capability
- No turn-by-turn acquisition

Digital BPM system



Digital BPM system: Pros and Cons

Pros

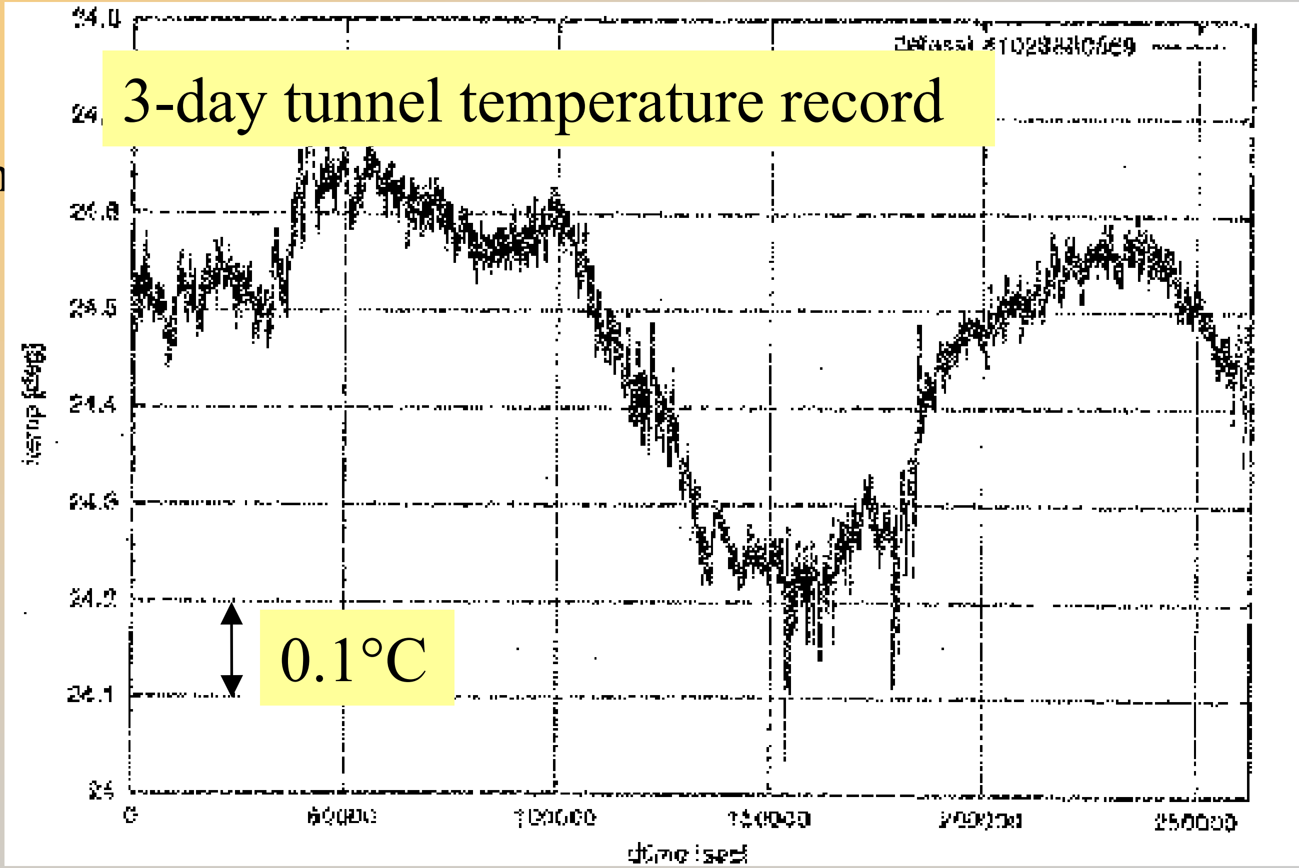
- Programmable → turn-by-turn as well as stored beam
- Excellent resolution
  better resolution = lower beam noise OR wider bandwidth with fast feedback
- Large dynamic range (AGC)
- Digital Down Conversion has no offset
- Commercially available from i-tech (see i-tech talk at this workshop).

Cons

- Need elaborate calibration scheme (gain ratios vary with AGC voltage)
- Current dependence and stability rely on excellent calibration performance for beam stabilization at the submicron level

Girder Stability for BPMs

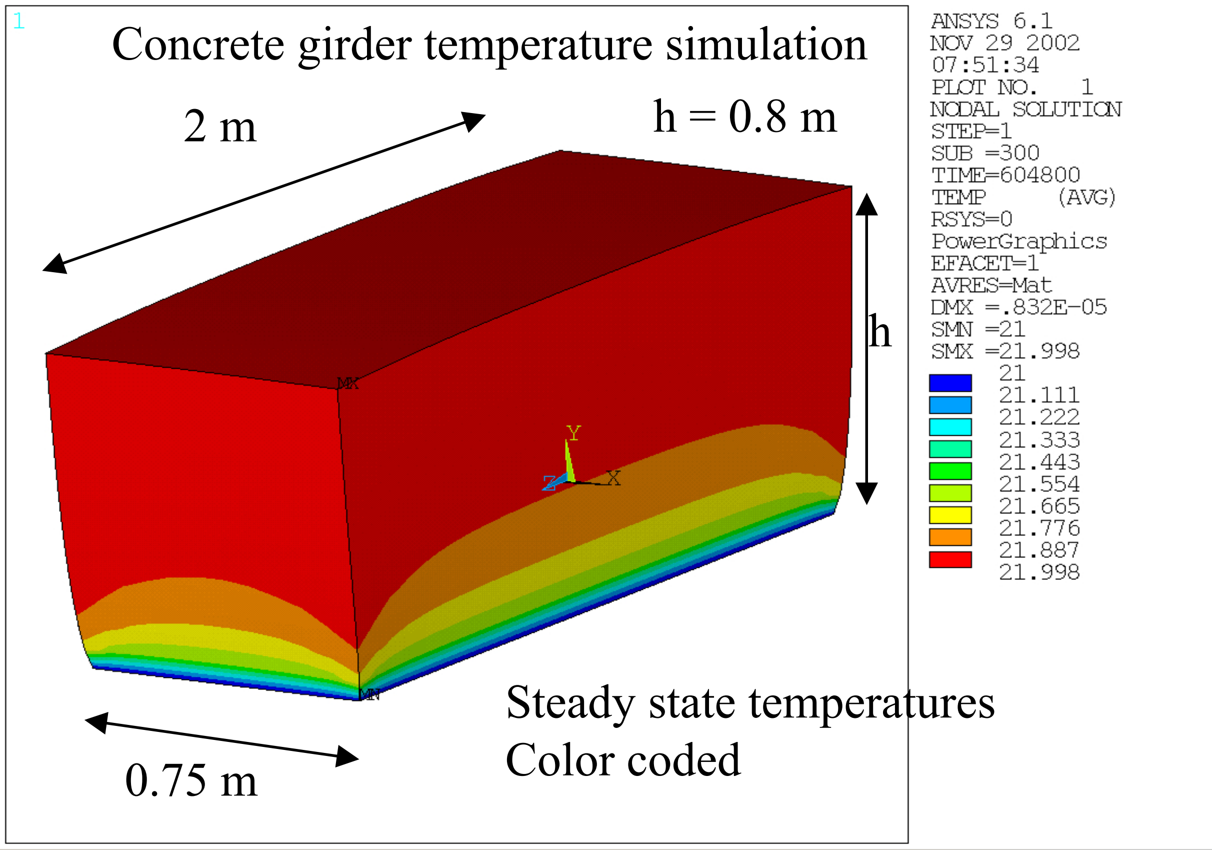
- Temperature stabilization
  SLS example :
  σT ≈ 0.2 °C rms
- Soleil beam height
  = 1.2 m
- Steel girders:
  Δh/h = 11E-6 / °C
- then BPM drift
  σY ≈ 2.6 µm rms



Courtesy of M. Bögel

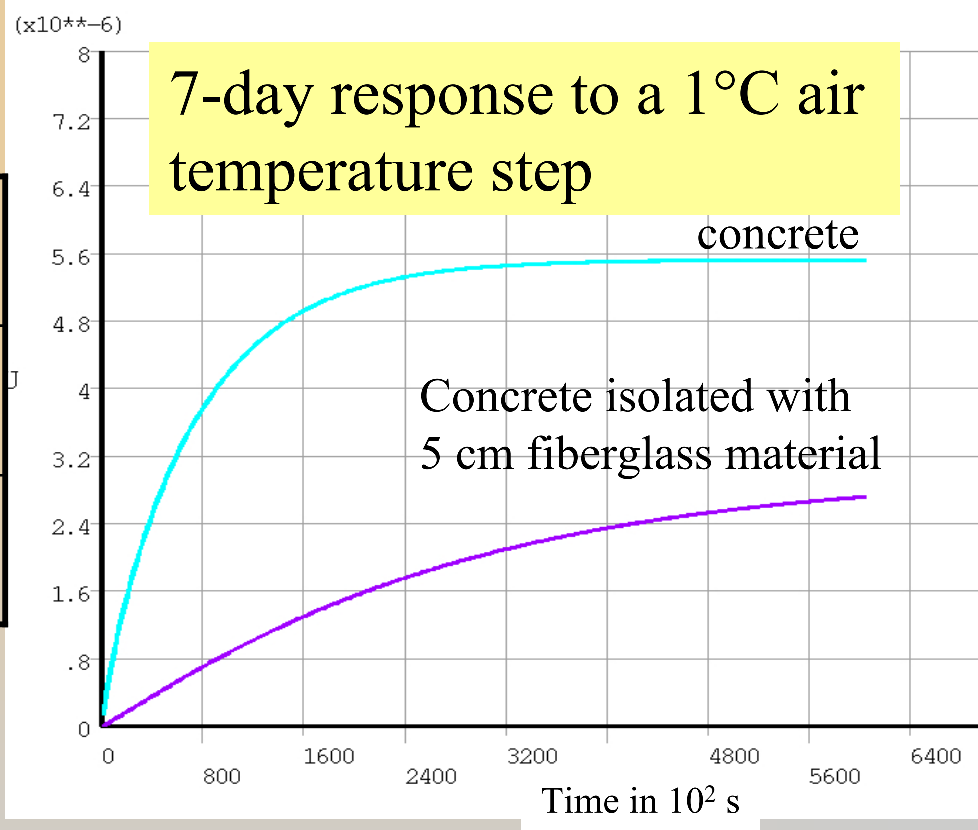
Looking for Solution for Future Machines

- Standard steel girders have ≈ 1 hour thermal inertia and follow tunnel temperature changes
- Concrete girders (like at ELETTRA) have a large thermal inertia
- Simulation on figure → steady state of 1 °C air temperature step



Expected Damping of Air Temperature Drifts with Concrete Girders

Girder material	steel	concrete	Isolated concrete
inertia	≈ 1 hour	≈ 1 day	≈ 10 days
ΔY rms	2.6 µm rms	0.41 µm rms	0.041 µm rms



Conclusions

- BPM electronic is improving to the submicron level
- Mechanical interface with vacuum chamber should be OK at the submicron level
- Temperature related issues with the girders are likely to be a problem at the submicron level