Radiation test of Pressure Sensors and Transducers for the LHC machine

Results from test campaigns in TCC 2

2000 - 2001

LHC requirements

<table>
<tr><th>Position
(@ room temperature)</th><th>Purpose</th><th>Range
(abs)</th><th>Accuracy</th><th>Quantity</th></tr>
<tr><td>SSS w. jumper</td><td>1.8 K phase separator</td><td>0..100 mbar</td><td>0.3 %FS</td><td>233</td></tr>
<tr><td>SSS w. jumper</td><td>Cold mass</td><td>0..20 bar</td><td>0.5 %FS</td><td>233</td></tr>
<tr><td>DFB</td><td>Helium bath</td><td rowspan="2">0..4 bar</td><td rowspan="3">1.5 %FS</td><td>43</td></tr>
<tr><td>QRL s.m.A line C</td><td>LHe supply at 4.6 K</td><td>121</td></tr>
<tr><td>QRL s.m.A line D</td><td>Beamscreen return</td><td>0..1.6 bar</td><td>121</td></tr>
</table>

Market survey → 16 interested
→ 12 qualified

→

2000: 24 transducers tested
2001: 17 sensors tested

Expected doses

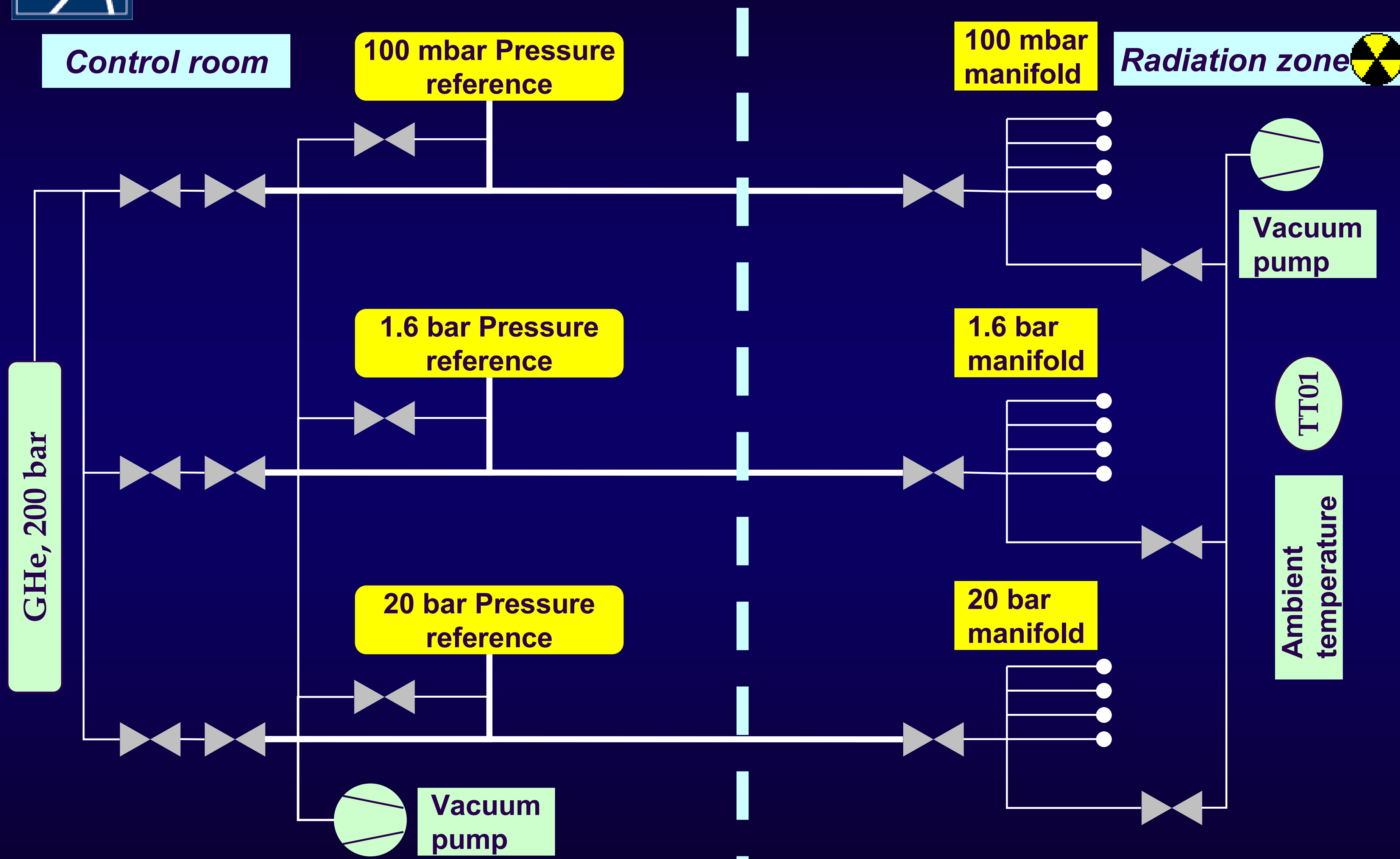
Pressure measurements will be performed around

- QRL service module A,
- SSS,
- DFB

→ Poorly protected

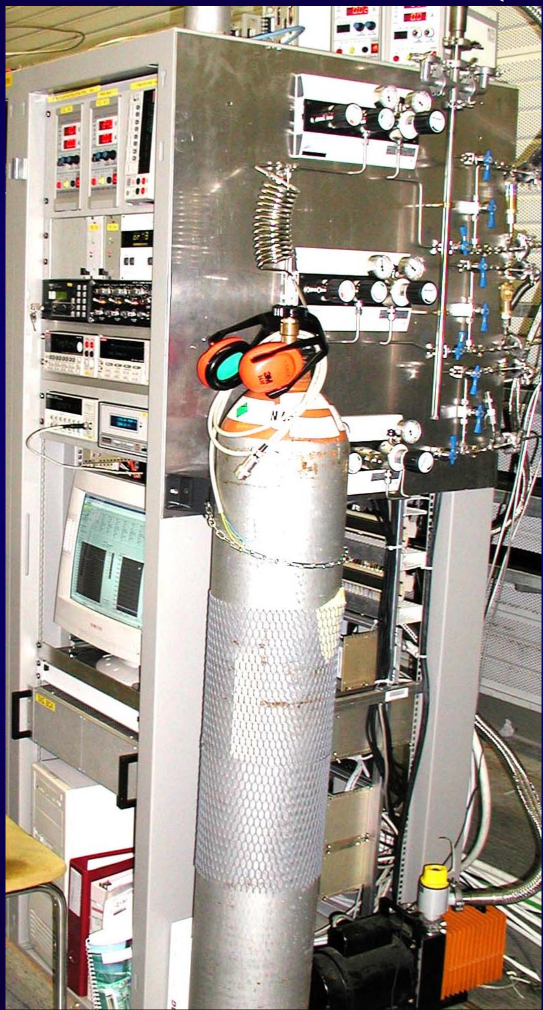
Expected dose	Arc	10-20 Gy/y
	DS	20-200 Gy/y
	LSS	?

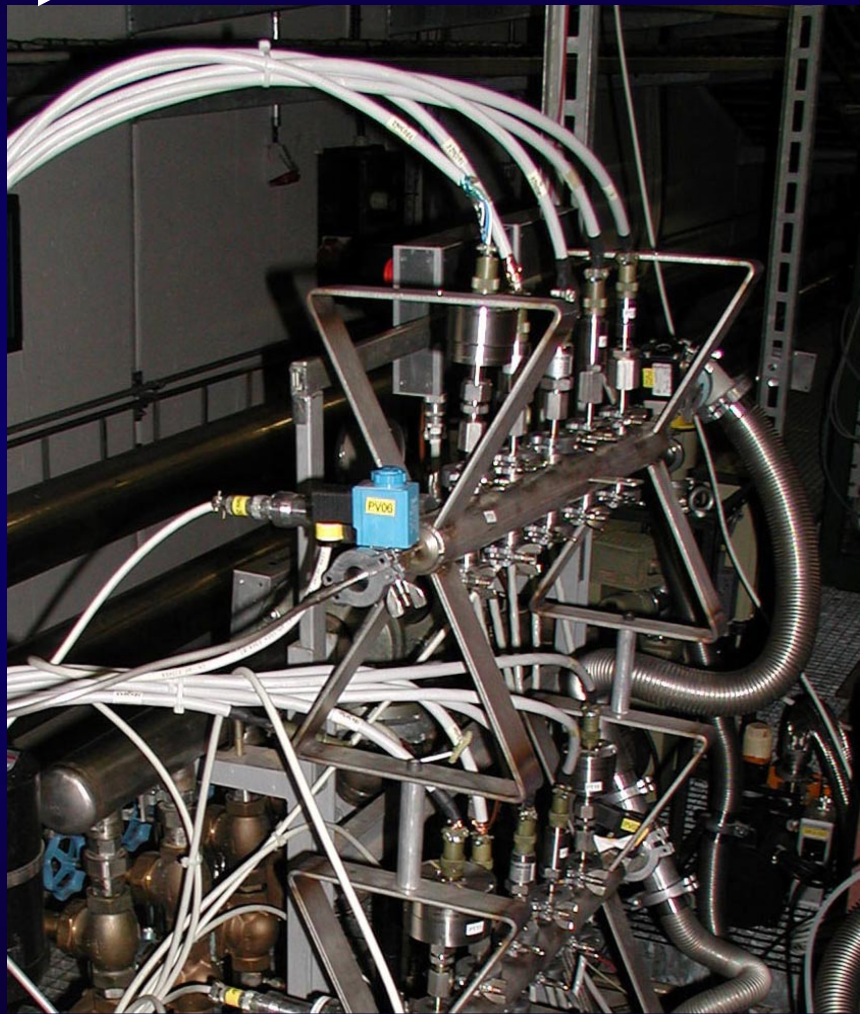
TCC 2, Pneumatic Layout



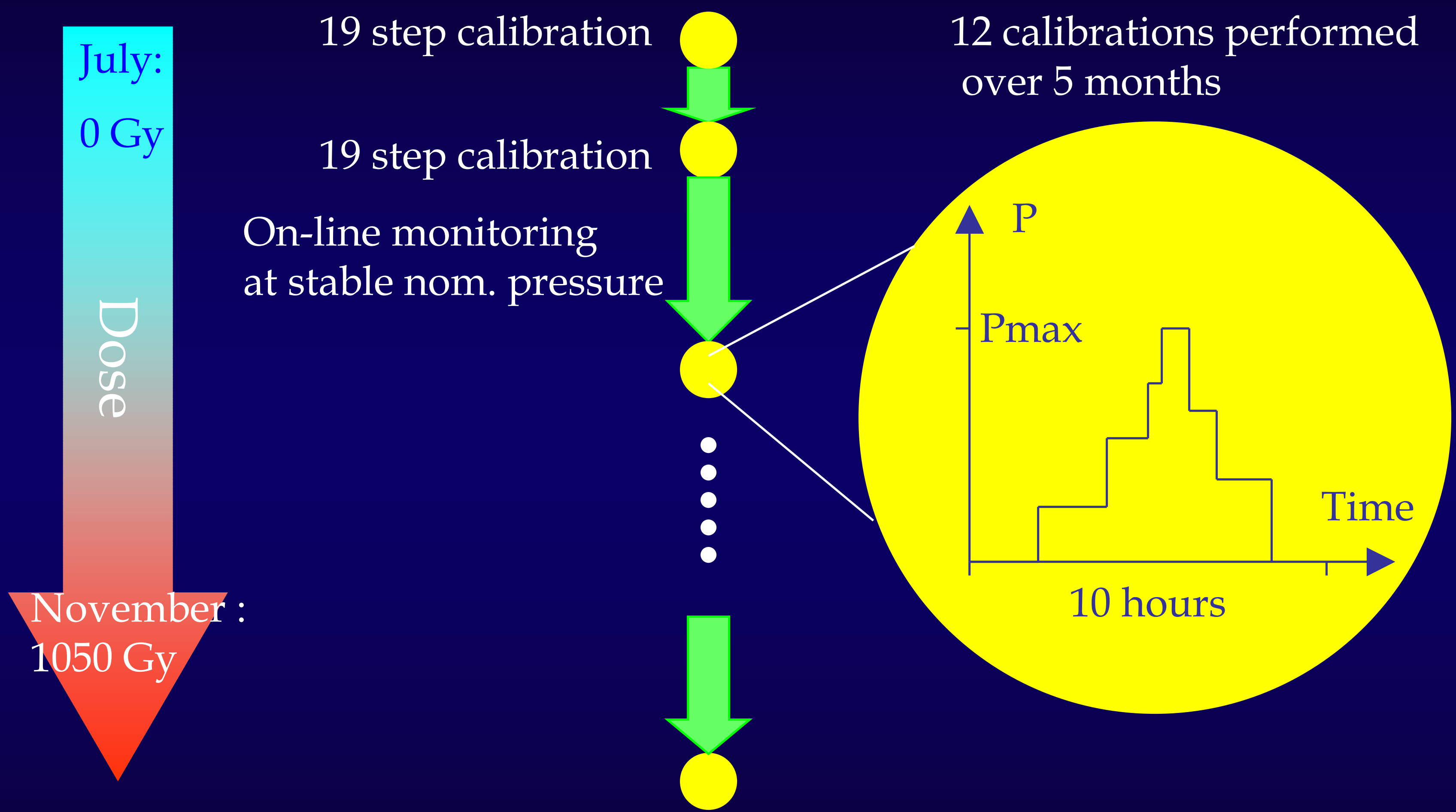
Installations

Control room ⟵ 160 m ⟶ Irradiation zone

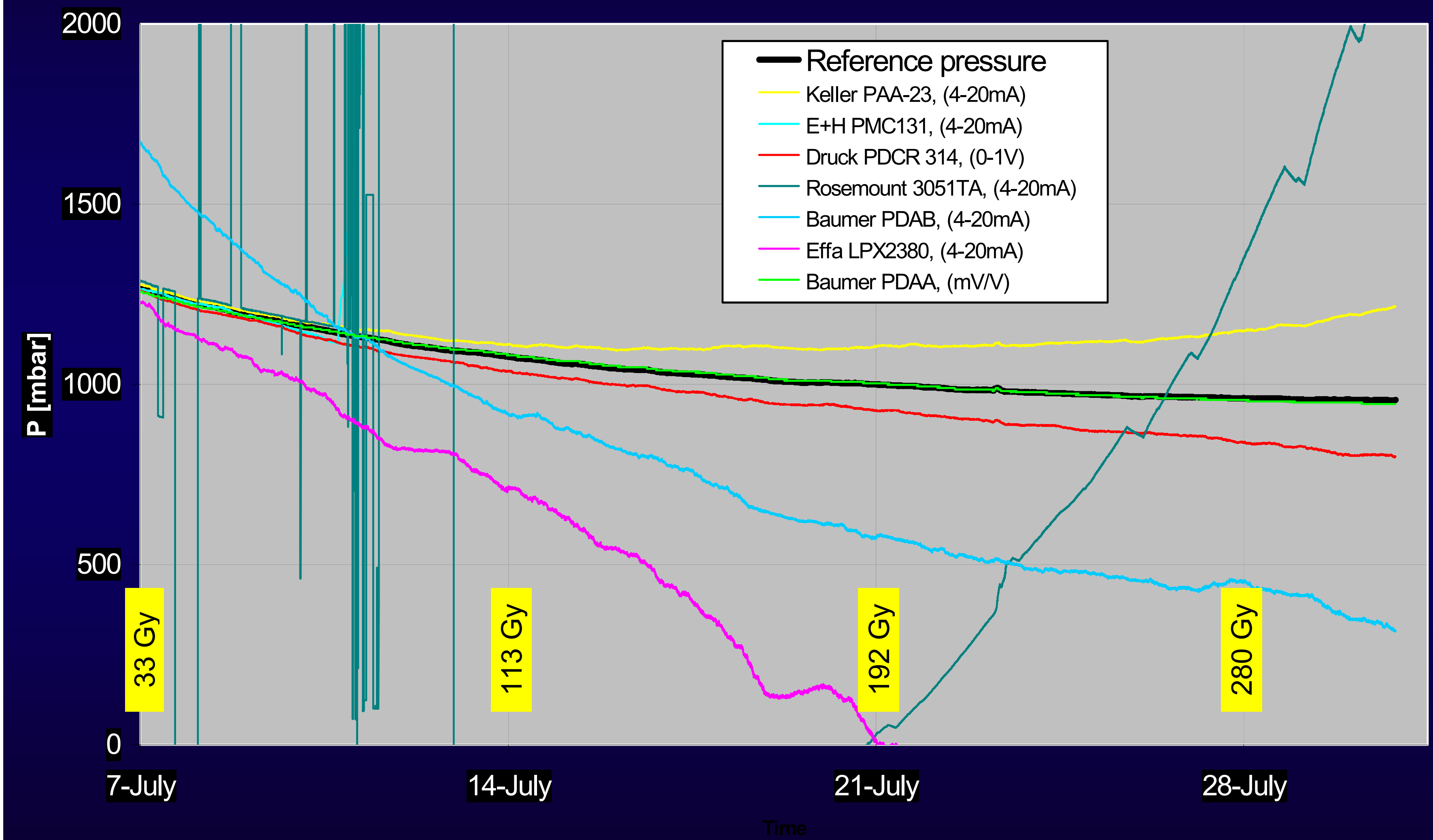




Data acquisition sequence



On line monitoring of transducers with integrated electronic (campaign 2000)



Summary of campaign 2000

Manufacturer	Technology	Failure type	Drift [ppm/Gy]
Rosemount	SGchip,integ.4-20mA,HART	SEE + drift→sat.	
Keller	SG chip, integ. 4-20 mA	Drift	+ 60
Kistler		Drift, dead @190Gy	- 70
Haenni		Drift	Neg.
Baumer	Metal SG, integ. 4-20 mA	Drift	- 1000
Trafag		Drift, dead @155Gy	?
Effa	Inductive, integ. 4-20 mA	Drift	- 800
E+H	Capacitive, integ. 4-20 mA	Drift, dead @ 70 Gy	- 60
Druck	Integ. ampli. 0-1 V	Drift→ zero	- 80
Effa	Inductive, remote electronic	No failure	N/A
HBM	Metal SG, remote electronic		
Baumer			

Re-tested in 2001

Irradiation campaign 2001, sensors under test

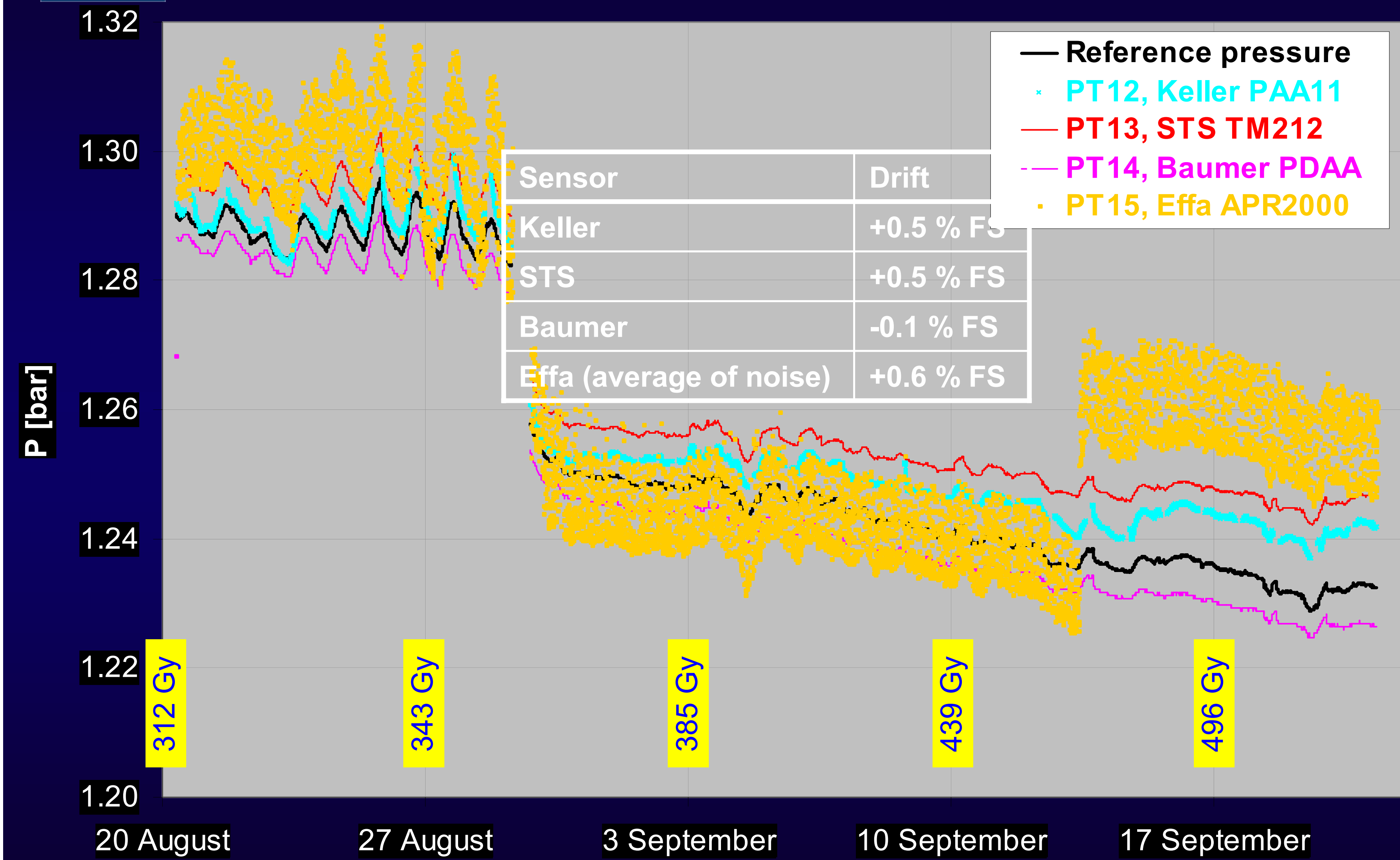
Manufacturer	Ranges [bar]	Technology	Output
Effa	0.1, 1.6 (4), 20	2 coils, inductance, no oil	56 kHz
Keller	0.1, 1.6 (4), 20	piezo-resist. SG chip, oil separation	250 mV
STS	0.1, 1.6 (4), 20		100 mV
Baumer	1.6, 4, 20	metal thin film SG, no oil	20 mV
HBM	20	metal SG glued on membrane, no oil	20 mV

All sensors are energised by a **remote electronic** unit.

All membranes in stainless steel.

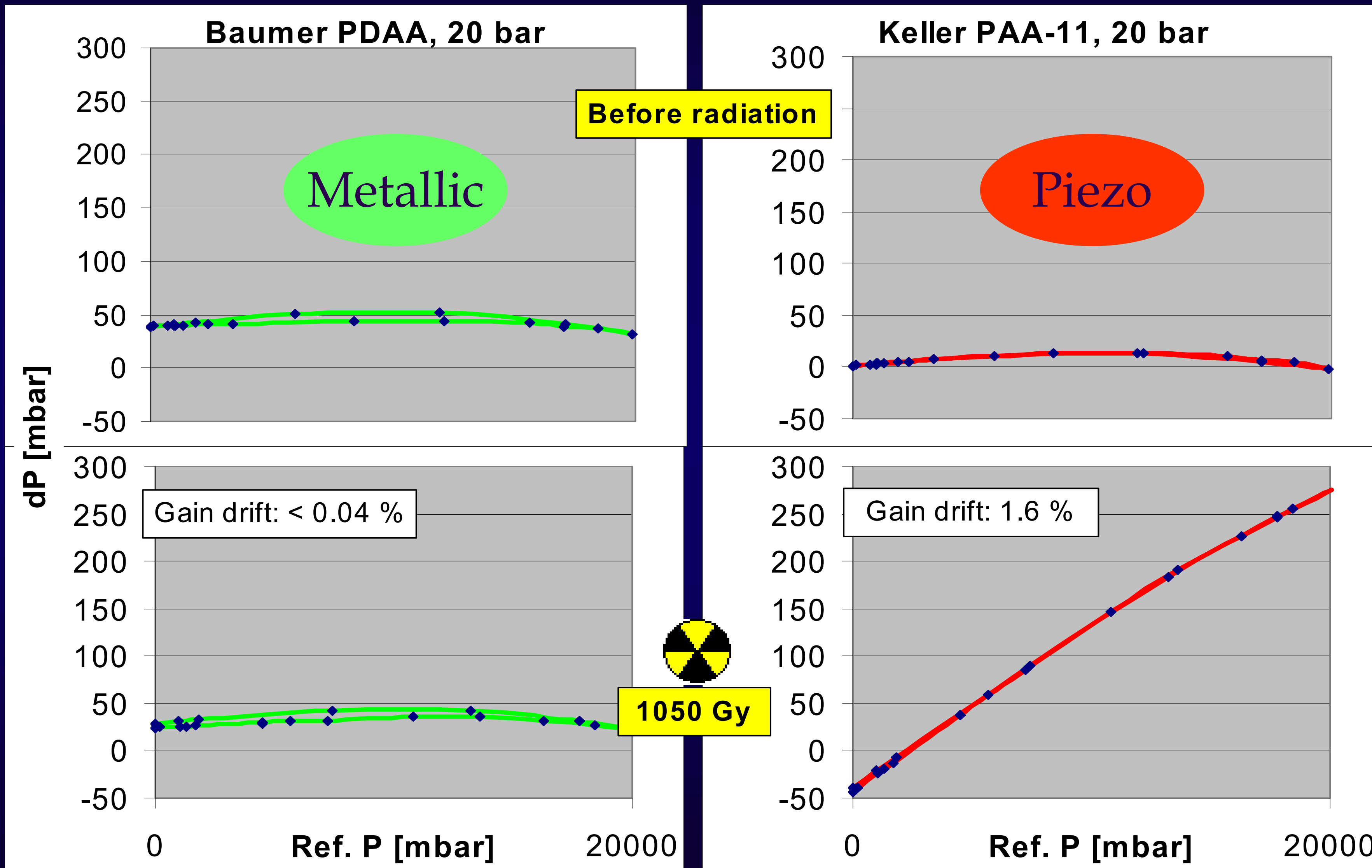
SG : Strain gauge resistors in wheatstone bridge.

On line monitoring of passive sensors

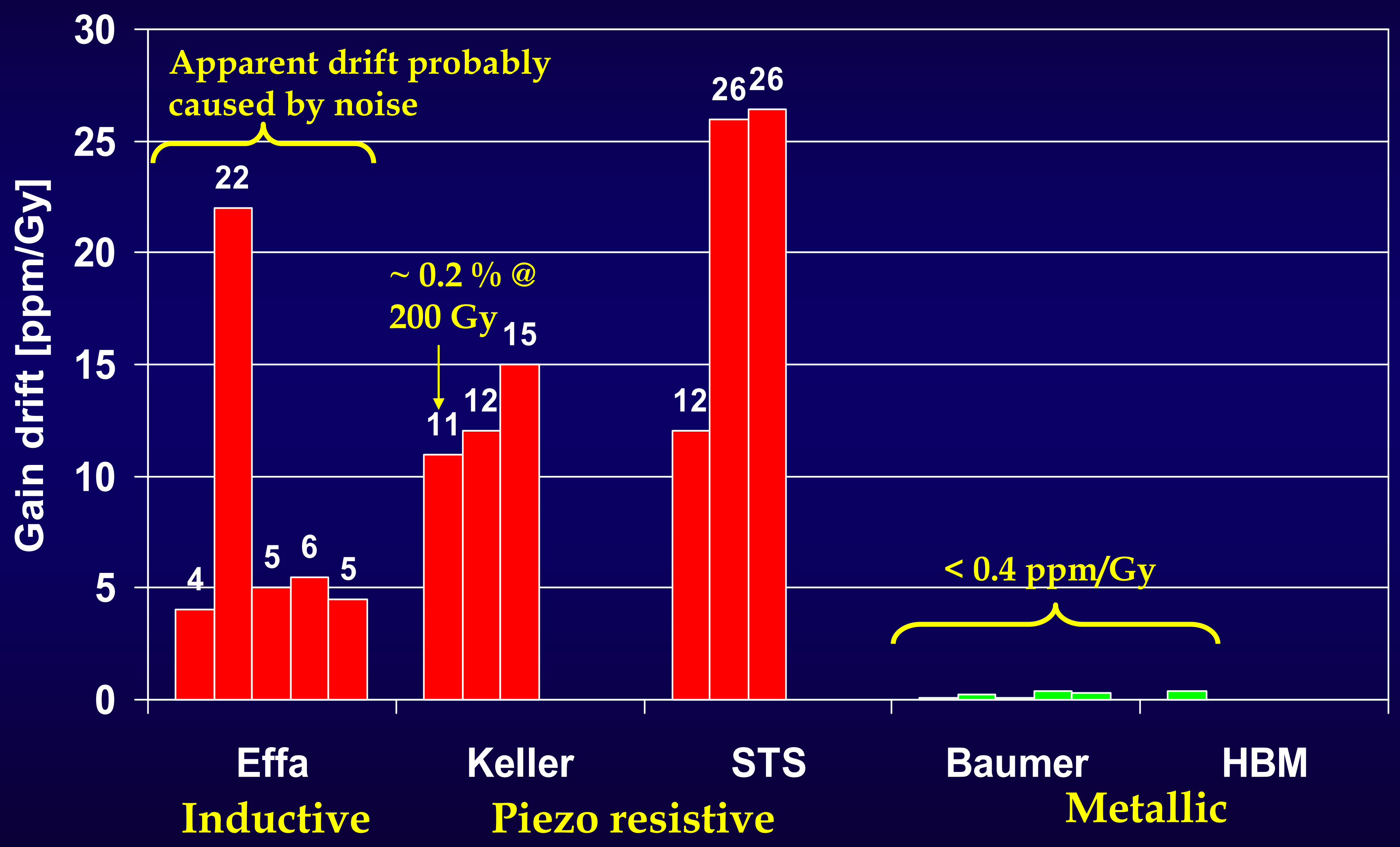


Sensor	Drift
Keller	+0.5 % FS
STS	+0.5 % FS
Baumer	-0.1 % FS
Effa (average of noise)	+0.6 % FS

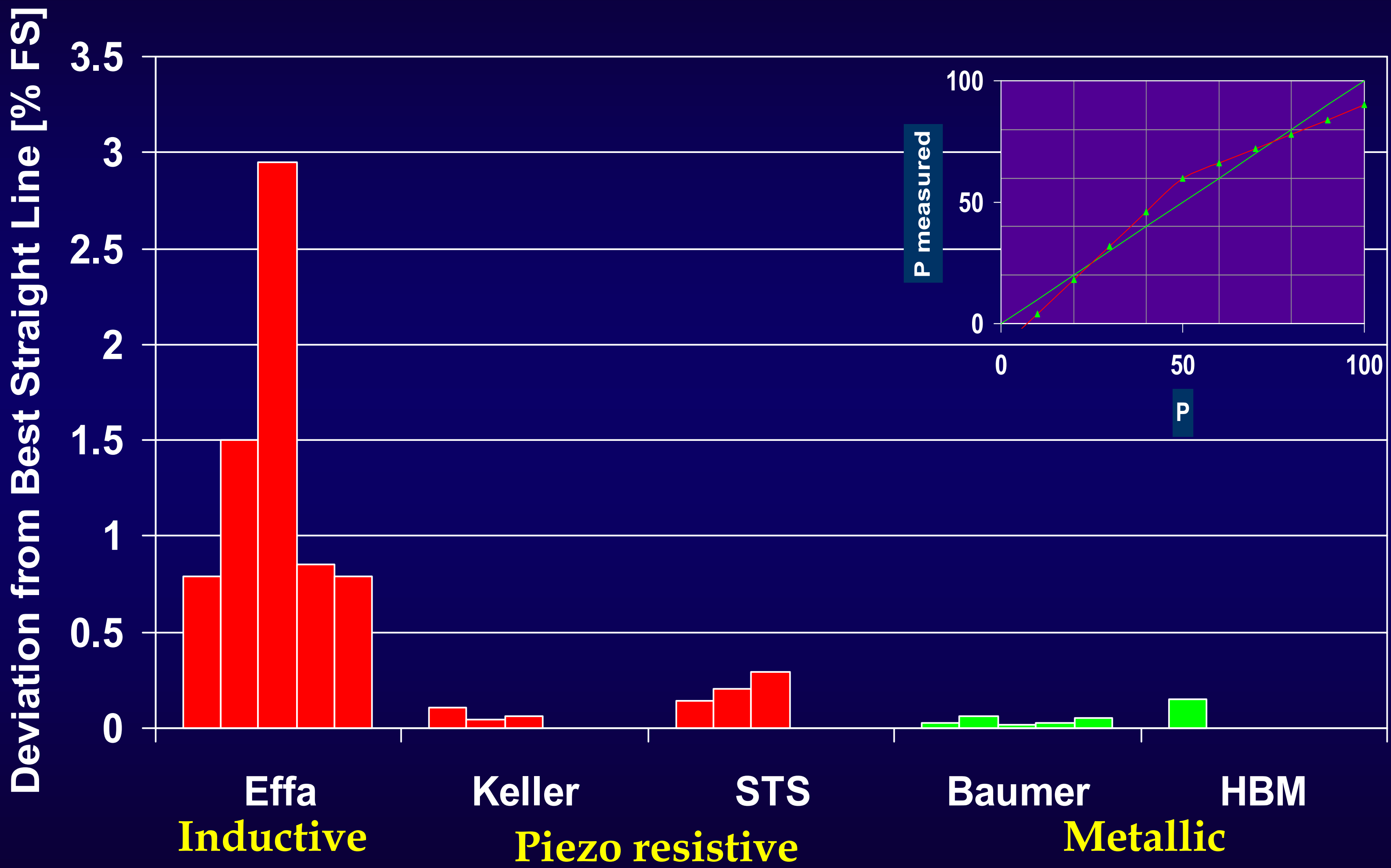
Calibration shift of Baumer and Keller sensors



Passive sensors, gain drift with radiation



Passive sensors, linearity



Estimated survival time in LHC tunnel, arc

Arc : estimated 10-20 Gy/y

	Transducer or Sensor type		
Pressure range	**Integrated electronic**	**Piezo resistive strain gauge**	**Metallic strain gauge**
100 mbar	< 1 year	< 3 years	N/A
1.6 bar	< 4 years	< 16 years	> 20 years
4 bar	< 4 years	< 16 years	> 20 years
20 bar	< 1.5 year	< 6 years	> 20 years

Estimated survival time in LHC tunnel, DS

Dispersion suppressor : estimated 20-200 Gy/y

	Transducer or Sensor type		
Pressure range	Integrated electronic	Piezo resistive strain gauge	Metallic strain gauge
100 mbar	< 1 month	< 0.5 year	N/A
1.6 bar	< 5 months	< 2 years	> 20 years
4 bar	< 5 months	< 2 years	> 20 years
20 bar	< 2 months	< 1 year	> 20 years

Conclusion: the test facility

- A facility allowing on-line monitoring of pressure sensors & transducers has been built and operated in TCC 2.
  - Operation during radiation
  - Remotely controlled valves & vacuum pumps
  - 10^{-2} mbar – 20 bar absolute
  - 3 pressure reference instruments
  - Multimeters & scanners and voltage/current supplies

- Possible improvement : better information on the spatial distribution of radiation in TCC 2 zone

Conclusion: results 1

- **Integrated electronic**

Pro's	*Con's*
Simple installation	Fast deterioration in radiation

Not accepted

- **Effa inductive sensors with remote electronic**

Pro's	*Con's*
Probably OK in rad.	Cable dependant non-linearity
	Crosstalk causing noise & offset
	Sensors not individually characterised
	Difficult to integrate with rad. tolerant electronic

Not accepted

Conclusion: results 2

- **Piezo resistive with remote electronic (Keller & STS)**

Pro's	*Con's*
Relative high output	deterioration @ LHC radiation doses
Linear	Oil deterioration with radiation
Sole viable 100 mbar sensor !	Oil-boiling at low pressures

Not fully accepted

- **Metallic resistive with remote electronic (Baumer & HBM)**

Pro's	*Con's*
Rad. hard	Low output voltage
Linear	Remote electronic
Sensors characterised on their own	

Accepted

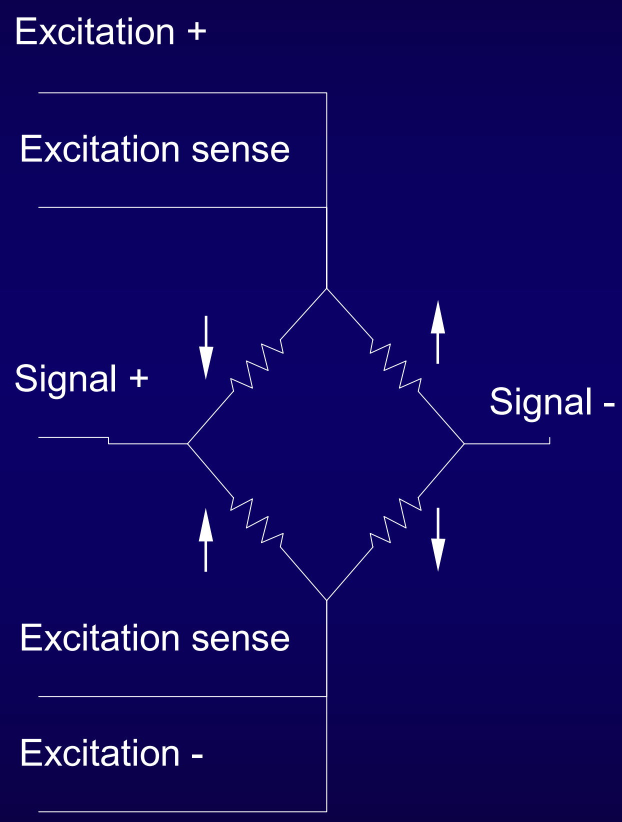
Outlook

- Confirmative test for piezo resistive sensors in TCC 2
- 100 mbar range test of integrated transducers at lower dose rates in TCC 2
- Test of alternative 100 mbar sensors ?

Appendix: working principle of SG sensor

Membrane with 4 strain sensitive resistances moves with pressure.

Bridge un-balance measured by remote electronic using either AC or DC excitation.



Advantages:

- Several high precision conditioners available on the market.
- Sensor characterized on their own. (No in situ calibration)

Appendix: working principle of Effa sensor

Relative inductance of 1 or 2 coils is changed by a membrane that moves with pressure.

Remote electronic detects the change by using either kHz AC excitation.

Advantages:

• High overpressure capability.