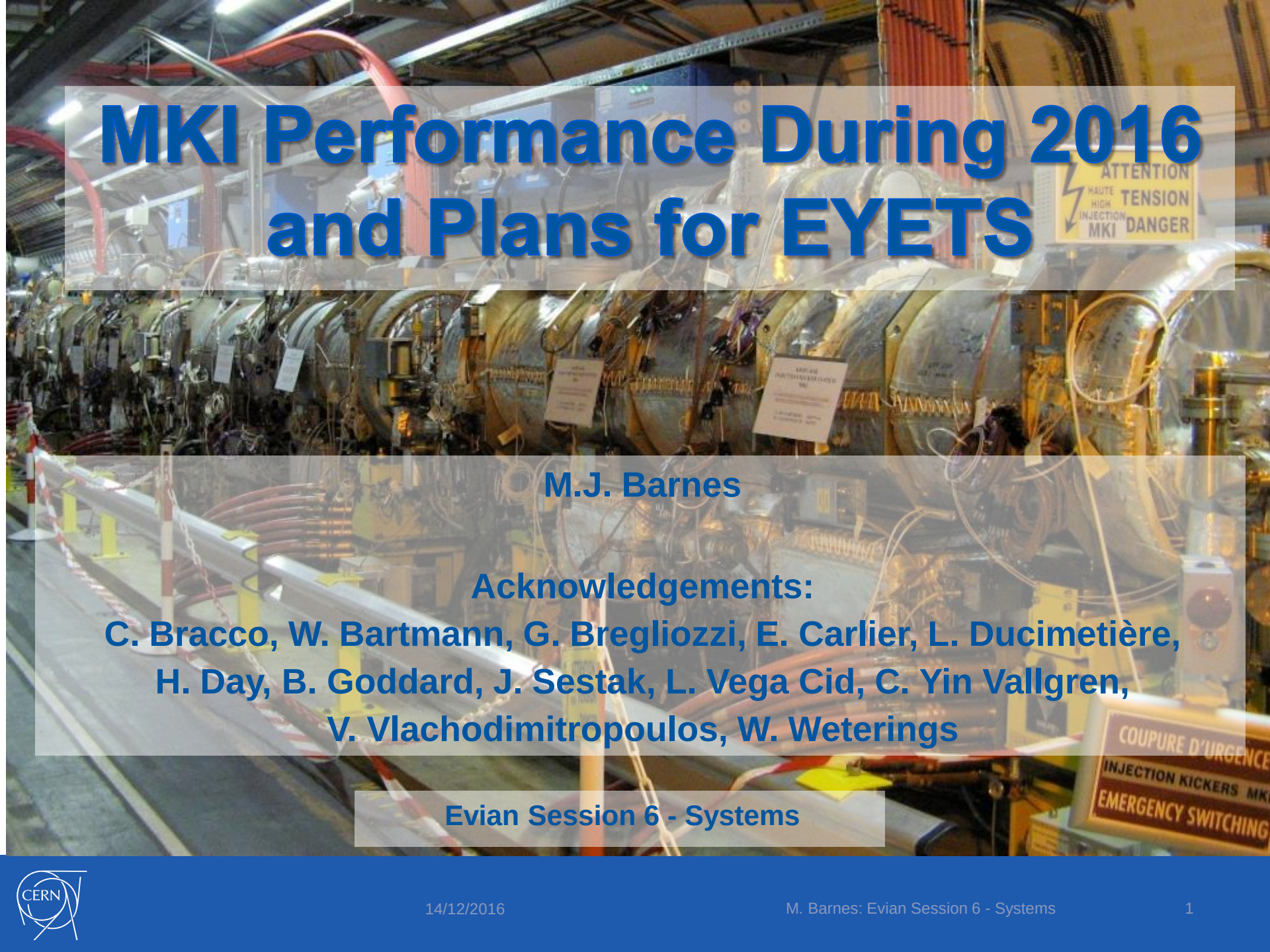


MKI Performance During 2016 and Plans for EYETS

M.J. Barnes

Acknowledgements:
C. Bracco, W. Bartmann, G. Bregliozzi, E. Carlier, L. Ducimetière, H. Day, B. Goddard, J. Sestak, L. Vega Cid, C. Yin Vallgren, V. Vlachodimitropoulos, W. Weterings

Evian Session 6 - Systems

Outline of talk

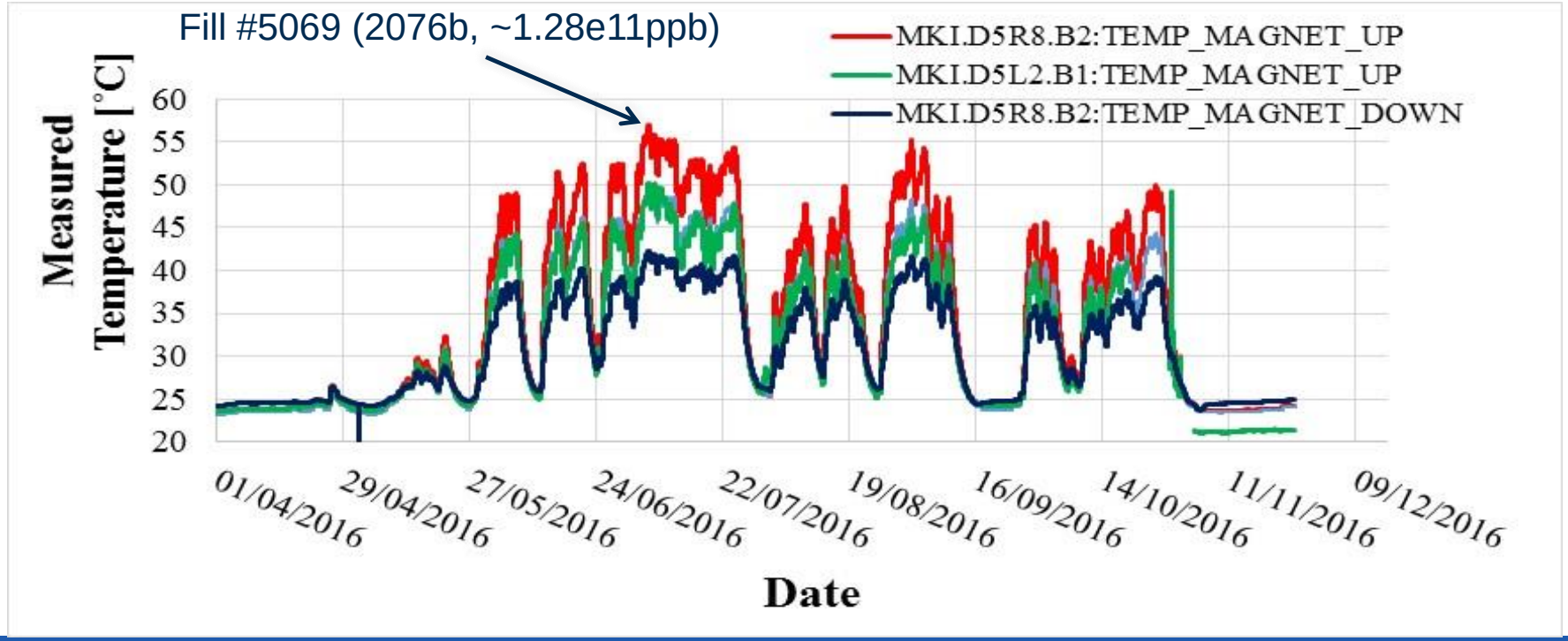
- MKI beam induced heating;
- Vacuum limits and mitigations during EYETS;
- Flashovers during SoftStart for pulse length > 4μs;
- Bad contact at entry box end of MKI2D magnet;
- Surveillance Voltage Monitoring (SVM) faults;
- Erratic turn-on of a thyratron.

Beam Induced Heating

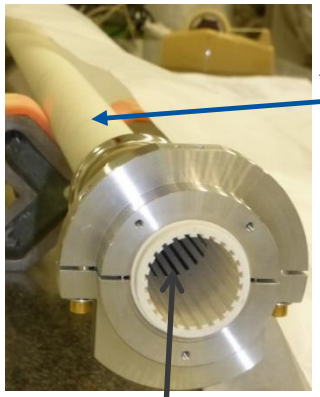
- Substantial upgrades to MKI beam screen during LS1: 24 (c.f. 15) screen conductors installed – MKI heating has not limited LHC operation since LS1;
- Maximum measured "ferrite" temperature during 2016 ⇨ 57˚C (fill #5069)
  - ⇨ Corresponds to a ferrite temperature of ~80˚C;

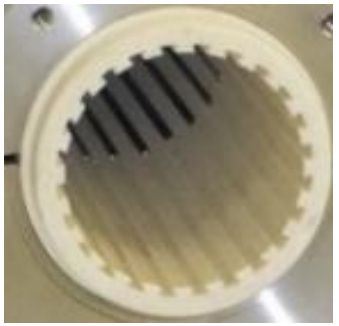
☺ **No issues with MKI heating expected during Run 2 (2808 bunches).**

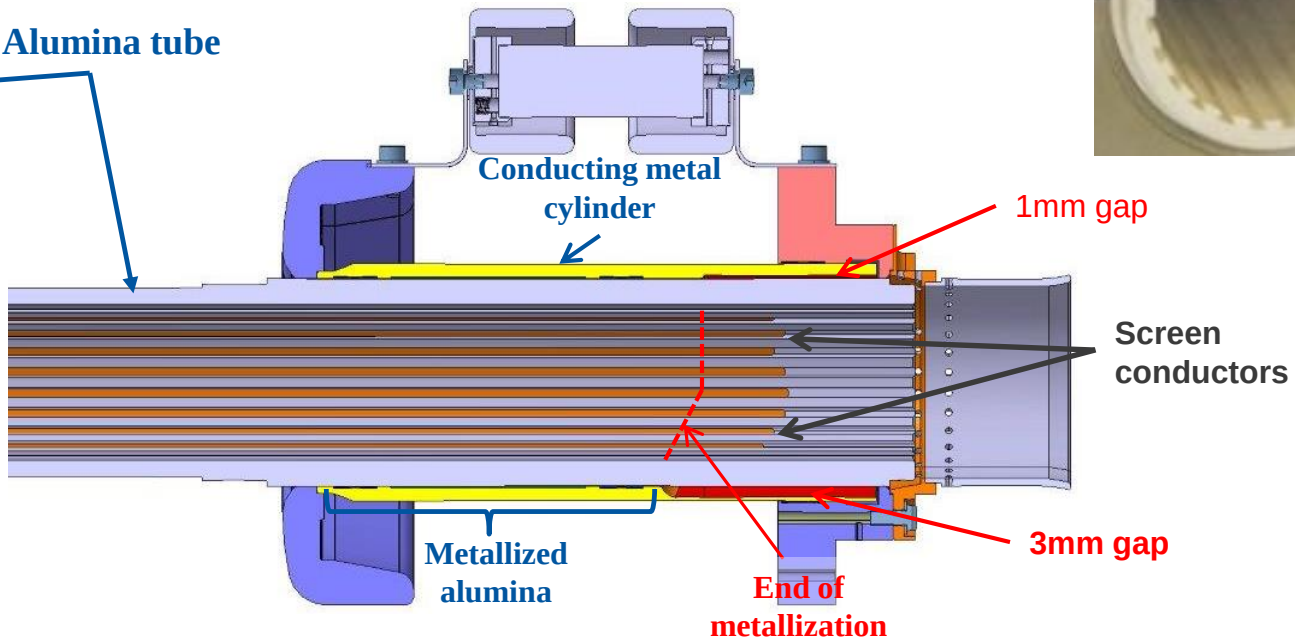
- **No changes planned during EYETS.**



MKI – Beam Screen

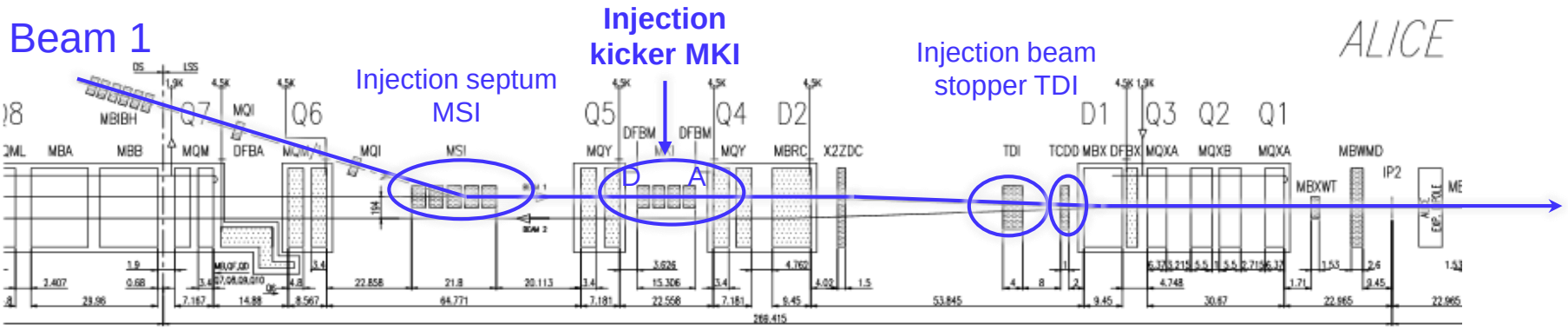






- High purity alumina tube with conductors in its inner wall – to screen the ferrite from beam;
- Screen conductors are **connected to beam pipe at one end and capacitively coupled at the other end**;
- Voltage is induced on screen conductors during field rise (**up to 30kV**) and fall (to -17kV);
- **Rise in vacuum pressure, at capacitively coupled end, can result in breakdown/ flashover – hence there is an (SIS) interlock to prevent injection when this pressure is above threshold.**

Injection System

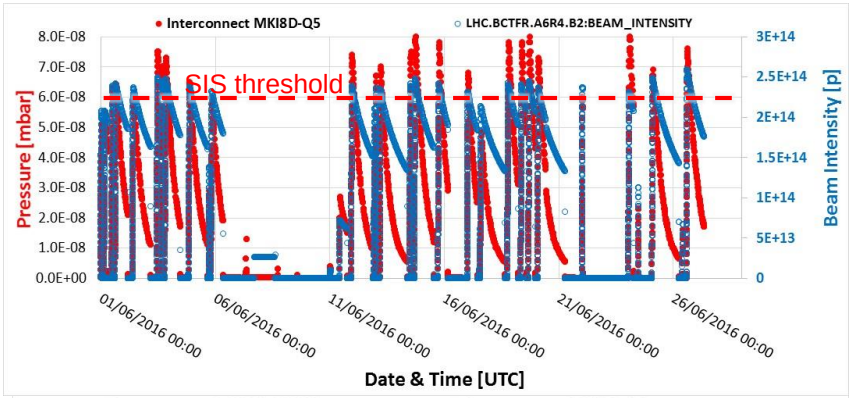


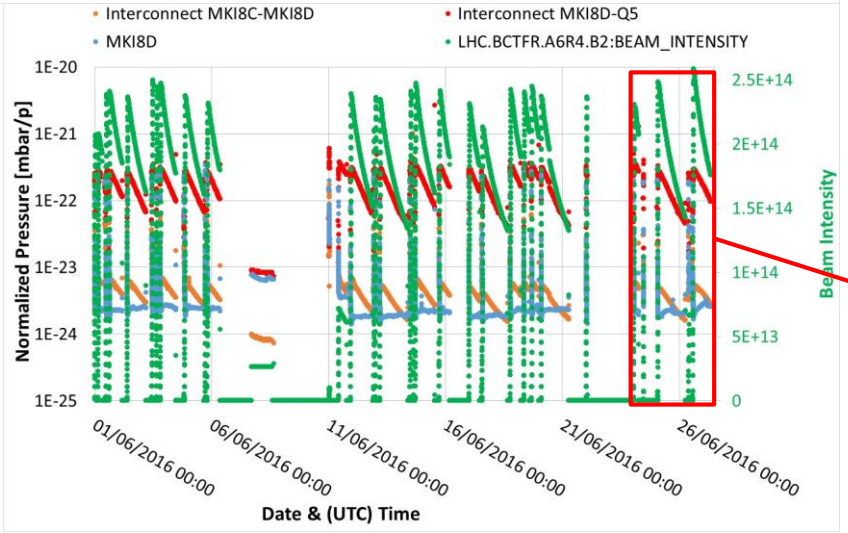
During LS1, the vacuum systems on the interconnects between MKI magnets were upgraded:

- ✓ Interconnects NEG coated;
- ✓ Prior to LS1, ion pumps provided a nominal pumping rate of 30 l/s of hydrogen.
  - ✓ During LS1, a NEG cartridge was integrated ⇨ 400 l/s for hydrogen.

☺ **During Run 2, there haven't been any issues with the SIS vacuum thresholds on the interconnects <u>between</u> adjacent MKIs !**

Dynamic Pressure Around MKI8D





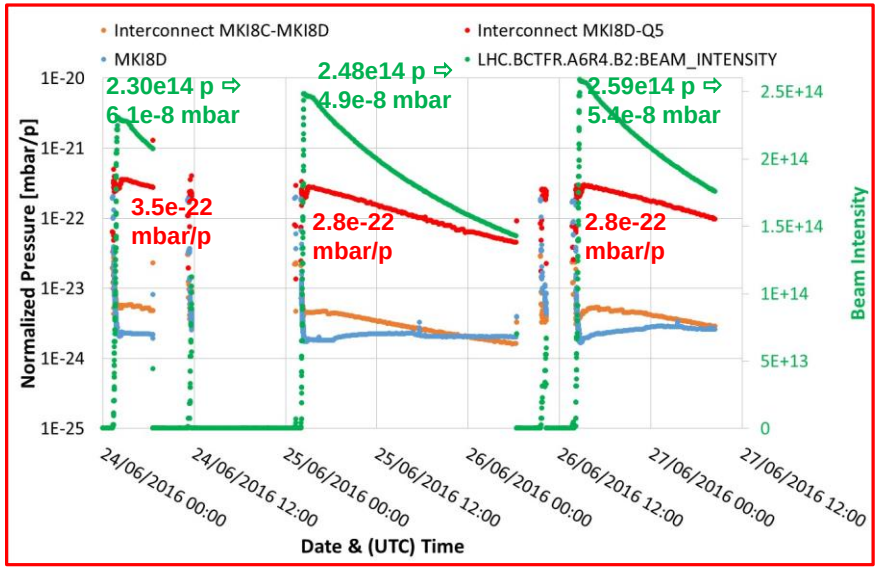
Dynamic pressure rise, c.f. no beam:

- Factor of ~20 in most MKI8 interconnects
- BUT factor of ~1000 in MKI8D-Q5 interconnect
- Factor of ~10 in MKI tanks

Fill 5038
25ns, 72bpi
B2 – 3 injections missing

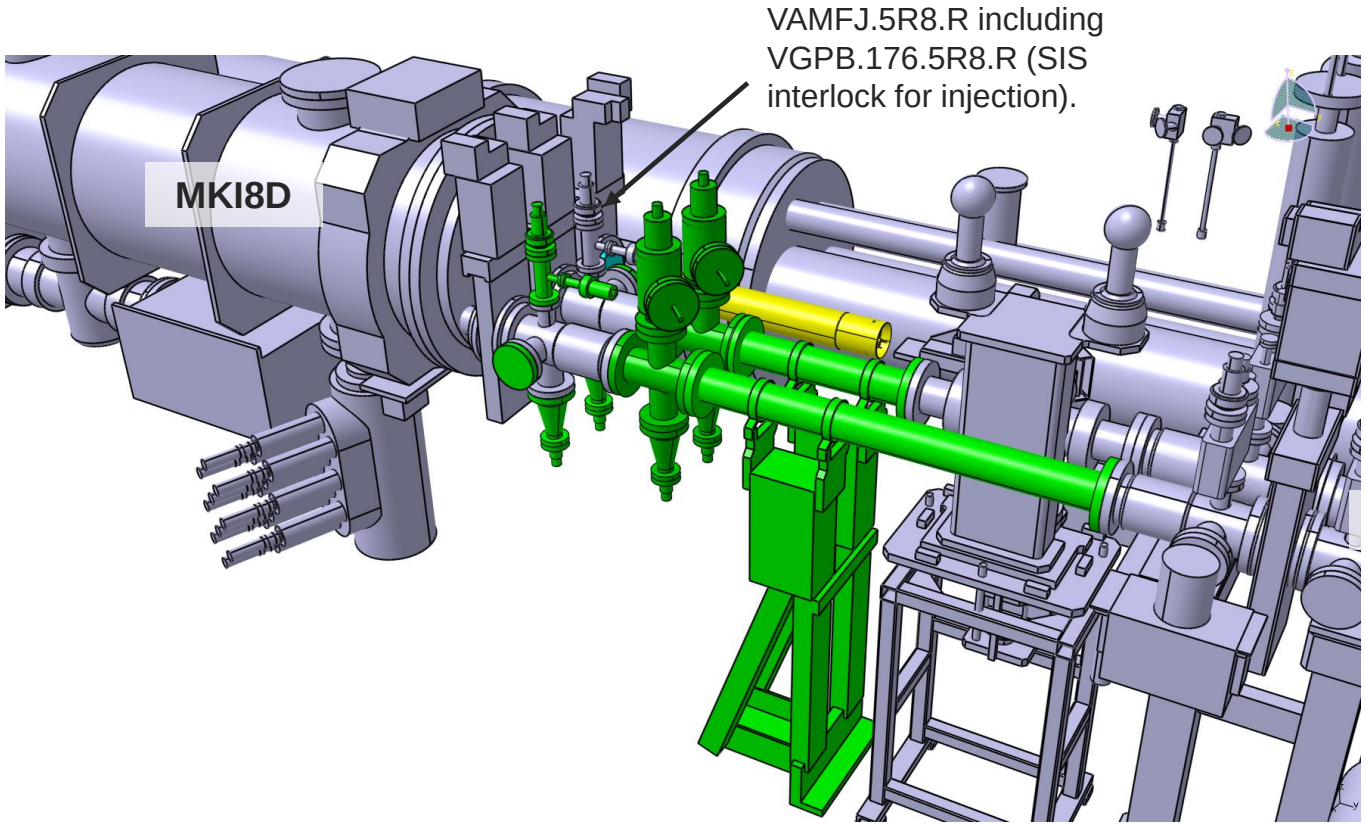
Fill 5043 (2x48).
25ns_2076b_2064_1717_1767_96bpi_23inj

Fill 5045 (2x48).
25ns_2076b_2064_1717_1767_96bpi_23inj (design luminosity !)



* Dynamic pressure in all MKI interconnects, except for MKI8D-Q5, << 5e-8 mbar *

MKI8 Vacuum – Upgrade during EYETS

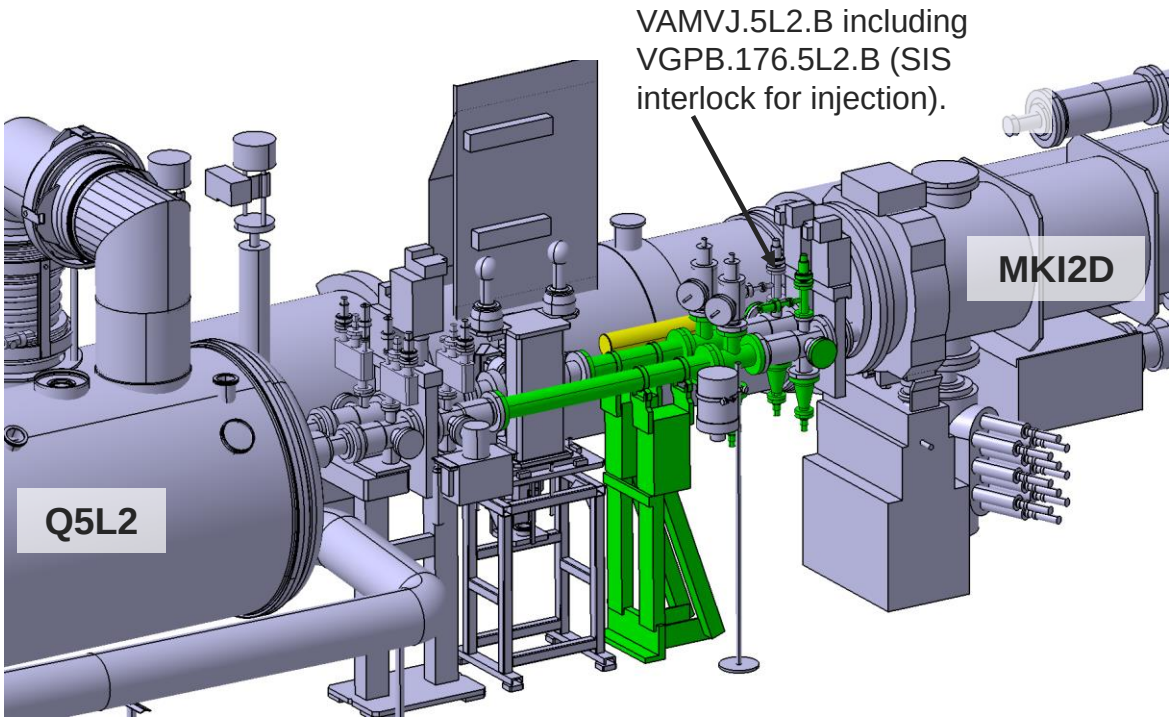


EYETS - Two new NEG cartridges of 400 l/s each (nominal speed for H_2) will be integrated in new modules of vacuum sector I5R8.

☺ **The upgrade will locally increase the pumping speed and hence maintain the dynamic pressure increase in the MKI8D-Q5 interconnect** (VGPB.176.5R8.R) **well below the SIS interlock threshold (5e-8 mbar) up to the nominal number of 25 ns bunches.**

MKI2 Vacuum – Upgrade during EYETS

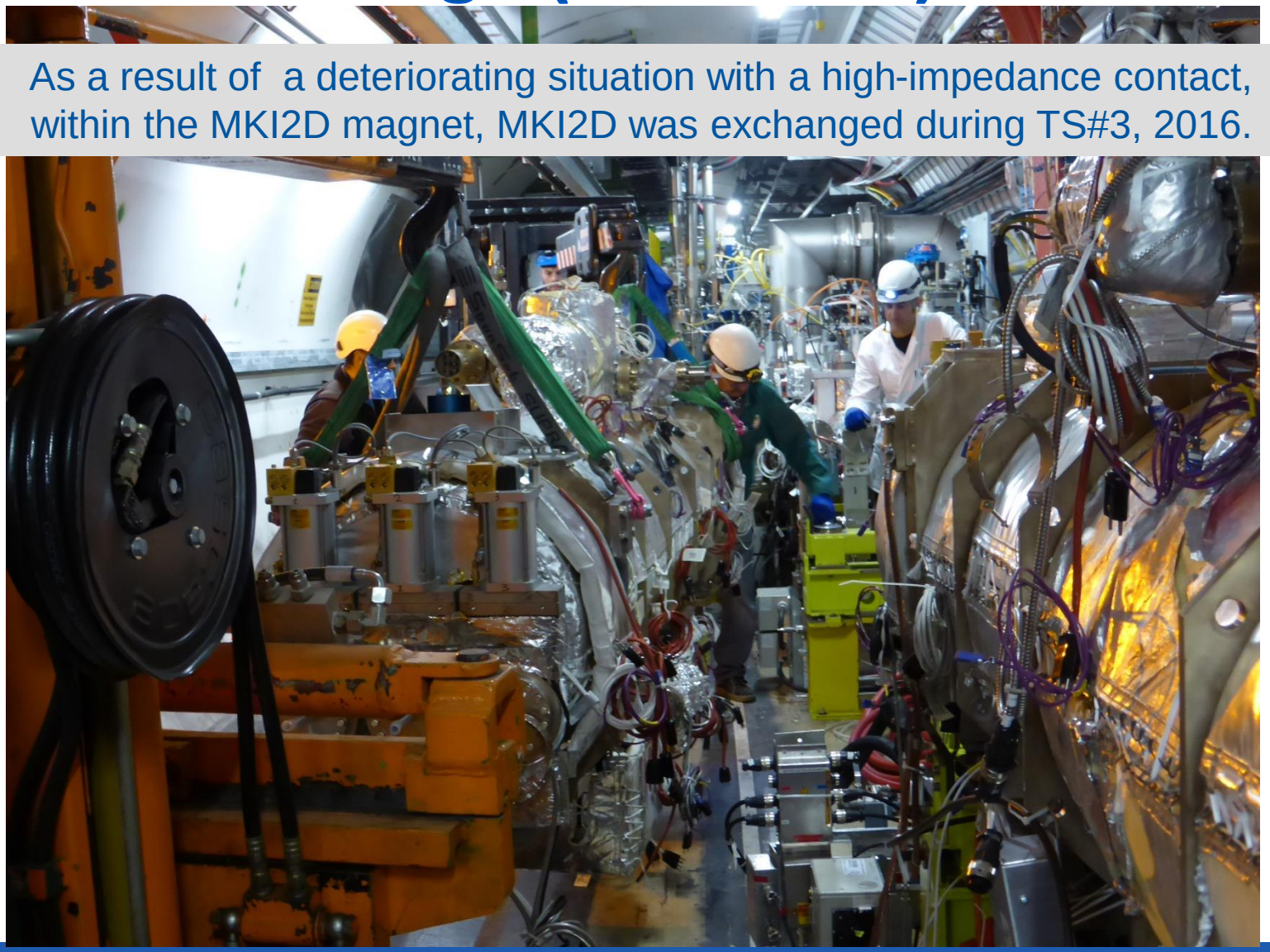
MKI2D was exchanged during TS3 2016.



- **EYETS -** Two new NEG cartridges of 400 l/s each (nominal speed for H_2) will be integrated in new modules of vacuum sector I5L2.
- Note: due to the exchange of MKI2D, following EYETS the alumina tube will need conditioning with beam; however this vacuum upgrade will assist to more rapidly increase number of bunches.

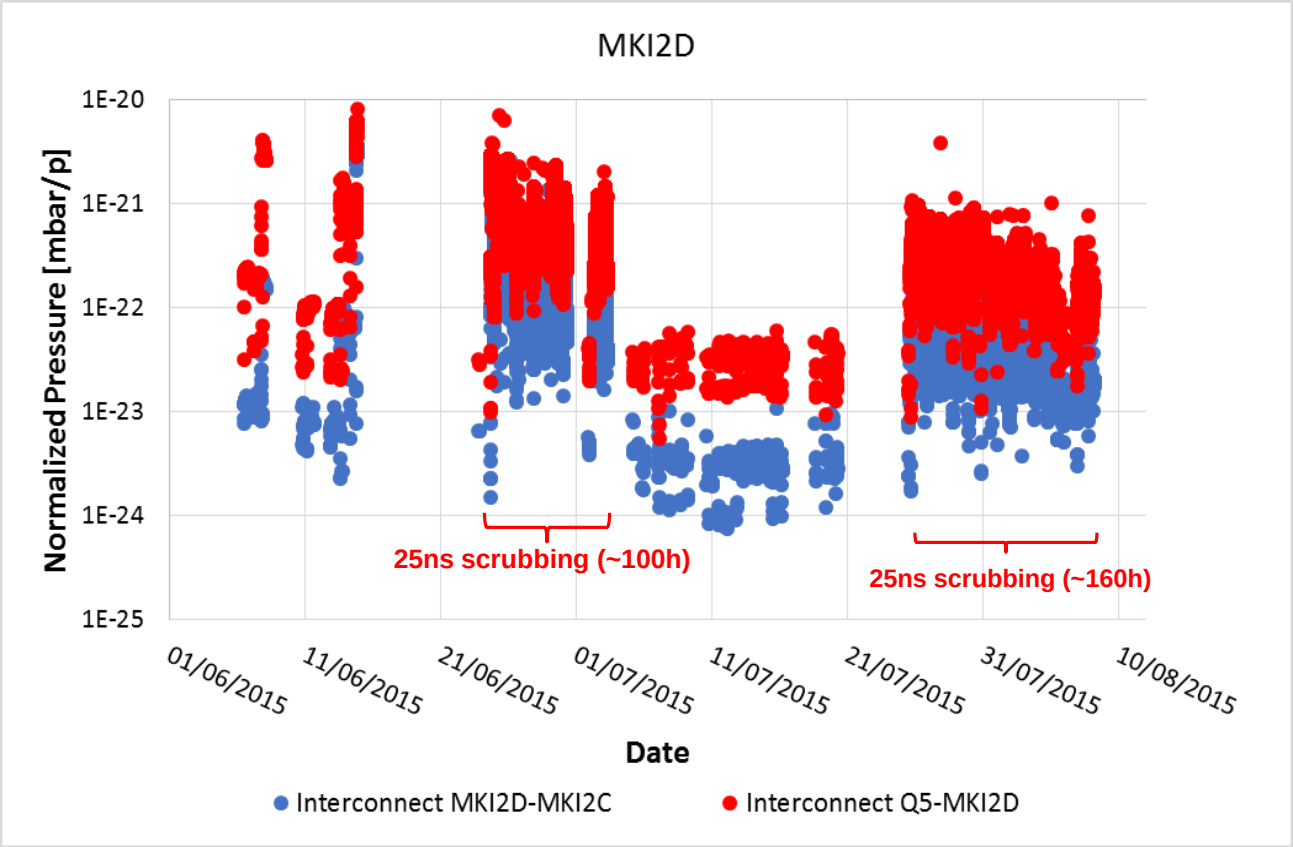
MKI2D Exchange (TS3, 2016)

As a result of a deteriorating situation with a high-impedance contact, within the MKI2D magnet, MKI2D was exchanged during TS#3, 2016.



MKI2D Expected Dynamic Pressure

Pressure after LS1, measured on MKI2D interconnects, normalized to the number of protons;

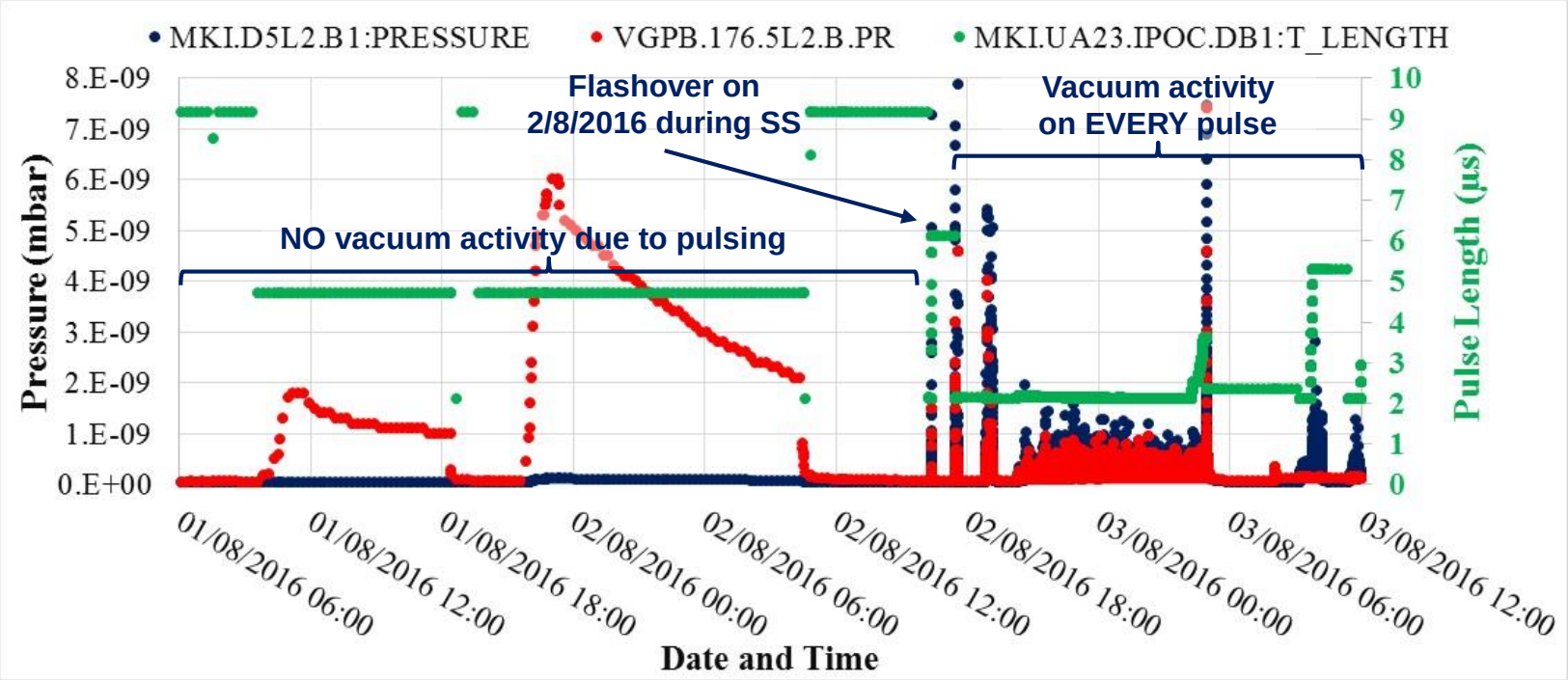


- **The alumina tube of the newly installed MKI2D (TS3 2016) will require condition with beam;**
- **With 1.2e11 ppb, 2808 bunches, and an SIS interlock threshold of 5e-8 mbar ⇨ normalized pressure to reach threshold ⇨ 2.2e-22 mbar/p.**
  - **Vacuum system upgrade will assist to more rapidly increase number of bunches.**

MKI2D Flashovers

Electrical breakdowns of MKI2D (MKIMA-08 T-11 MC-09), during Run 2:

Date	Time	PFN Voltage	Pulse Length	Comments
30-Oct-15	06:45	50.8kV	Top of rising edge, very close to magnet center	Spark during SS
24-Jul-16	23:58	48.53kV	~3.6us into flattop, very close to magnet input	Spark during Inj
02-Aug-16	18:40	50.7kV	~2.5us into flattop, very close to magnet input	Spark during SS

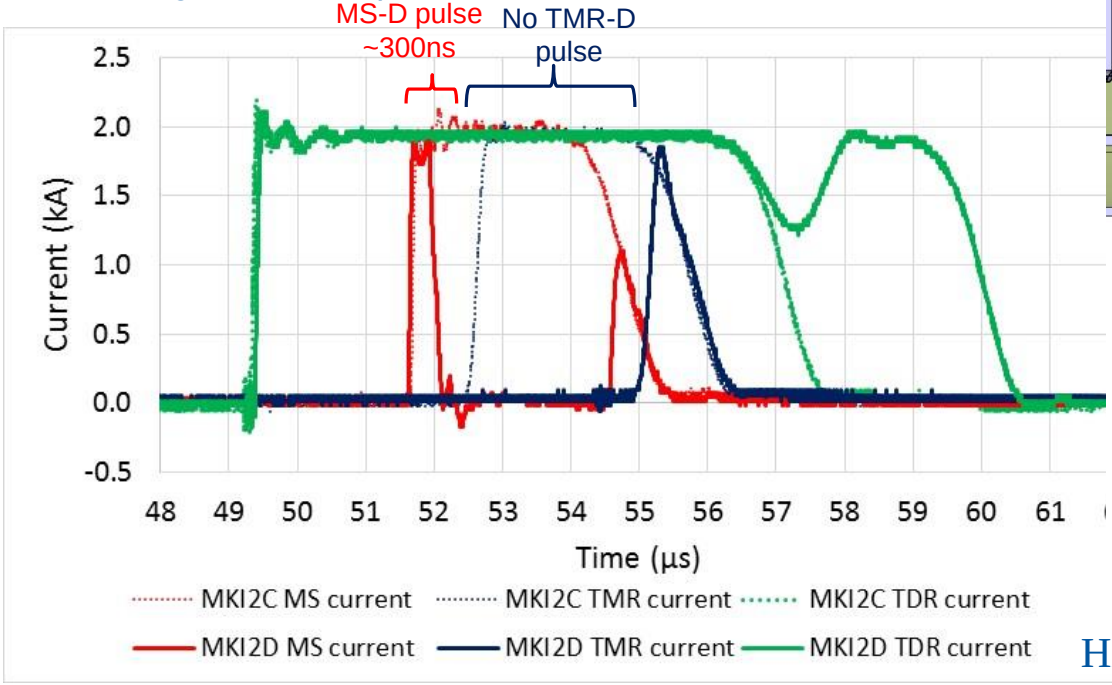


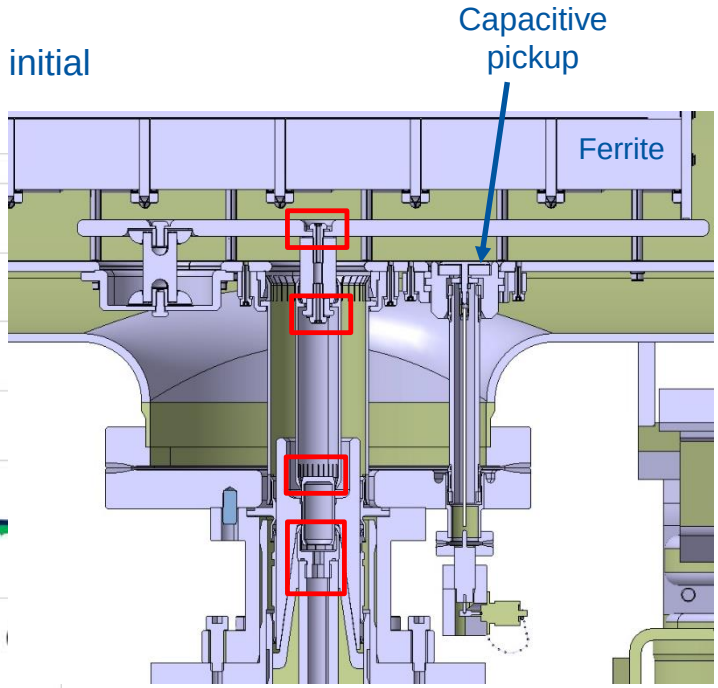
August 2016 to TS3 2016: MKI2D operated with ~3 µs field pulse flattop.

MKI2D High Impedance Contact

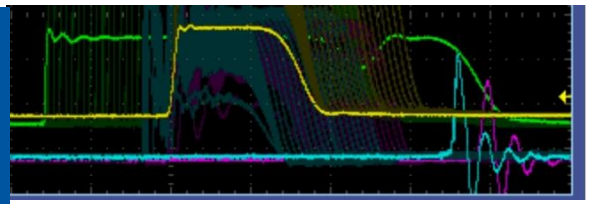
03/10/2016 @ 06:20:14hrs

SoftStart (1st pulse generally at 20 kV PFN, c.f. 30+ kV demanded: initial SS voltage increased)





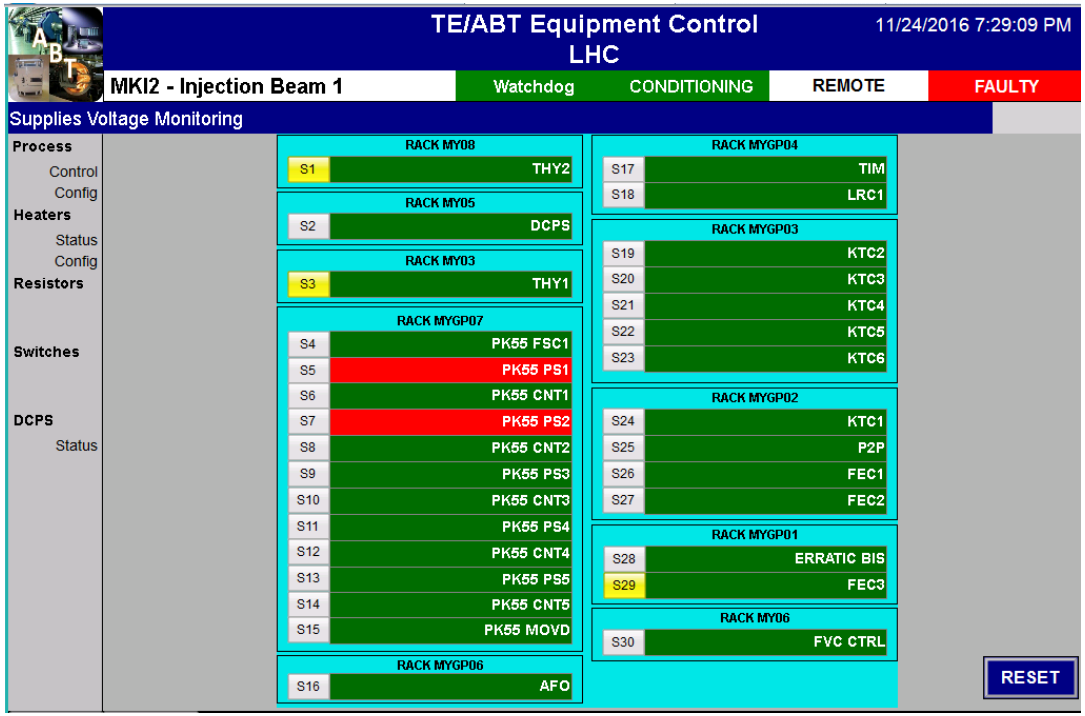
Scope in UA23 (infinite persistence, bright traces for 03/10/16 @ 22:27:40):
MKI2D TDR
MKI2A TMR
CPU In
CPU Out



High impedance contact issue of the removed MKI2D not yet inspected due to high priority of EYETS MKE and MKP preparation work.

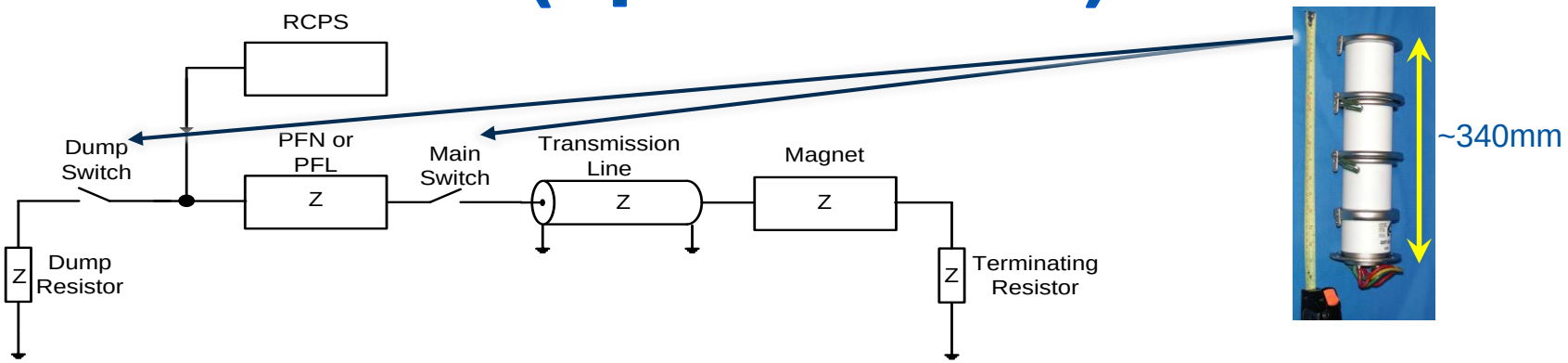
Nothing planned in tunnel for EYETS.

MKI2 SVM Faults



- Surveillance Voltage Monitoring (SVM) of +5V and ±15V, for the MKI, introduced during TS#1 and TS#2, 2016 (based on LBDS experience);
- SVM worked OK until November then “false” faults – hence signals masked;
- Source of faults is incorrect value of resistors mounted on the PCB during hardware production and not detected during lab tests before installation;
- **Concerned hardware will be returned for correction during EYETS and then reinstalled.**

MKIs: Erratic (Spontaneous) Turn-on



One Main Switch (MS) thyratron erratic during resonant charging for injection on 2/9/2016: 876 circulating bunches of which ~210 miskicked.

Since Nov. 2014 there has been a total, for the 2 MKI systems, of ~1.2 million pulses. During 2015:

- *20% of the pulses were for injection;*
- *80% of the pulses during SoftStarts (SS);*
- *Almost 60% of the pulses were at or above the nominal injection voltage.*

A total of 3 erratics (all on MS's):

- one at each of Pt2 and Pt8 during SS (both at voltages >2kV above nominal);

Only one erratic below nominal voltage. Estimated probability of Main Switch erratic during resonant charging : ~4×10^{-6} per pulse per system.

EYETS: check reservoir power supply settings and read-back…

Summary

MKI2:

- Several issues with MKI2D during 2016;
- Magnet MKI2D exchanged in TS3;
- Vacuum upgrade of MKI2D-Q5 planned for EYETS to increase pumping speed. Upgrade will reduce conditioning time of MKI2D alumina tube with beam.

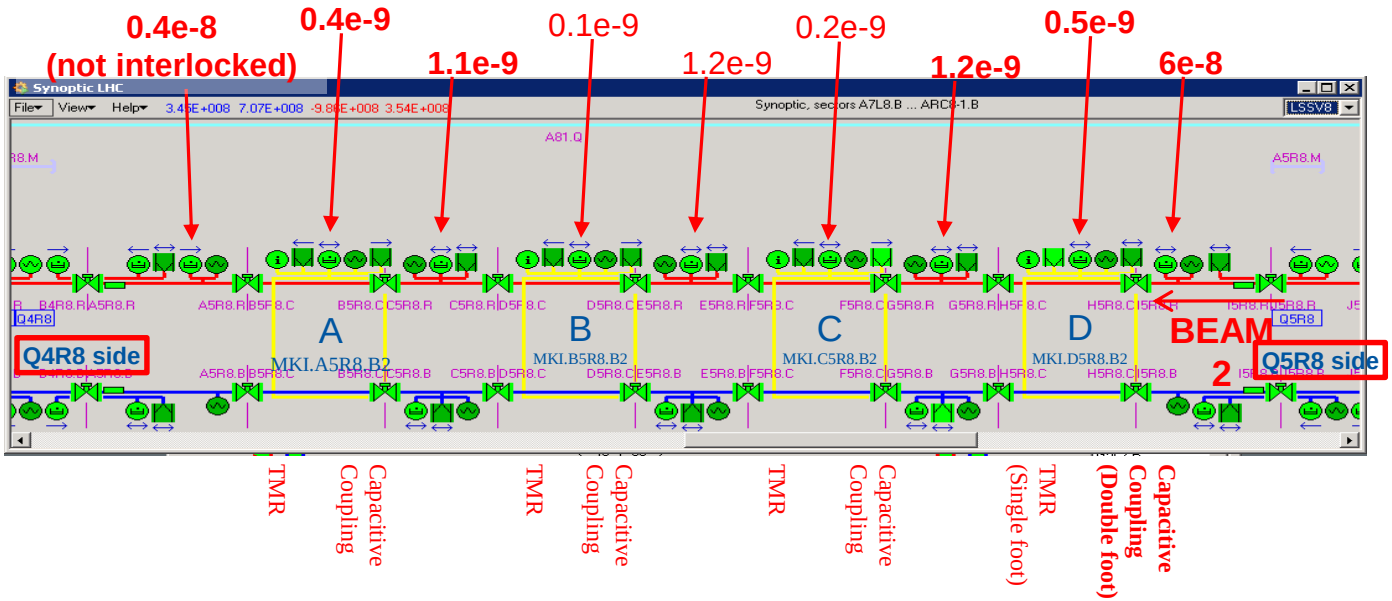
MKI8:

- No magnet exchange planned in EYETS;
- Vacuum upgrade of MKI8D-Q5 planned for EYETS to increase pumping speed - no longer expected to limit injection with nominal number of 25 ns bunches.

Thank you for your attention

MKI8: Summary of Maximum Pressure

Maximum vacuum readings (mbar) on 18 June 2016 (25ns beam, 2040 bunches, 72 bunches per injection, 30 injections):



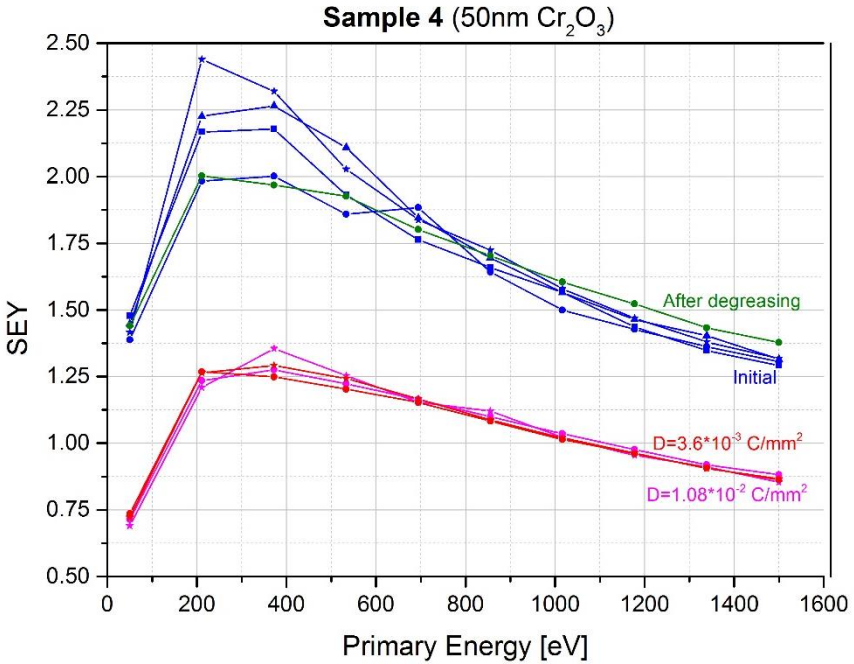
Interconnects between MKIs have ion pumps provides a nominal pumping rate of 30 l/s of hydrogen. However, since LS1, there is also an integrated NEG cartridge (**400 l/s of hydrogen**).

For the interconnects between the Q4-MKIA and MKID-Q5 there is only a **30 l/s** ion pump (and not a NEG cartridge), which is approximately 1.6 m from the end of the MKI tanks.

- "High" pressure is on Q5R8 (capacitively coupled) side and, to a lesser extent, on the Q4R8 side.
  - Factor of ~1000, above background, in MKI8D-Q5 interconnect
  - Factor of ~300 , above background, in Q4-MKI8A interconnect

Alumina Tube: Cr_2O_3 Coating

- "Naked" alumina has an SEY of ~10 !
- Possible surface coatings and treatments, e.g.:
  - Amorphous Carbon (aC)
  - Cr_2O_3 (Polyteknik, Denmark):



Planned to put a liner in the SPS during EYETS, with a Cr_2O_3 coating: two sets of liners now coated;

Note: Cr_2O_3 has previously been shown to substantially increase the surface flashover voltage of ceramic [T.S. Sudarshan and J.D. Cross, "The Effect of Chromium Oxide Coatings on Surface Flashover of Alumina Spacers in Vacuum", IEEE Trans. on Electrical Insulation, Vol. EI-11, No. 1, March 1976, pp32-35.]
High voltage tests are planned in the lab.

Thermal Simulations forMKI8D