Dust issues and beam losses in LHC injection kickers: What can we learn from it?

M.J. Barnes

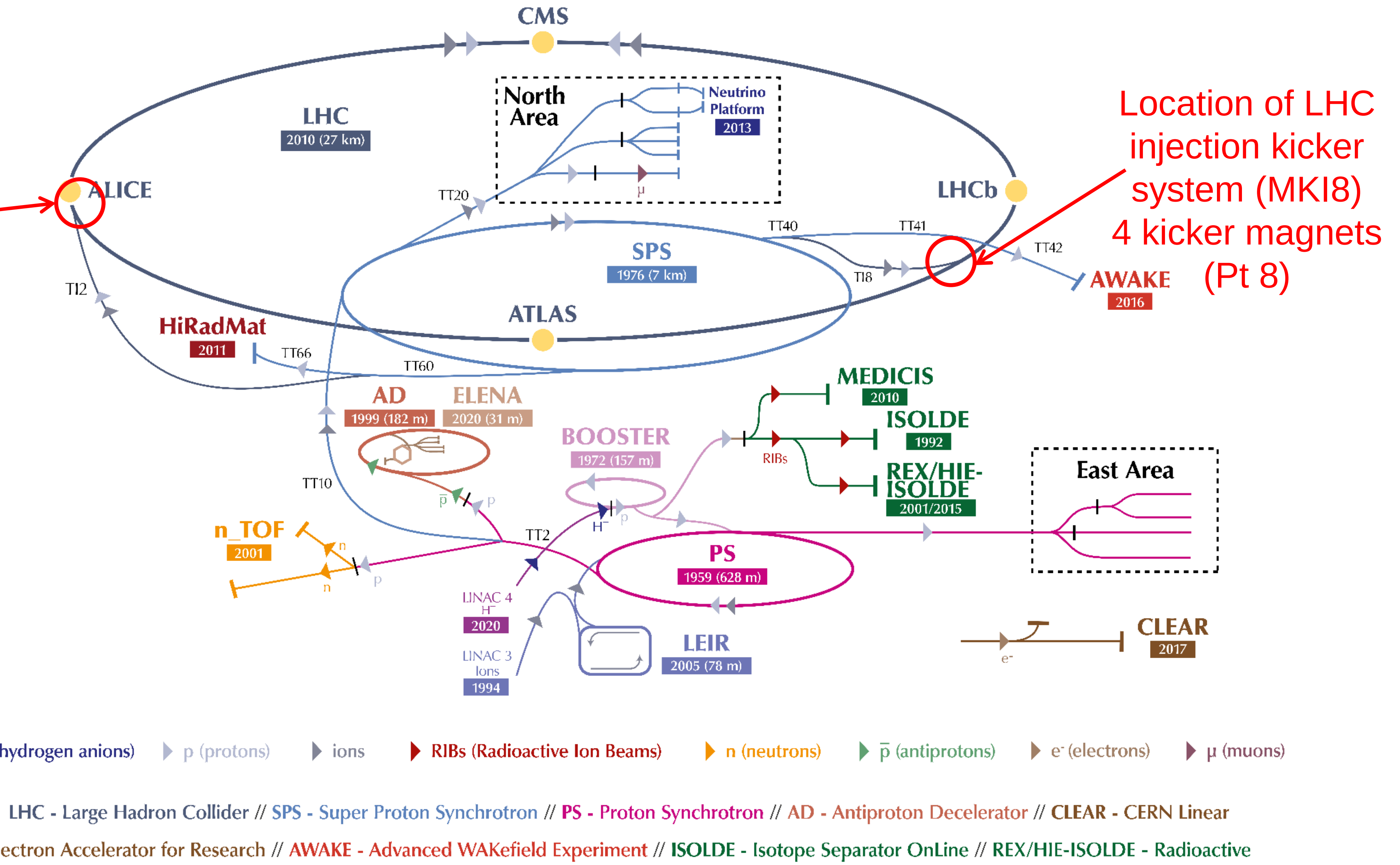
Acknowledgements:
Former and present colleagues from CERN ABT, BE, MME, OP, VSC….

Overview of Presentation

- Brief introduction to the LHC injection kicker magnets (MKIs)
- 2011 & 2012: UFOs around the MKIs
- Studies of the MKI UFOs
- Upgrade of MKIs during LS1 (~2013/2014)
- Statistics of UFOs around the MKIs after upgrades and new procedures
- Conclusions

CERN Accelerator Complex

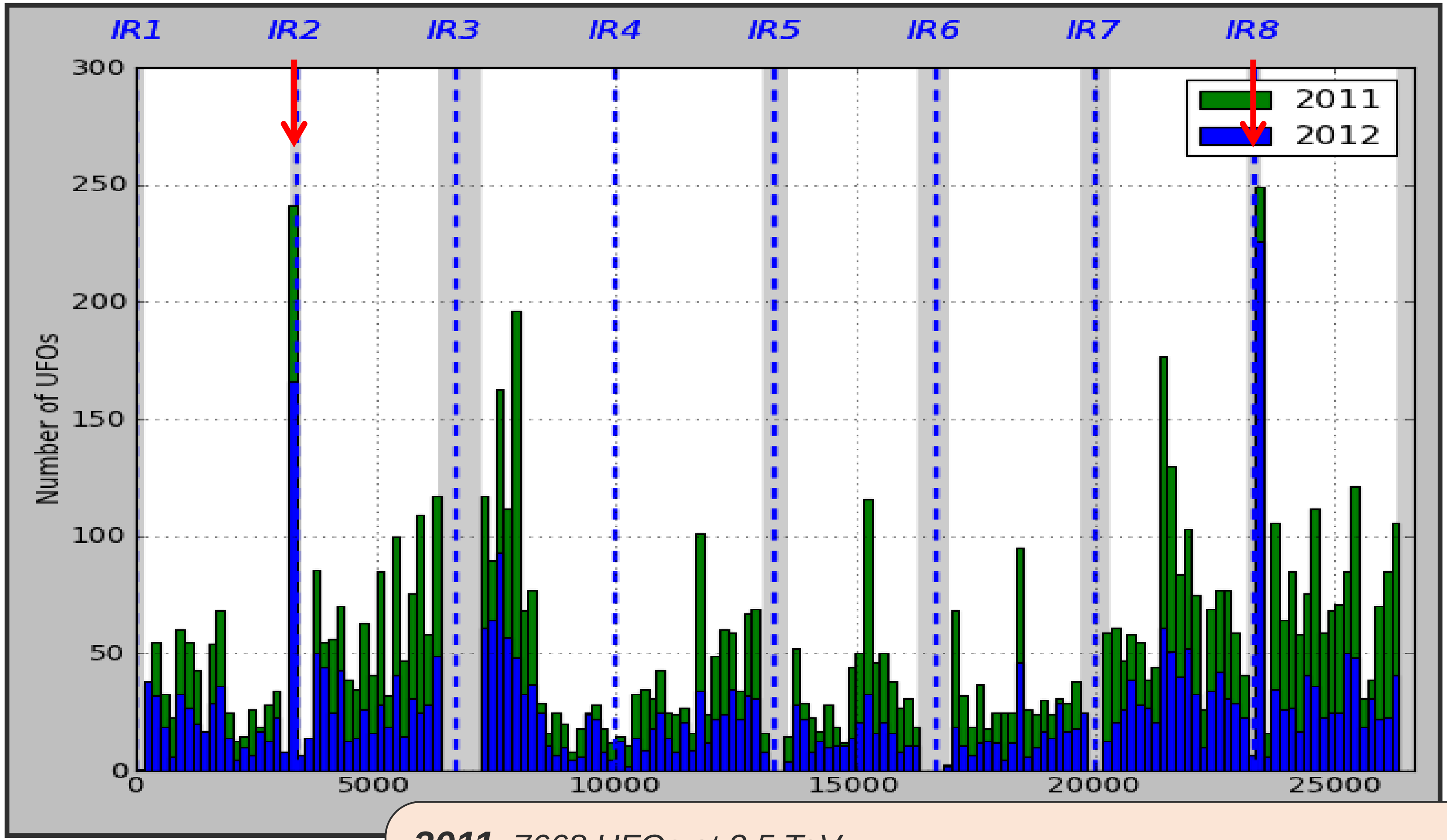
Location of LHC injection kicker system (MKI2)
4 kicker magnets
(Pt 2)



Location of LHC injection kicker system (MKI8)
4 kicker magnets
(Pt 8)

UFOs: LHC Longitudinal Distribution

Plot courtesy of **T. Baer**



During 2011 and 2012, a significant proportion of the UFOs were associated with the MKIs !

2011: *7668 UFOs at 3.5 TeV.*

2012: *3719 UFOs at 4 TeV.*

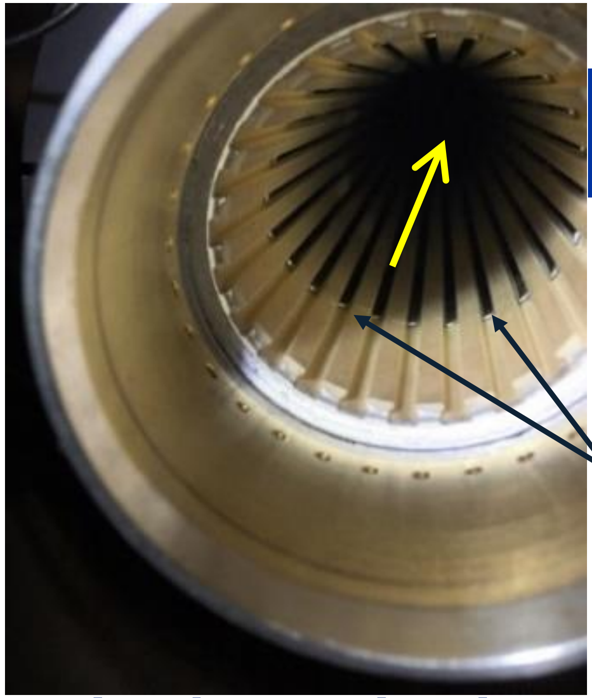
Signal RS04 > $2{\cdot}10^{-4}$ Gy/s.

Grey areas around IRs are excluded from the analysis.

LHC INJECTION KICKER MAGNETS

- Four kicker magnets per LHC injection system
- Approximately 25 kV applied to each kicker magnet during injection (~5 kA current pulse)
- Magnetic field rise-time of ~800 ns. Magnetic field flat-top up to ~8 µs.

High purity **alumina** tube (>3m long, **~38mm ID**)

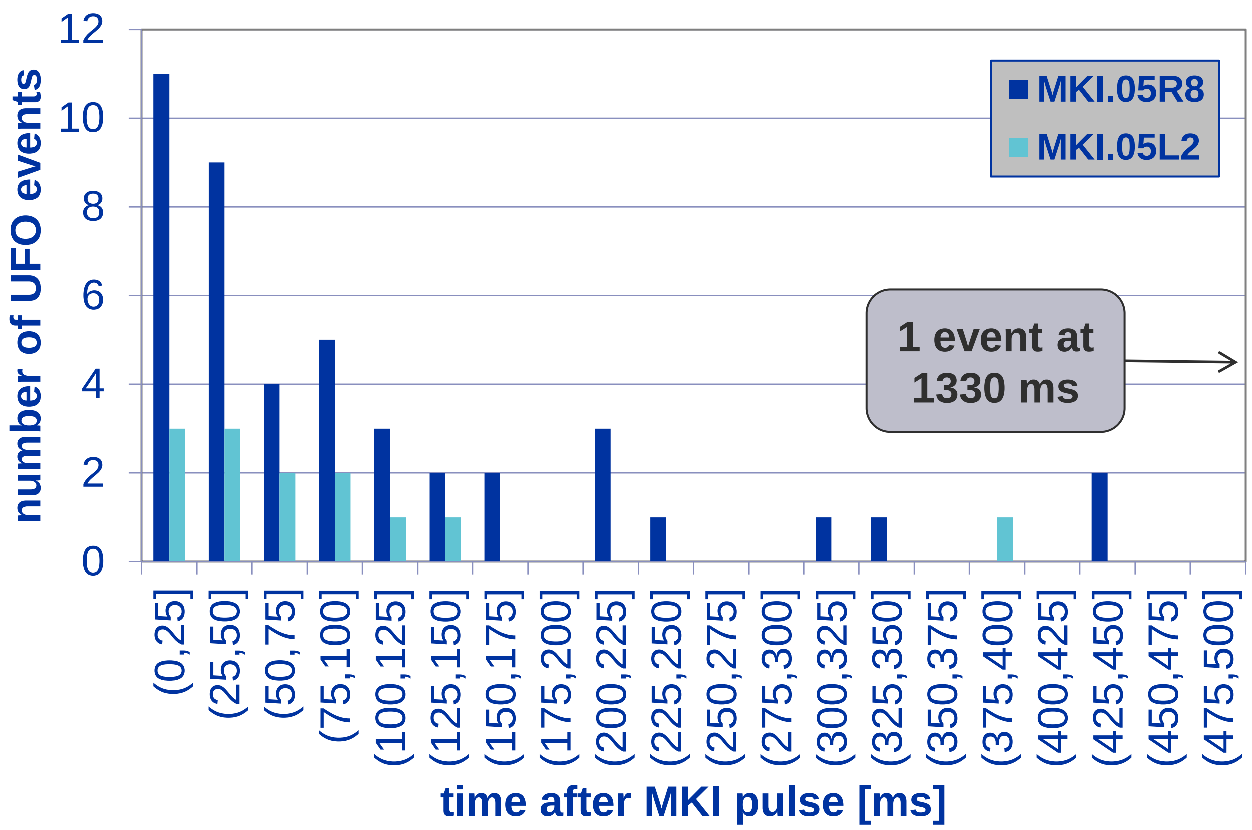


Injected and circulating beam

Metallic screen conductors (**in [24] slots on inside wall of alumina tube**)

- ➢ Screen conductors carry beam image current and significantly reduce beam induced power deposition
- ➢ An alumina tube is required, for each MKI kicker magnet, to:
  - ➢ Mechanically supports screen conductors
  - ➢ Provides **electrical insulation** between screen conductors and to busbars of the kicker magnet
- ➢ Alumina tube manufactured by extrusion. It is not feasible to machine inside of tube

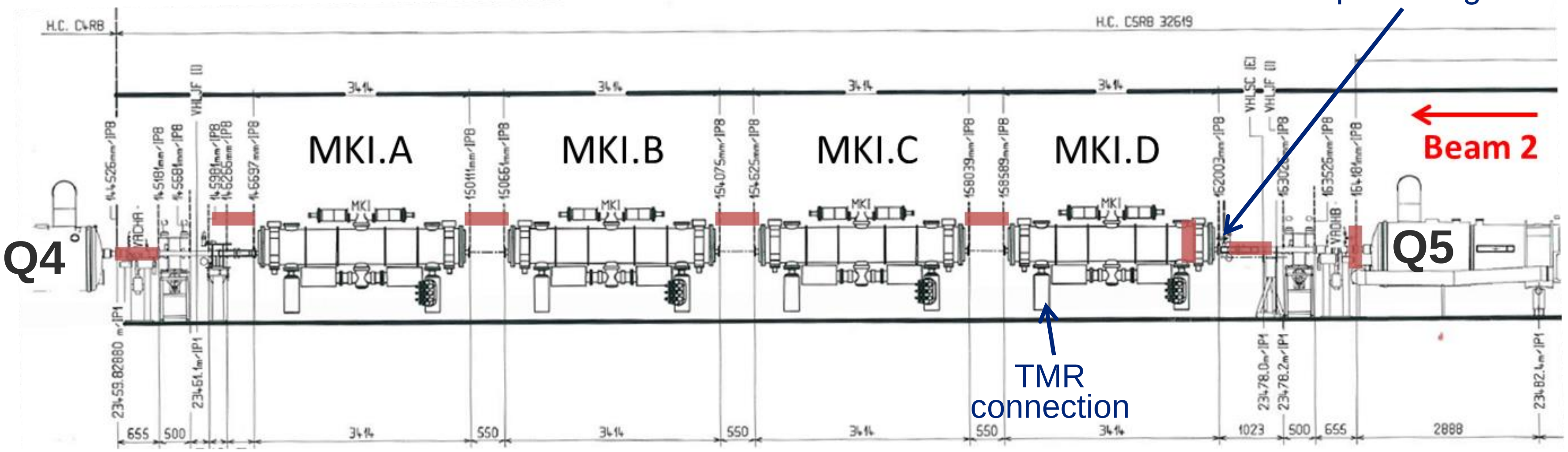
TEMPORAL DISTRIBUTION OF OBSERVED UFOS AFTER MKI PULSE



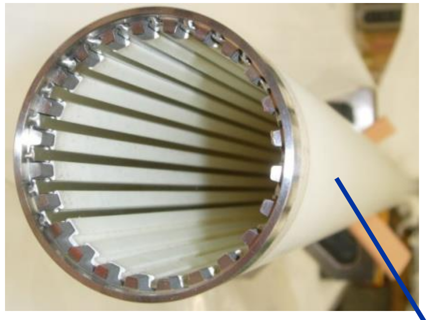
Courtesy of T. Baer, Chamonix 2012.

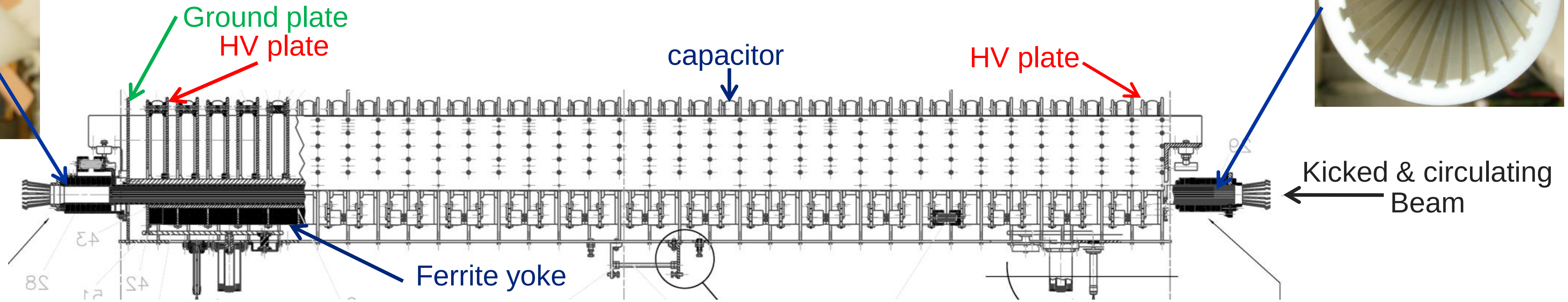
- A significant proportion of UFO events occur **≤50 ms after the MKI pulse**
- Assuming a particle is released from the top of the aperture during the kicker pulse, and accelerated only by **gravitational force** towards the beam**,** the **expected delay is more than 60 ms**
  - Thus, **gravity does not explain many of the relatively short times between pulsing an MKI and the UFO occurring** *(T. Baer et al., CERN-ATS-Note-2012-018 MD; F. Zimmermann, 66th LIBD Meeting).*

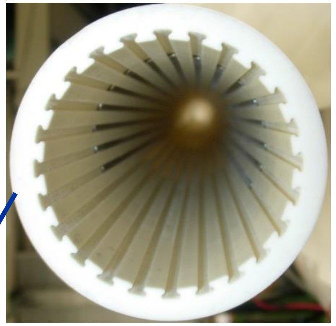
LAYOUT OF MKI8 REGION



- ➢ Four MKI magnets per beam, between Q4 and Q5, each pulsed at ~25 kV
- ➢ Vacuum valves at tank ends, plus sector valves: 10 in total per beam;
- ➢ Until end of 2012, generally **only 15 (of 24) screen conductors installed per alumina tube.**







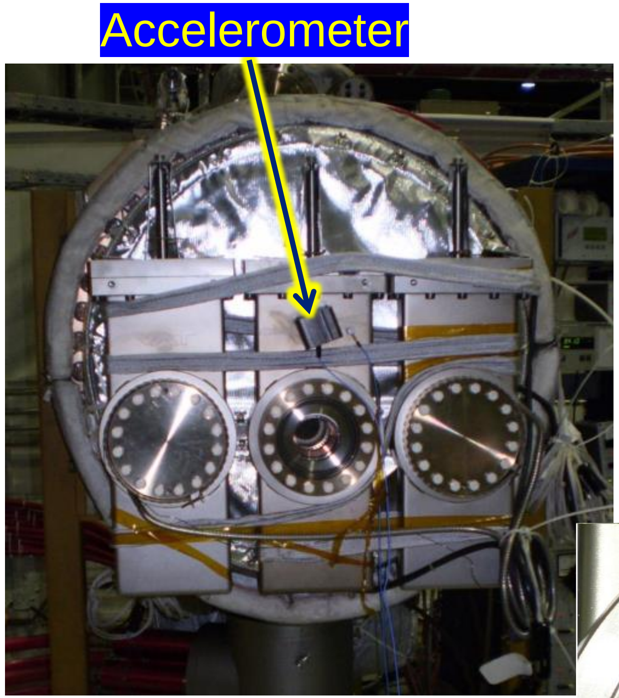
MKI UFO STUDIES

- **FLUKA: UFO location must be in MKIs (or nearby upstream).**
  (A. Lechner, 3rd LHC UFO Study Group Meeting)

- **A minimum particle radius of 40 μm** is needed to explain a large UFO event on 16.07.2011.
  (T. Baer et al., Evian Workshop 2011)

- **Vibration measurements using accelerometers and lasers: Mechanical vibrations of tank, in 60Hz to 300Hz range, (~10 nm) resulting from MKI pulse.**
  (R. Morón Ballester et al., EDMS: 1153686)

- **Mechanical vibrations of alumina tube (~nm??) resulting from MKI pulse.**



**** Are the mechanical vibrations sufficient to dislodge dust ?? ****

Macro Particles in MKIs

MKI.C5L2 (removed from LHC during a Technical Stop at the end of 2010/11) was opened.

Alumina tube was **flushed** 3 times with high pressure nitrogen into **a filter for analysis by CERN MME**.

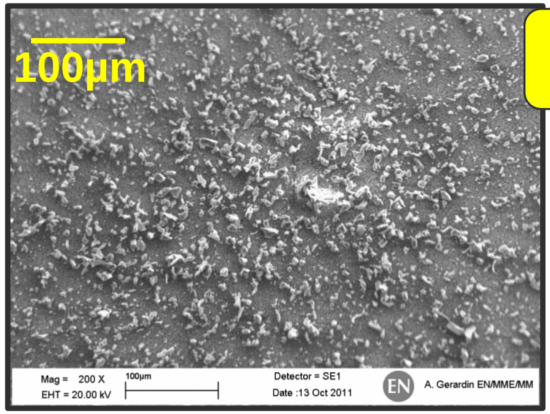
Energy-dispersive X-ray spectroscopy showed **particles mainly consist of Al and O [7]**, leading to the conclusion that the **macro particles originate from the Al_2O_3 alumina tube**

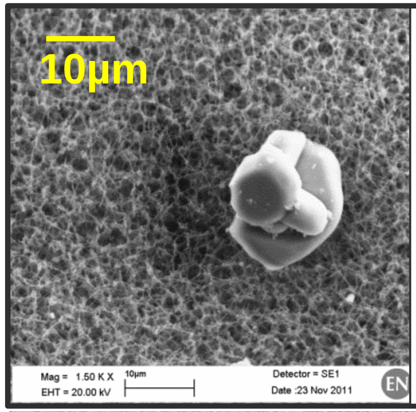
- **Reference measurements*:**
  - *clean room air: 100 particles on filter*
  - ***virgin alumina tube: 10,000** particles on filter (Note: At the end of production, alumina tubes are cleaned 6 times with high pressure water (> 100 bar), using a multi-jet in a "dirty" factory, then baked out at ~800˚C)*

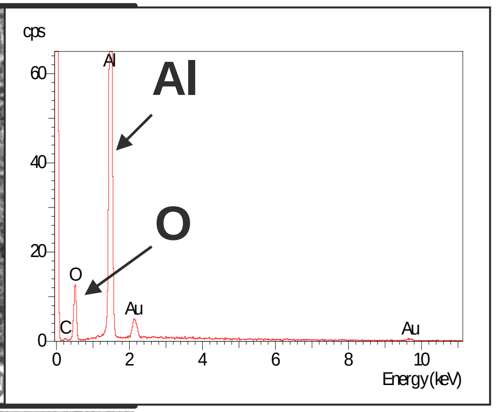
- **5,000,000* particles on filter (following flushing of alumina tube, of removed MKI, with 10 bar nitrogen onto a filter)**
- **Typical macro particle diameter: 1-100µm**

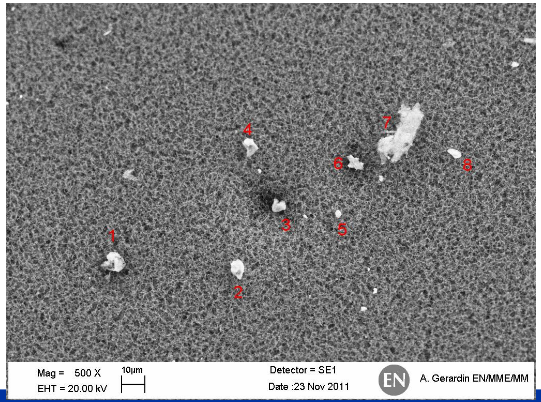
***: Note – manual counting, so likely an underestimate**

A. Gerardin, N. Garrel [7]





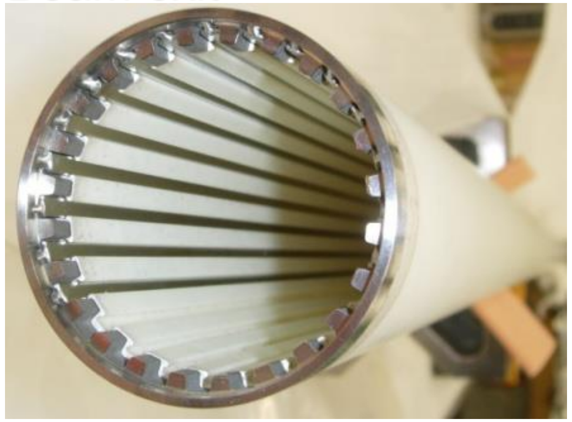




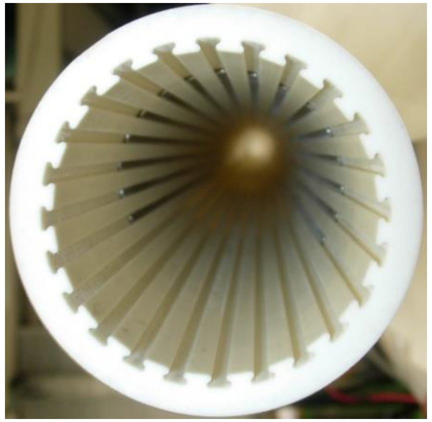
Particles	Main elements
1	Al,O
2	Al,O
3	Al,O
4	Al,O
5	Al,O
6	Ni,Cr
7	C,O
8	Al,O+Ni,Cr

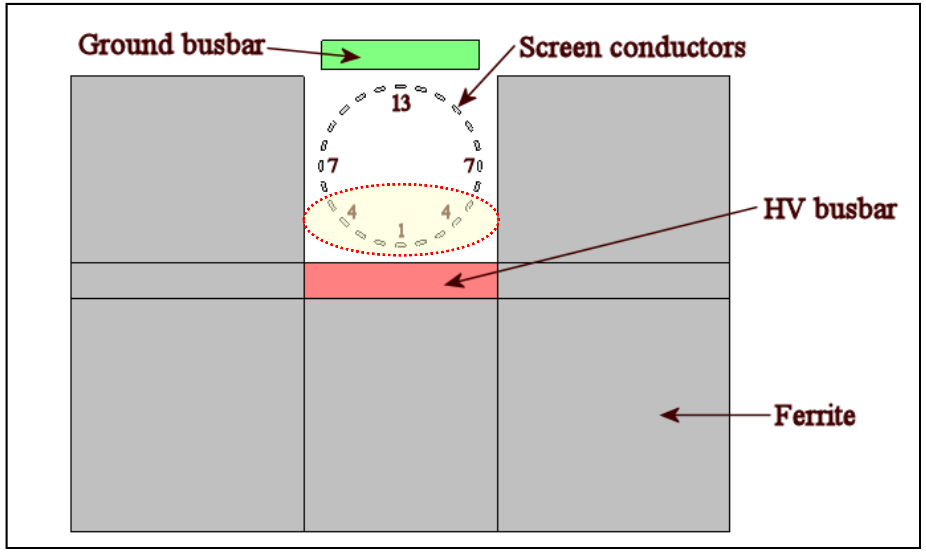
Screen Conductors

Beam exit



Beam entrance

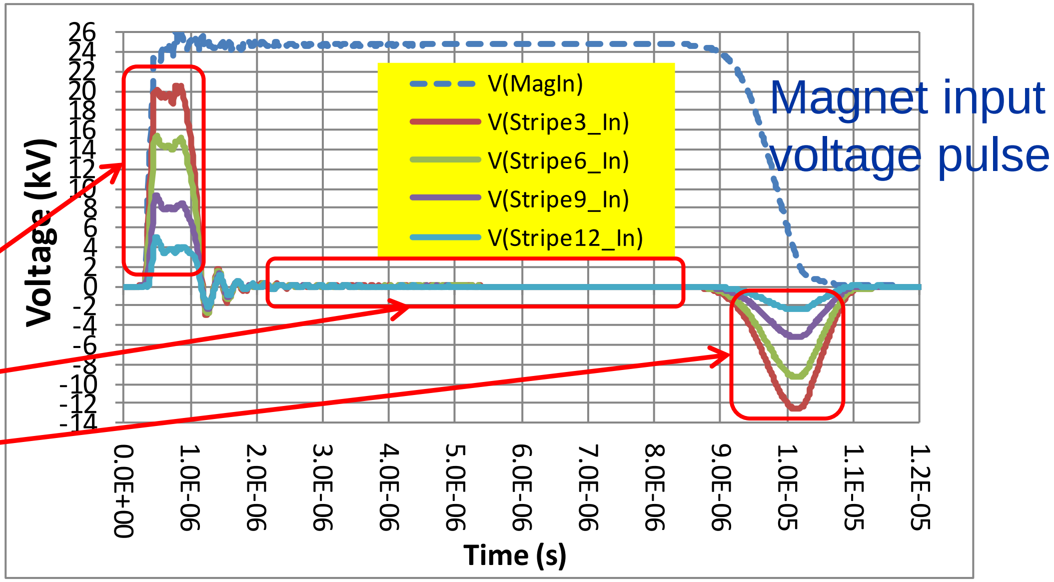




Originally, for beam coupling impedance reasons, **24 NiCr screen conductors were** to be installed;
In general, **15 screen conductors** were installed, prior to LS1, to minimize HV electrical breakdown issues.

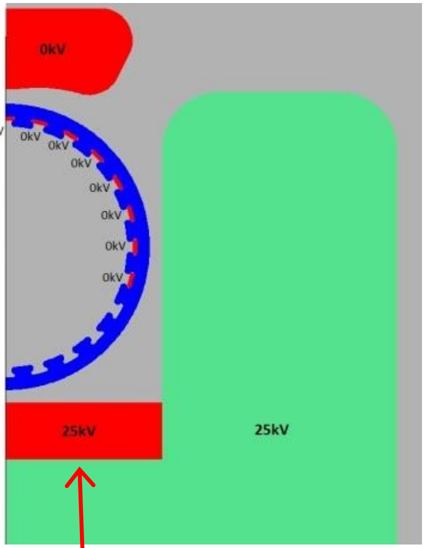
Notes:

- Screen conductors are hard-coupled to "ground" at beam-exit, and **capacitively coupled to "ground" at beam entrance**;
- Voltage on screen conductors at beam-entrance:
  - transiently go to +ve HV during field rise;
  - **0V during flattop of field pulse**;
  - transiently go to −ve HV during field fall.
- Alumina has a high SEY (max ~9), resulting in eCloud, and is slow to condition with beam.



ELECTRIC FIELD FOR 15 SCREEN CONDUCTORS

15 screen conductors

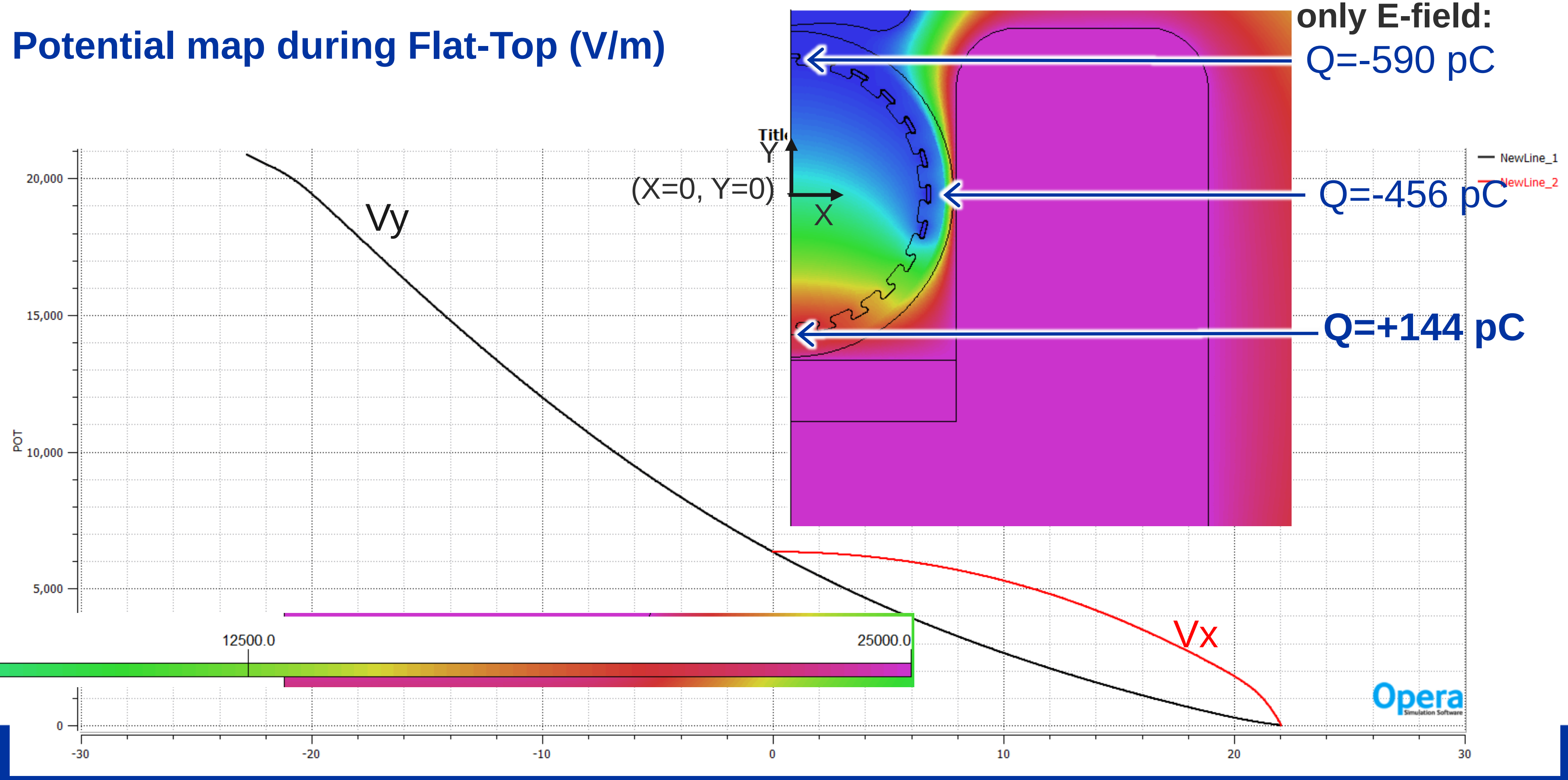


HV Busbar

UFOs occurring before ~60 ms after a pulse cannot be explained by gravity: however, they *might* be due to **charged particles accelerated by the electric field of the MKIs** [6]. Assume a 50 µm diameter alumina particle: estimate charge on particle required to accelerate the particle in 8 µs and to reach the beam in 10ms (velocity ~2 ms/s after 8 µs [distance travelled in 8 µs: ~0.008mm]):

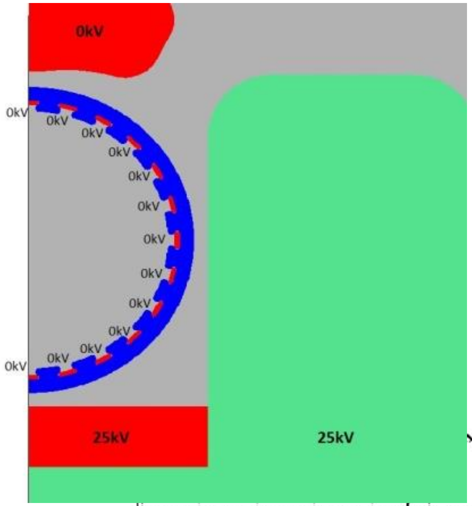
Potential map during Flat-Top (V/m)

Considering only E-field:



Electric Field for 24 Screen Conductors

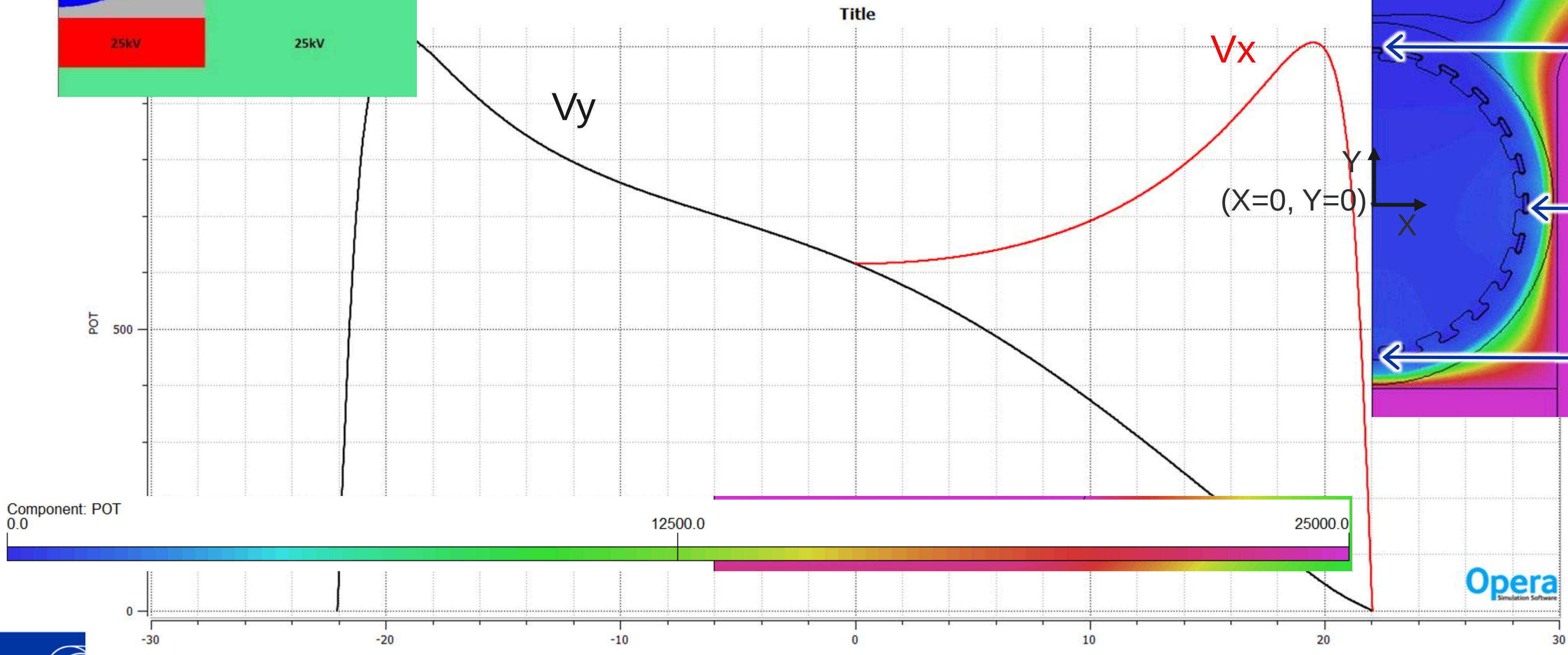
24 screen conductors



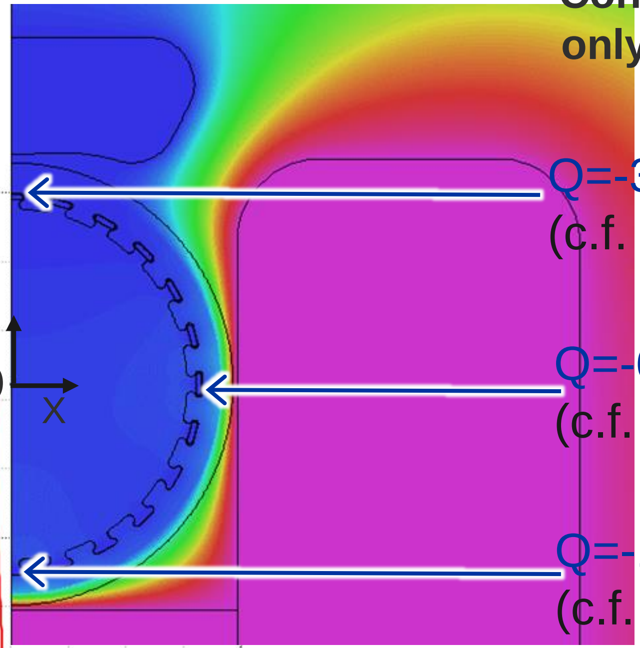
During LS1 (2013/14) the MKIs were upgraded to have 24 screen conductors.

Assume a 50 µm diameter alumina particle: estimate charge on particle required to accelerate the particle in 8 µs and to reach the beam in 10ms (velocity ~2 ms/s after 8 µs [distance travelled in 8 µs: ~0.008mm]):

Potential map during Flat-Top (V/m)



Considering only E-field:



Q=-3.2 nC (c.f. -590pC)

Q=-60 pC (c.f. -456pC)

Q=-115 pC (c.f. +144pC)

Note: **negative charges with 24 Screen** Conductors – would need +Q on bottom with 15 SC

IMPROVED CLEANING OF MKI ALUMINA TUBES

- Prior to LS1 (start of 2013) alumina tubes were **only** cleaned with high pressure (> 100 bar) water at the factory, then baked out at ~800˚C.
- **Alumina particles** are **dislodged when inserting screen conductors** into grooves at CERN:
  - Particle count **resulting from inserting conductors increased by a factor of 10 to 20** [15]

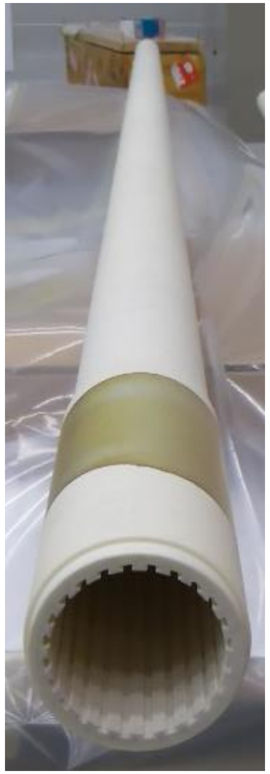
Hence, procedure implemented, during LS1, for cleaning MKI alumina tubes:

1. Insert 4 screen conductors at top of tube
2. Four times go and return, flushing with 10 bar nitrogen (no filter)
3. Rotate alumina tube by 60 degrees and insert 4 screen conductors at top of alumina tube
4. Four times go and return, flushing with 10 bar nitrogen (no filter)

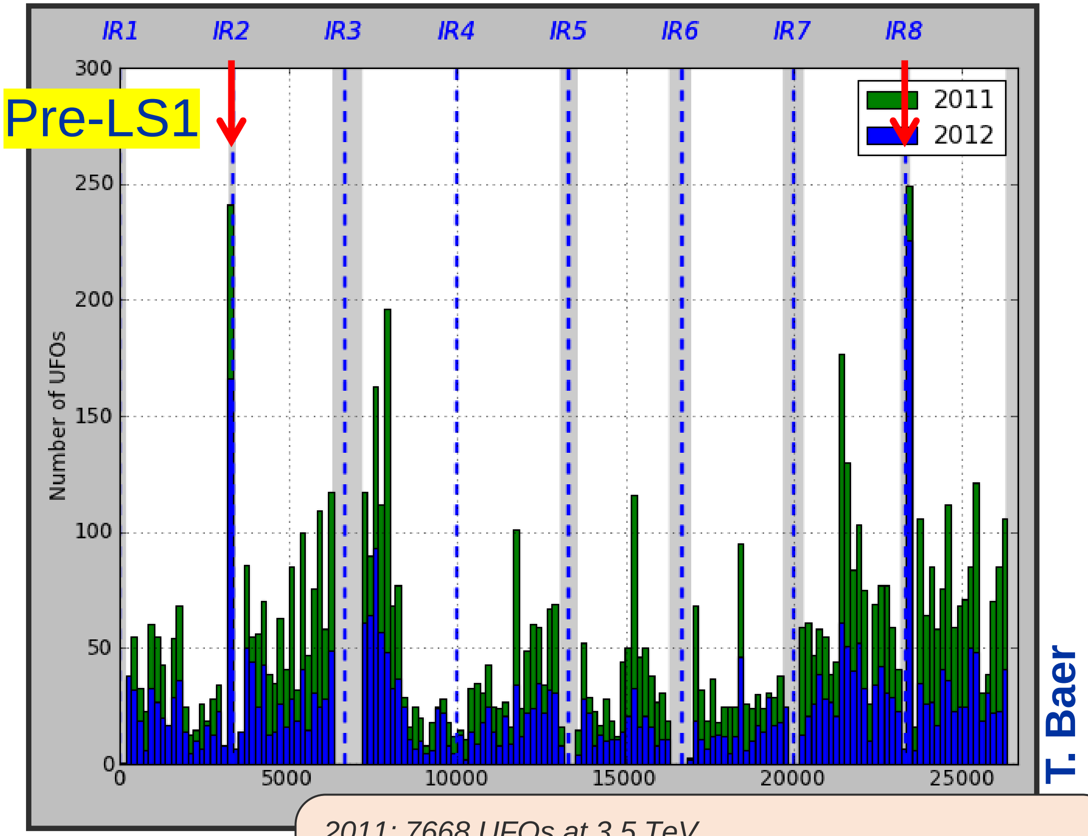
Repeat items 3 & 4 until tube is populated with all 24 screen conductors

5. Six times go and return, flushing with 10 bar nitrogen (use filter [#1] to catch "dust" particles)
6. Ten times go and return, flushing with 10 bar nitrogen (no filter)
7. Six times go and return, flushing with 10 bar nitrogen (new filter [#2] to catch "dust" particles)
8. Twenty times go and return, flushing with 10 bar nitrogen (no filter)
9. Six times go and return, flushing with 10 bar nitrogen (new filter [#3] to catch "dust" particles)

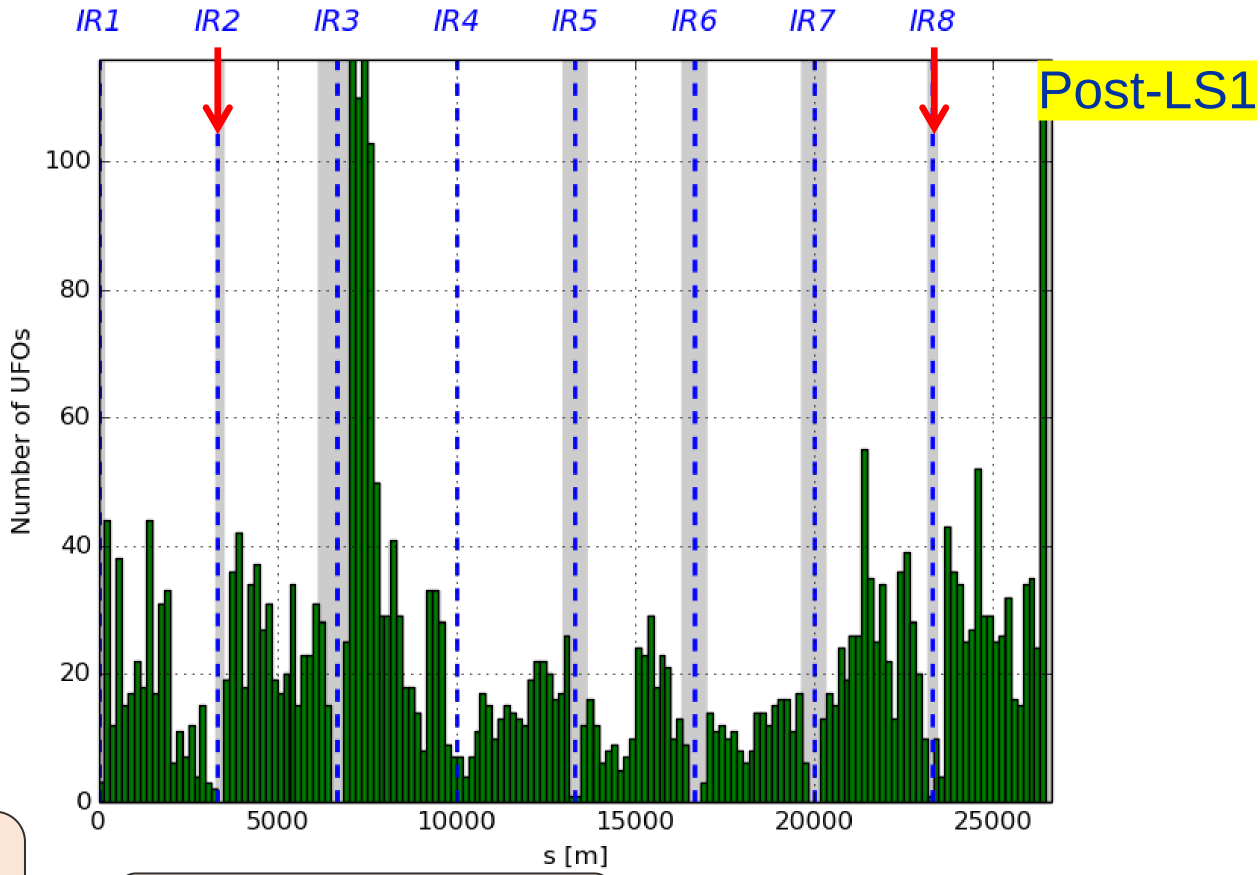
Typically, an order of magnitude reduction in dust count between filters #1 and #3



UFOs Longitudinal Distribution



2011: 7668 UFOs at 3.5 TeV.
2012: 3719 UFOs at 4 TeV.
Signal RS04 > $2 \cdot 10^{-4}$ Gy/s.
Grey areas around IRs are excluded from the analysis.



***2015**: 3621 UFOs at 6.5 TeV.*
Signal RS04 > $2 \cdot 10^{-4}$ Gy/s.`

Plots courtesy of G. Papotti et. al, “Busting UFOs – part 1”, LMC 22/07/2015

24 screen conductors and improved cleaning procedure for alumina tubes implemented during LS1: Post-LS1 **MKIs have virtually vanished from the UFO statistics**

Coating of Alumina Tube

- In 2016/17 it was decided to **coat the inside of an MKI alumina tube with Cr_2O_3** to:
  - **Further improved High Voltage** behaviour of screen conductors
  - **Reduce Secondary Electron Yield (SEY)** of alumina surface and thus decrease electron cloud and conditioning time of surfaces
- Following a series of tests and measurements, application of **Cr_2O_3 by magnetron sputtering** was chosen because:
  - Initial testing of samples with **Cr_2O_3 applied by painting** showed low SEY but **dust** – it was possible to 'seal' the surface, to prevent dust, but this gave significantly higher SEY
- **Standard cleaning procedure of alumina tubes <u>before shipping for Cr_2O_3 coating</u>** (coated without screen conductors installed)
  - Reduced cleaning procedure <u>after</u> Cr_2O_3 coating (to minimize risk of damage to Cr_2O_3 coating) – see spare slides
  - Dust particle size generally ≤ 10 µm (majority 1 to 2 µm) [12, 13]
  - **No statistically significant change in occurrence of UFOs** after installation of MKI **with Cr_2O_3 coated alumina tube** [14]

CONCLUSIONS

- **Macro particles originate from inserting the screen conductors in to the alumina tube**
- With only 15 (of 24) screen conductors present, the **positively charged particles at bottom** of alumina tube ***could*** be accelerated towards the beam **by the electric-field during pulsing the MKI**
- **All 8 MKIs (plus spares) were upgraded during Long Shutdown 1** to have a full complement of 24 screen conductors, significantly changing the electric field during the pulse flattop
- In addition, during LS1, a significantly improved cleaning procedure for the alumina tube was implemented
- **Post-LS1 the MKIs virtually vanished from the UFO statistics**
- **Cr_2O_3 applied by magnetron sputtering does not increase the UFO statistics**

Spare Slides

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[1] T. Baer et al., “MKI UFOs at Injection", CERN-ATS-Note-2011-065 MD, Aug. 2011.
[2] A. Lechner, “FLUKA Studies of UFO-induced Beam Losses in the LHC”, CERN Accelerator School Poster Session, Sept. 2011.
[3] R. Morón Ballester et al., “Vibration analysis on an LHC kicker prototype for UFOs investigation”, CERN EDMS Document No. 1153686, Aug. 2011.
[4] J. Uythoven et al., “Synthesis and status of MKI vibration studies”, LHC UFO meeting, 15/09/2011.
[5] T. Baer et al., “MD on UFOs at MKIs and MKQs”, CERN-ATS-Note-2012-018 MD, 22/02/2012.
[6] F. Zimmermann, “Update on Dynamics Modeling - Effect of Kicker Field", 66th LHC Injection and Beam Dump Meeting, Nov. 2011.
[7] A. Gerardin et al., “EDS analyses of filters used for UFO sampling”, CERN EDMS Document No. 1162034, Sept. 2011.
[8] T. Baer et al., “UFOs: Observations, Studies and Extrapolations”, proc. of Evian 2011, https://indico.cern.ch/getFile.py/access?contribId=27&sessionId=5&resId=1&materialId=paper&confId=155520.
[9] T. Baer et al., “UFOs Will they take over?”, Chamonix Workshop 2012, 09/02/2012.
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[11] M.J. Barnes et al., “MKI Strategy Discussion. Developments: prospects for improvements, time-lines, ….”, 19/01/2012.
[12] E.Garcia-Tabares, “AUTOMATIC PARTICLE ANALYSIS OF FILTERS USED FOR UFO”, CERN EDMS Document No. 2044528, 24/06/2020. [Note: filters are for an MKI (MKI04-T09) installed during YETS 2017/18].
[13] E.Garcia-Tabares, “AUTOMATIC PARTICLE ANALYSIS OF FILTERS FROM MKI ALUMINA CHAMBERS”, EDMS Document No. 2354031, 24/06/2020. [Note: filters are for an MKI-Cool – however, Cr2O3 coated tube punctured during HV testing]
[14] Barnes M.J., “Update on prototype kicker”, LHC Machine Committee, 1 Aug 2018, https://indico.cern.ch/event/747798/
[15] A. Gerardin, “EDS analyses of filters used for UFO sampling -2-”, EDMS Document No. 1226810, 21/6/2012

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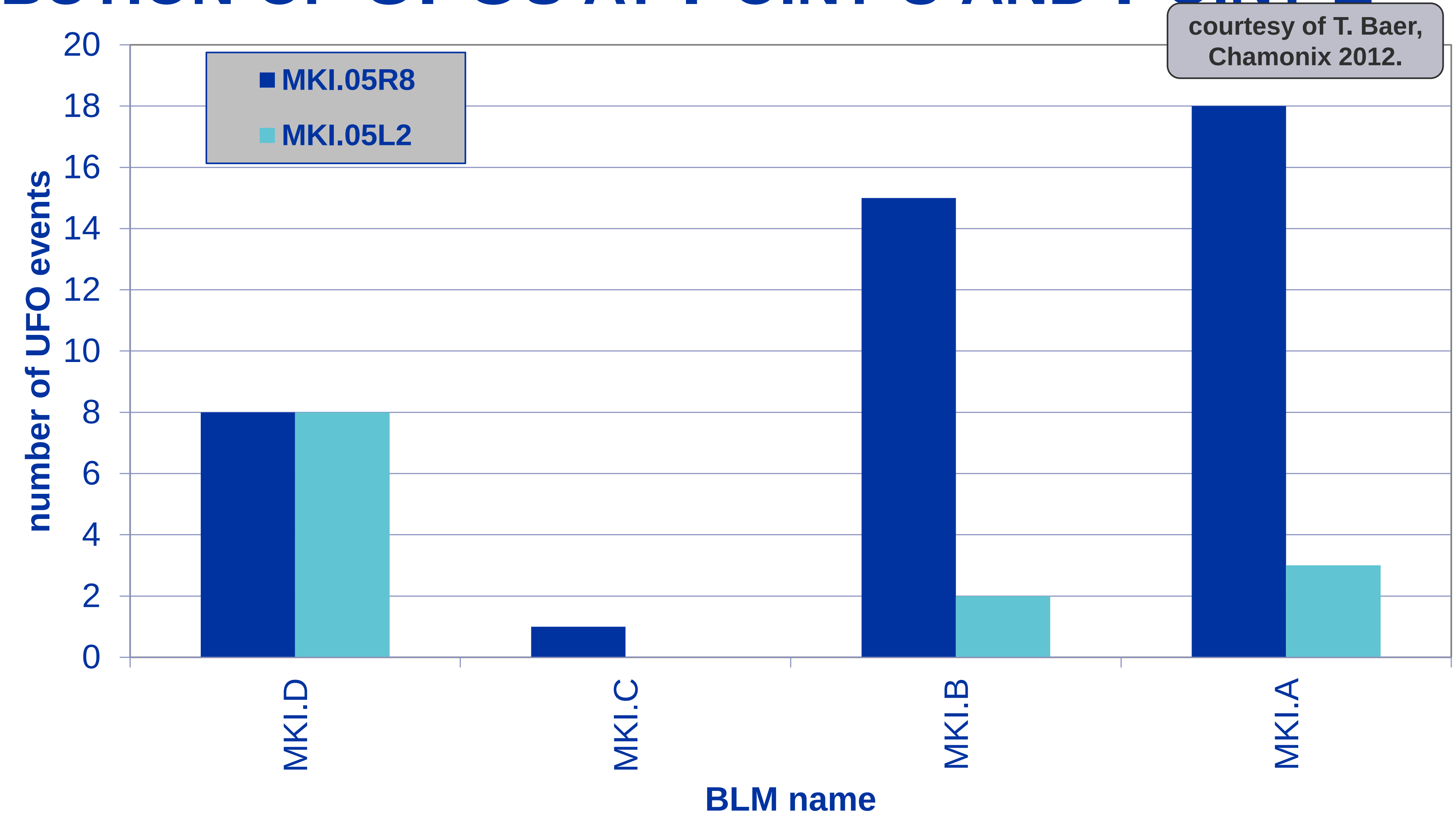
[1] M.J. Barnes, 5 April 2012, LHC UFO study group, https://lhc-ufo.web.cern.ch/
[2] See also spare slide for EDMS documents for MKI UFI Particle estimates

UFO PARTICLE ESTIMATES FOR ALUMINA TUBES

Order of upgrade	LS1	Particle estimate following Procedure 1 ($x10^6$)*	Particle estimate following Procedure 2 ($x10^6$)* (After 02/08/2013)	Particle estimate following Procedure 3* ($x10^6$)	EDMS Reference	Installed, Post-LS1	Comments
1	MKI11-T13-MC03	**20±1.9**			https://edms.cern.ch/document/1305133/1	MKI.D5R8.B2	24 Wires, optmzd lengths, No balls, **No drilled holes**, Offset cylinder.
2	MKI12-T12-MC01	**19±3**			https://edms.cern.ch/document/1307535/1	MKI.A5R8.B2	24 Wires, optmzd lengths,No balls, **4mm Drilled holes**, Offset cylinder.
3	MKI08-T11-MC09	13±3	**13±2**		https://edms.cern.ch/document/1307535/1	MKI.D5L2.B1	24 Wires, optmzd lengths, No balls, **4mm Drilled holes**, Offset cylinder.
4	MKI07-T08-MC08		5.3±0.6	**1.9±0.3**	https://edms.cern.ch/document/1318332/1	MKI.A5L2.B1	24 Wires, optmzd lengths, No balls, **No drilled holes**, Offset cylinder.
5	MKI06-T07-HC12	11±1.2	2.4±0.4	**2.4±0.6**	https://edms.cern.ch/document/1328212/1	MKI.B5L2.B1	24 Wires, optmzd lengths, No balls, **No drilled holes**, Offset cylinder.
6	MKI10-T06-HC13	56±8.4	8.5±0.7	**9.1±0.6**	https://edms.cern.ch/document/1335772/1	MKI.C5L2.B1	24 Wires, optmzd lengths, No balls, **No drilled holes**, Offset cylinder.
7	MKI02-T10-HC14	11±3.8	8.6±3.2	**9.9±2.8**	https://edms.cern.ch/document/1357987/1	MKI.B5R8.B2	24 Wires, optmzd lengths, No balls, **No drilled holes**, Offset cylinder.
8	MKI05-T02-HC15	6.9±2.6	4.8±0.97	**5.9±1.7**	https://edms.cern.ch/document/1368699/1	MKI.C5R8.B2	24 Wires, optmzd lengths, No balls, **No drilled holes**, Offset cylinder.
Spare 1	MKI01-T05-HC16	11±2.6	3.4±0.53	**6.8±4.6**	https://edms.cern.ch/document/1393343/1	Spare	24 Wires, optmzd lengths, No balls, **No drilled holes**, Offset cylinder.
Spare 2	MKI03-T01-HC17	33±7.1	11±1.9	**12±1.1**	https://edms.cern.ch/document/1394564/1	Spare	24 Wires, optmzd lengths, No balls, **No drilled holes**, Offset cylinder.
Spare 4	MKI09-T03-HC18	11±2.5	4.6±0.33	**4.3±0.77**	https://edms.cern.ch/document/1572366/1	Spare	24 Wires, optmzd lengths, No balls, **No drilled holes**, Offset cylinder.
Spare 3	MKI04-T09-HC19	51±18	24±9.6	**13±1.2**	https://edms.cern.ch/document/1429402/1	Spare	24 Wires, optmzd lengths, No balls, **No drilled holes**, Offset cylinder.
Cr_2O_3 coated	MKI04-T09-HC19	5.6	5	**1.8**	https://edms.cern.ch/document/2044528/1	MKI8D, YETS2017-18	24 Wires, optmzd lengths, No balls, **No drilled holes**, Offset cylinder. 56mm overlap (exposed ferrite rings)
1st MKI Cool proto Cr_2O_3	MKI08-T11-HC20 (LS2)	11.4	Burnt during carbon coating	0.74	Email of Elisa of 16/10/2019		**MKI Cool prototype.** 60mm long ferrite cylinder, Rin=38mm, Rout=48mm, 15mm inner Cu cylinder.
2nd MKI Cool. Cr_2O_3 coated	MKI08-T11-LS1-3	3.95	1.31	1.44	https://edms.cern.ch/document/2354031/1	MKI8D, YETS2022-23	**MKI Cool prototype.** 60mm long ferrite cylinder, Rin=38mm, Rout=48mm, 15mm inner Cu cylinder. **Water cooled**

	HISTORY	Particle estimate ($x10^6$)	EDMS Reference		Comment
	Was MKI2B (prior to Oct 2010)	170±3 4.5±1 24±3.3	https://edms.cern.ch/document/1240940/1		15 conductors, previously taken out of LHC. Patricle estimate AFTER removal.
	MKI8D, 19 screen conductors, installed during TS3 (2012)	16 ± 4.5 180 ± 40 180 ± 90 210 ± 70 390 ± 47	https://edms.cern.ch/document/1226810/1		New ceramic tube (machined for spheres). Patricle estimate BEFORE installation. **Before TS3, MKI8D had the highest UFO activity of the MKIs in Pt 8; replacement MKI8D had the lowest UFO activity.**

Distribution of UFOs at Point 8 and Point 2

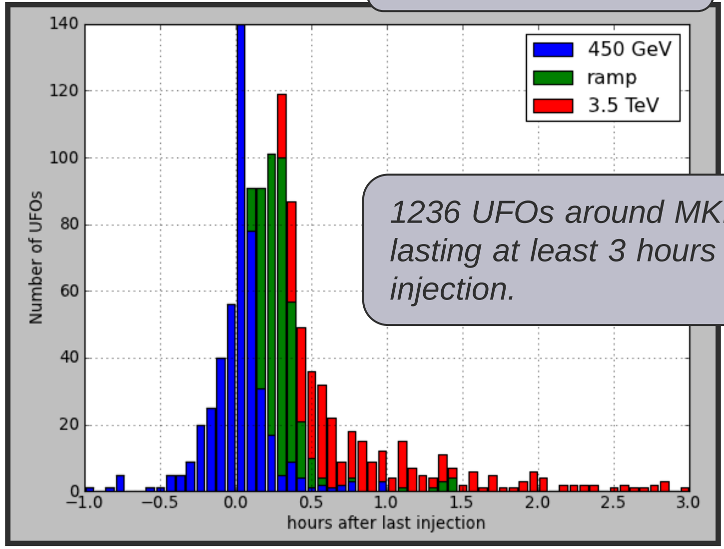


Distribution of the most upstream BLM at which the UFO is observable.
The BLM dedicated to an MKI is located directly downstream of the corresponding MKI tank.

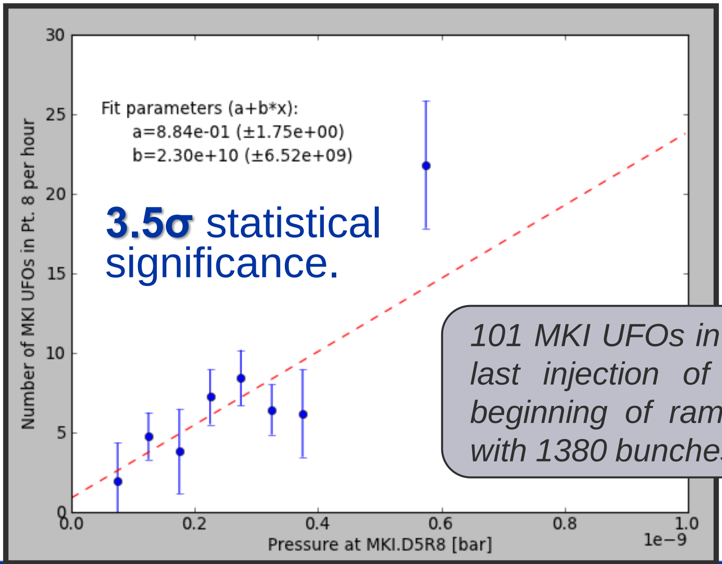
MKI UFOs

courtesy of T. Baer, Chamonix 2012.

- 11 dumps due to MKI UFOs in 2011.
  8 dumps at 3.5 TeV,
  2 dumps during stable beams.
- In total 2340 UFOs around MKIs
  847 in Pt.2 and 1493 in Pt.8.
- Temporal distribution:
  Mainly within 30 min after last injection.
  Many events within a few hundred ms after MKI pulse.
- **Positive correlation between MKI UFO rate and local pressure at 450 GeV.**



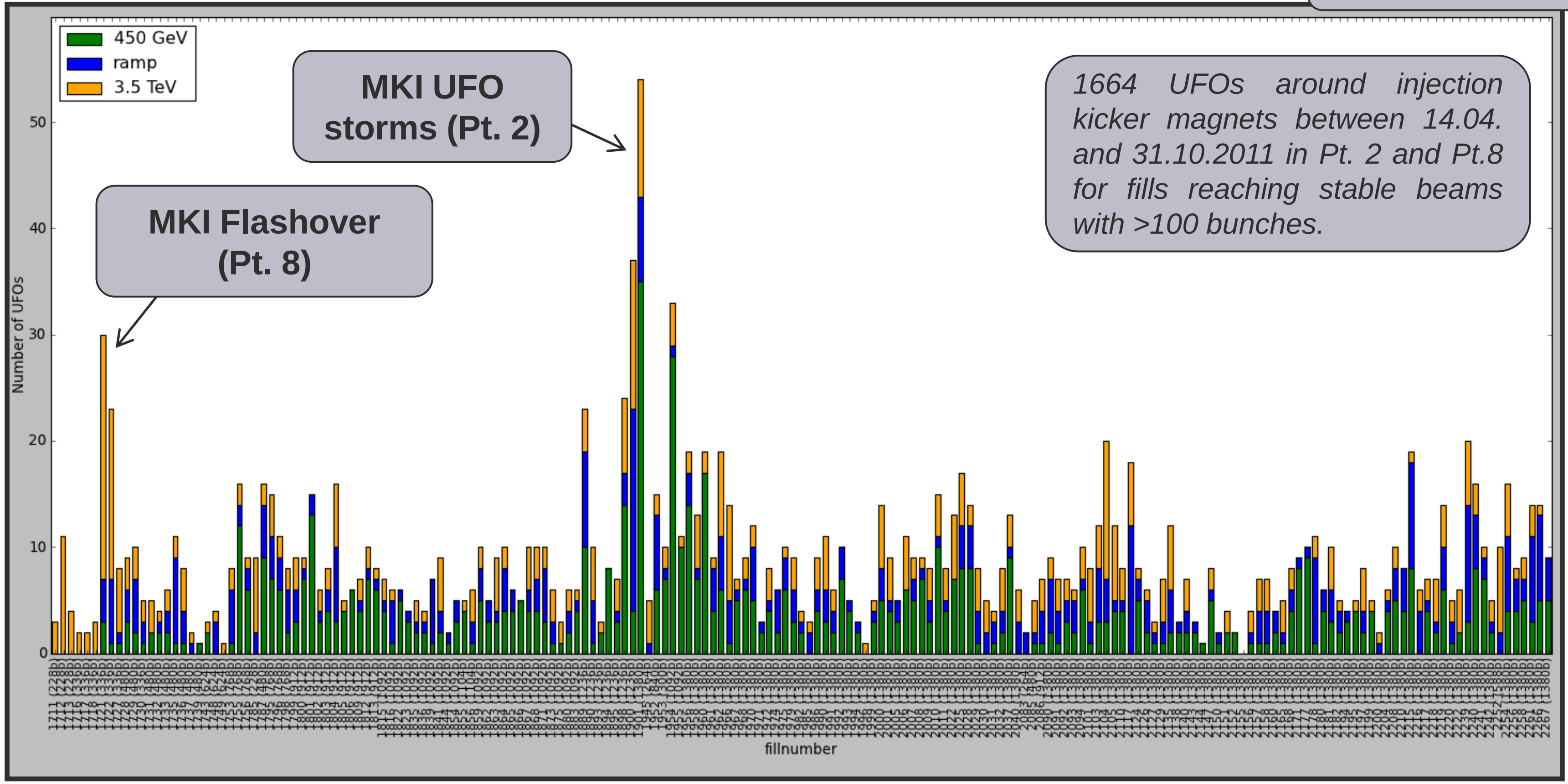
1236 UFOs around MKIs for fills lasting at least 3 hours after last injection.



101 MKI UFOs in Pt. 8 between last injection of beam 2 and beginning of ramp for 102 fills with 1380 bunches.

NUMBER OF MKI UFOS

courtesy of T. Baer, Chamonix 2012.



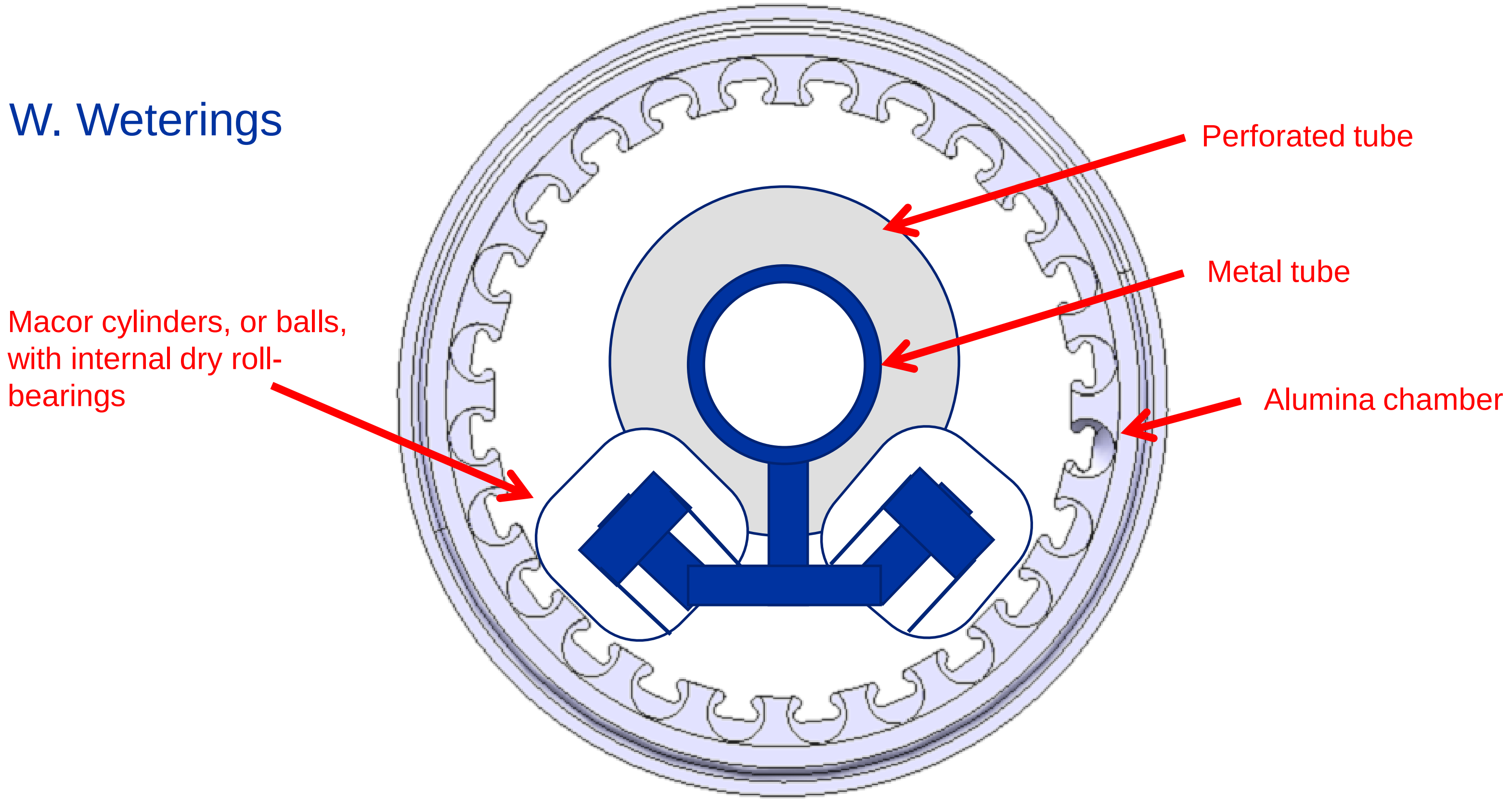
No general conditioning effect obvious for MKI UFOs.

On average: 8.9 MKI UFOs per fill.

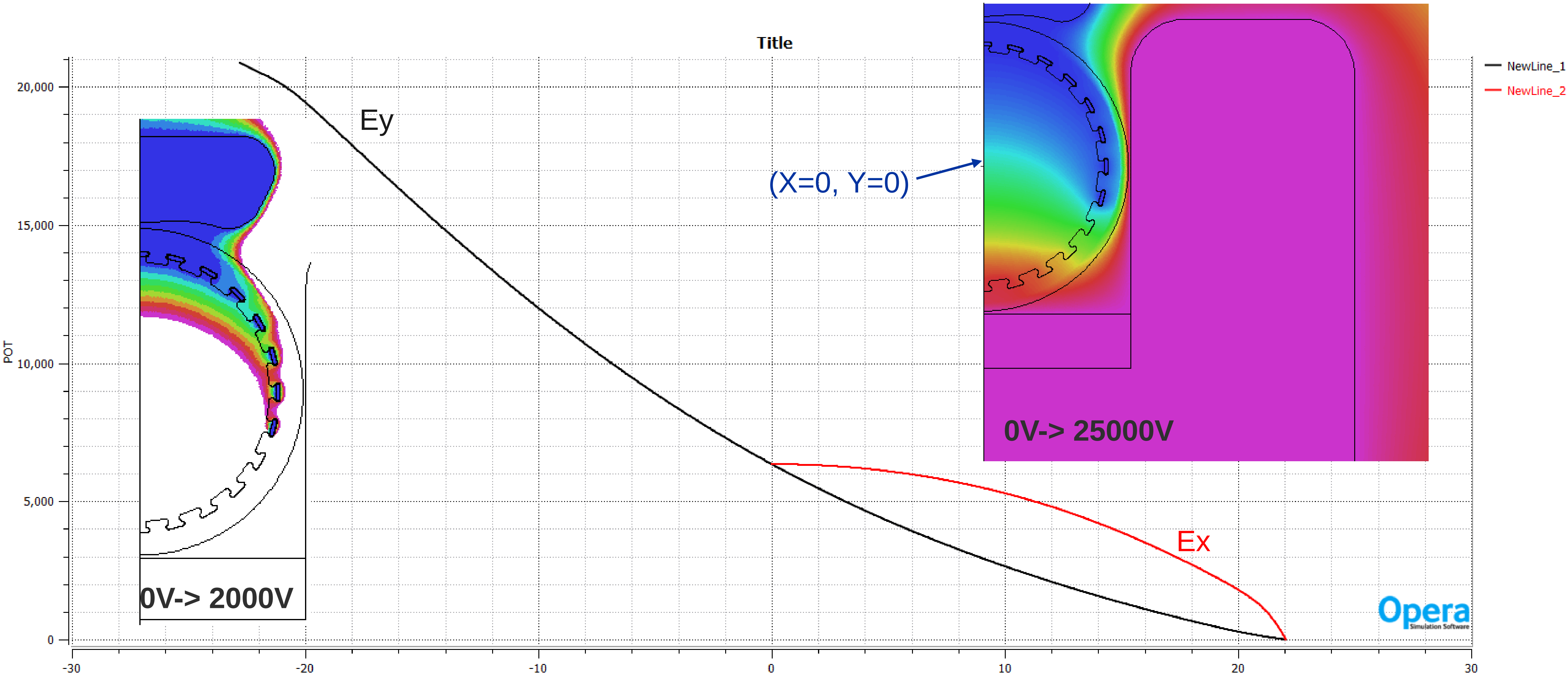
(3.4 at MKIs in Pt. 2 and 5.5 at MKIs in Pt. 8)

CLEANING FOR ALUMINA TUBES
ADDITIONAL CLEANING AT CERN

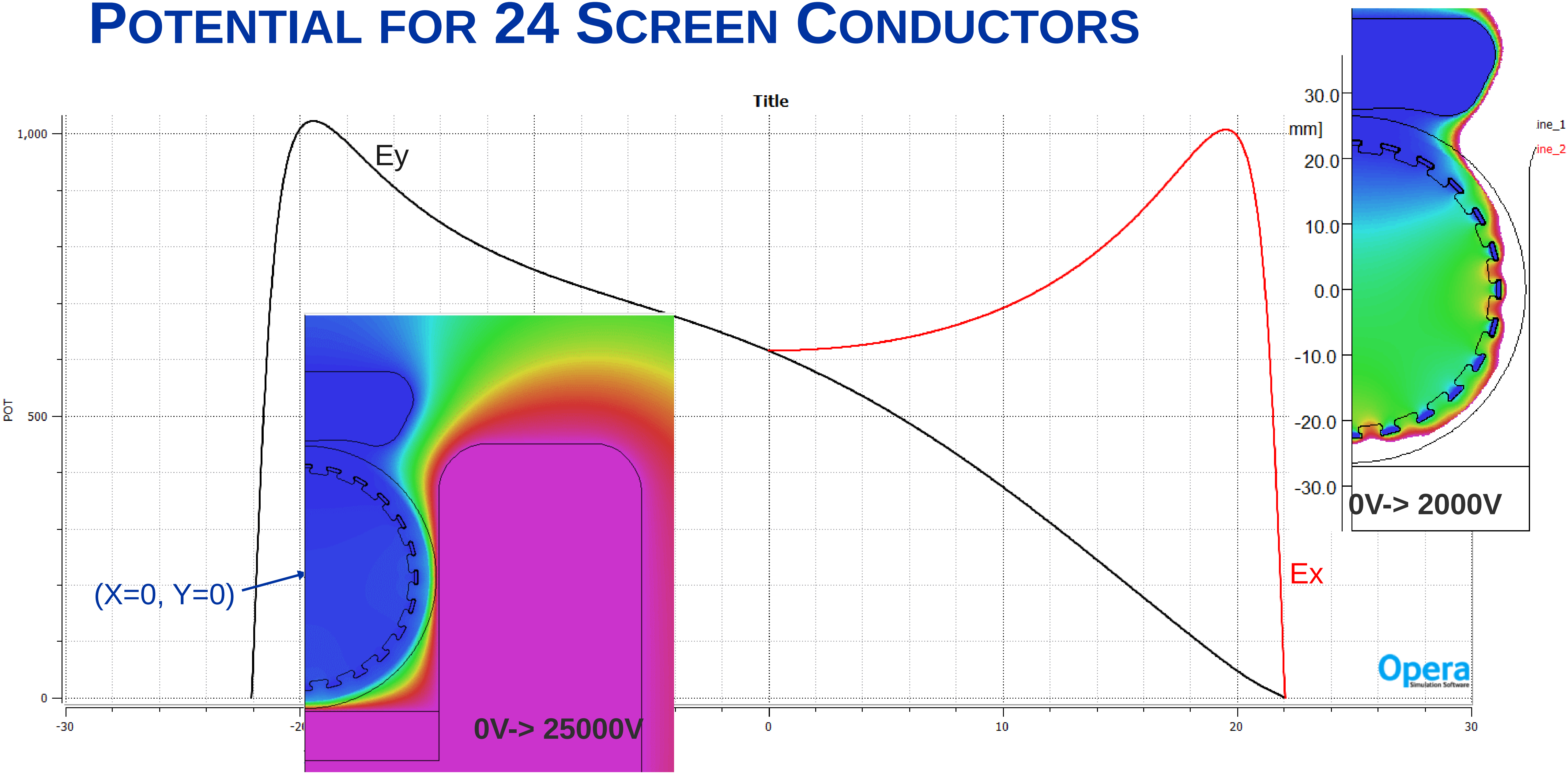
Slide courtesy of W. Weterings



POTENTIAL FOR 15 SCREEN CONDUCTORS

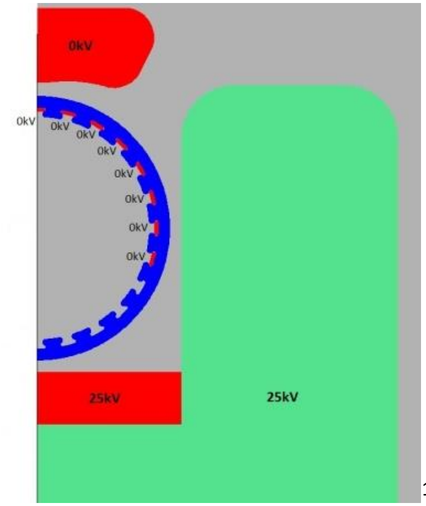


Potential for 24 Screen Conductors

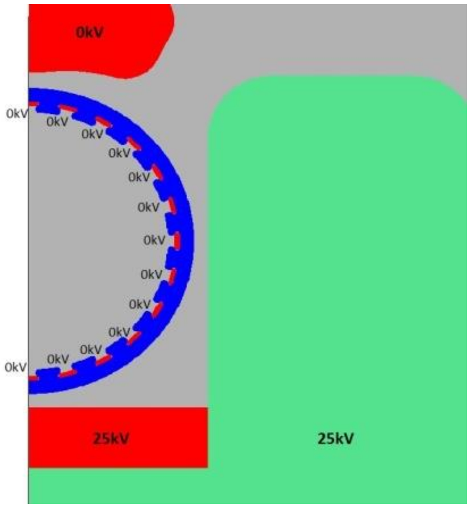


Electric Field for 15 & 24 Screen Conductors

15 screen conductors



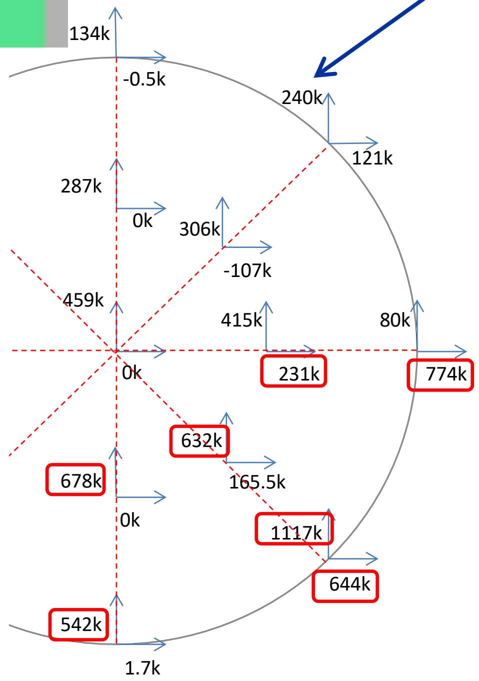
24 screen conductors

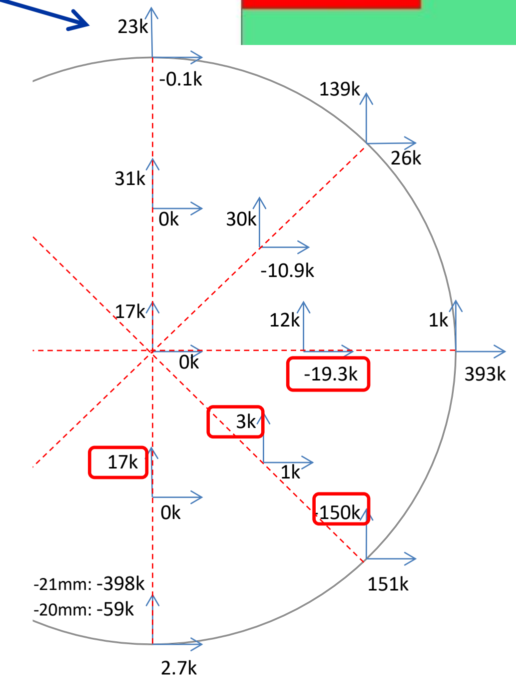


UFOs occurring before ~60 ms after a pulse cannot be explained by gravity: however, they *might* be due to charged particles accelerated by the electric field of the MKIs [6].

During LS1 (2013/14) the MKIs were upgraded to have 24 screen conductors.

Electric Field during Flat-Top (V/m)





✓ 24 screen conductors reduce beam induced heating in comparison with 15 screen conductors;

✓ **With 24 screen conductors, flattop electric field is significantly lower (by more than a factor of 10)** than with 15.

✓

Cleaning of MKI Alumina Tubes AFTER Coating

A reduced cleaning procedure, of the alumina tubes, is used after Cr_2O_3 coating, to minimize the risk of damage to the (50 nm thick) Cr_2O_3 coating:

1. Insert 8 screen conductors at top of tube
2. Two times go and return, flushing with 10 bar nitrogen (no filter)
3. Rotate alumina tube by 120 degrees and insert 8 screen conductors at top of alumina tube
4. Two times go and return, flushing with 10 bar nitrogen (no filter)
5. Rotate alumina tube by 120 degrees and insert final 8 screen conductors at top of alumina tube
6. Two times go and return, flushing with 10 bar nitrogen (use filter [#1] to catch “dust” particles)
7. Two times go and return, flushing with 10 bar nitrogen (new filter [#2] to catch “dust” particles)
8. Two times go and return, flushing with 10 bar nitrogen (new filter [#3] to catch “dust” particles)

Cr_2O_3 Coated Alumina Tube

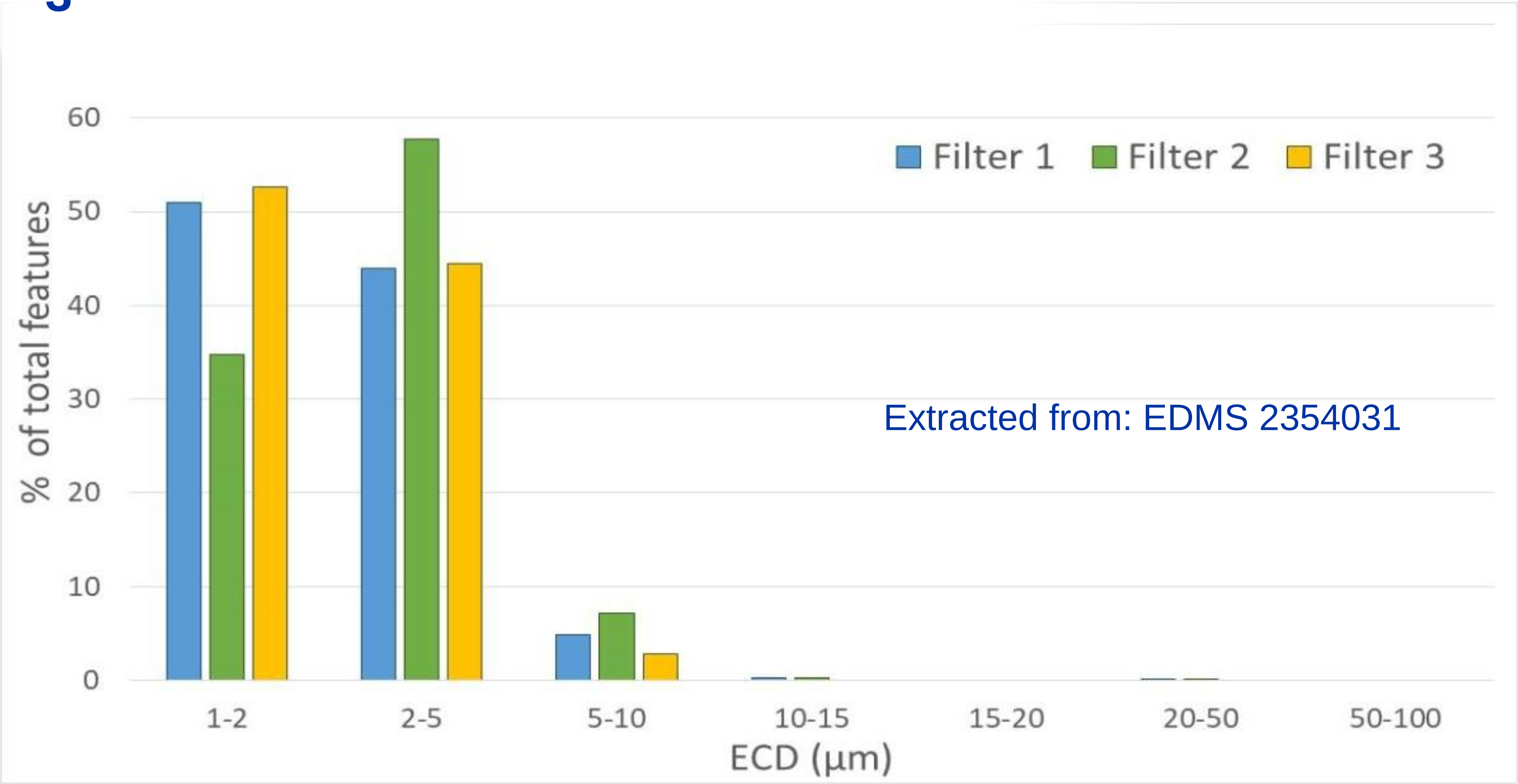
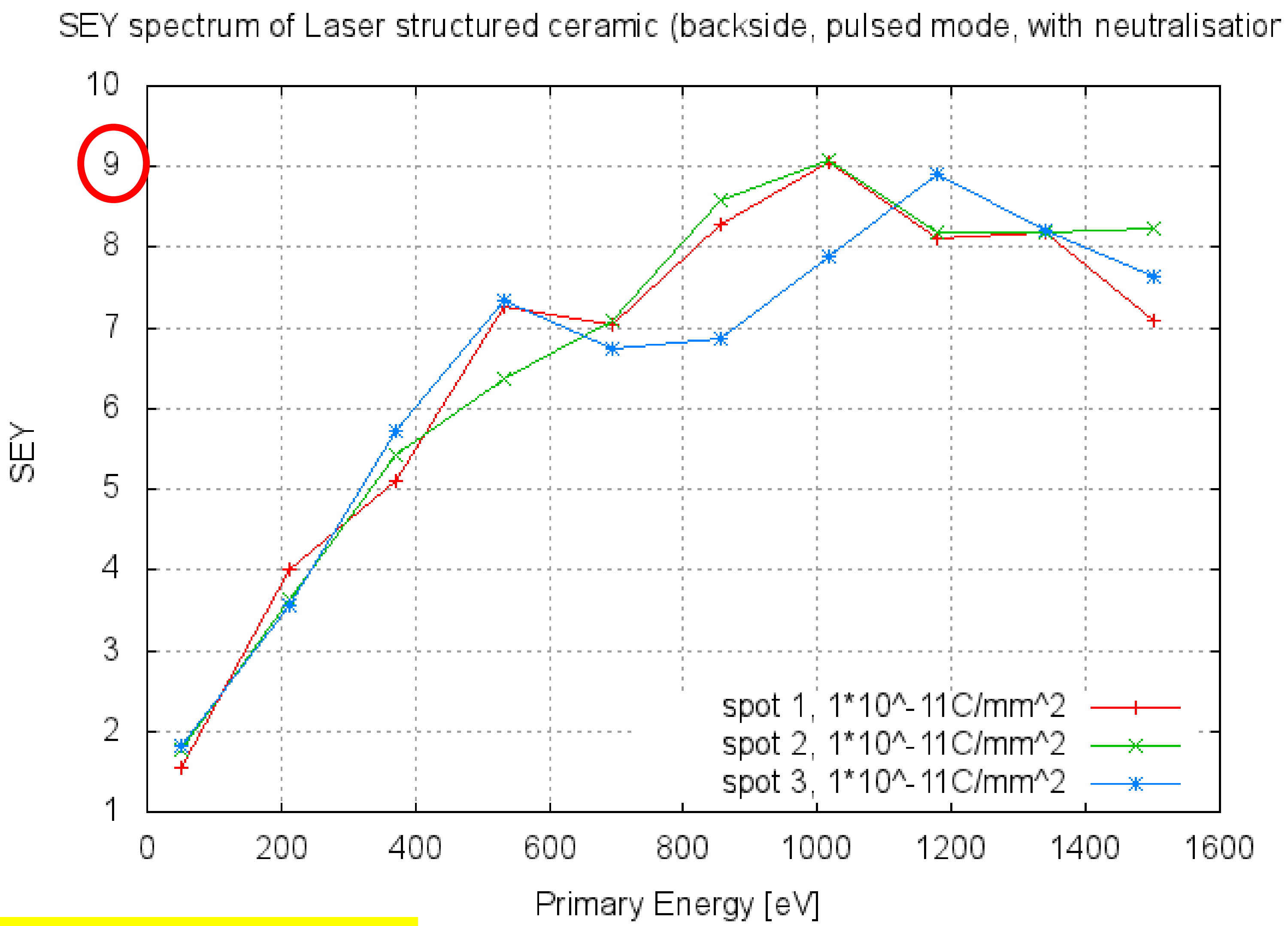


Figure 1 – Size distribution of particles for the three analysed filters.

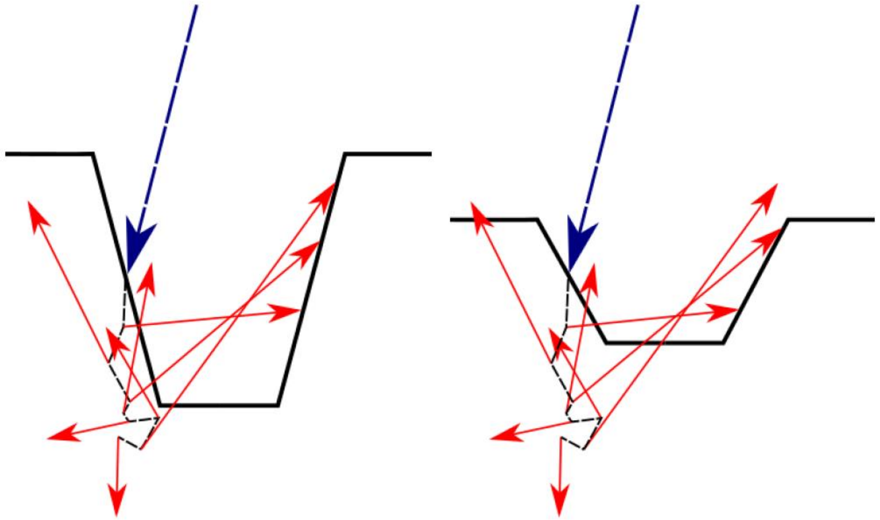
SEY on Al2O3 as Received: Backside of Alumina

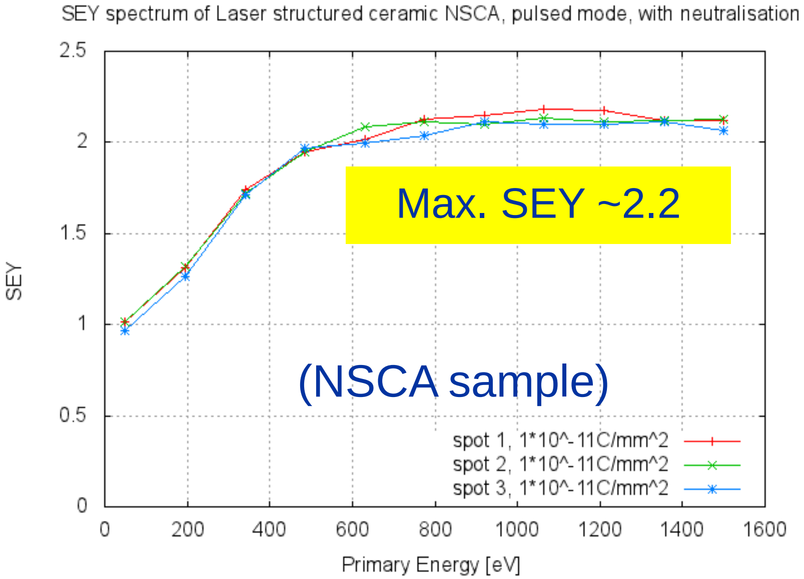


Measurements courtesy of Holger Neupert

SEY REDUCTION

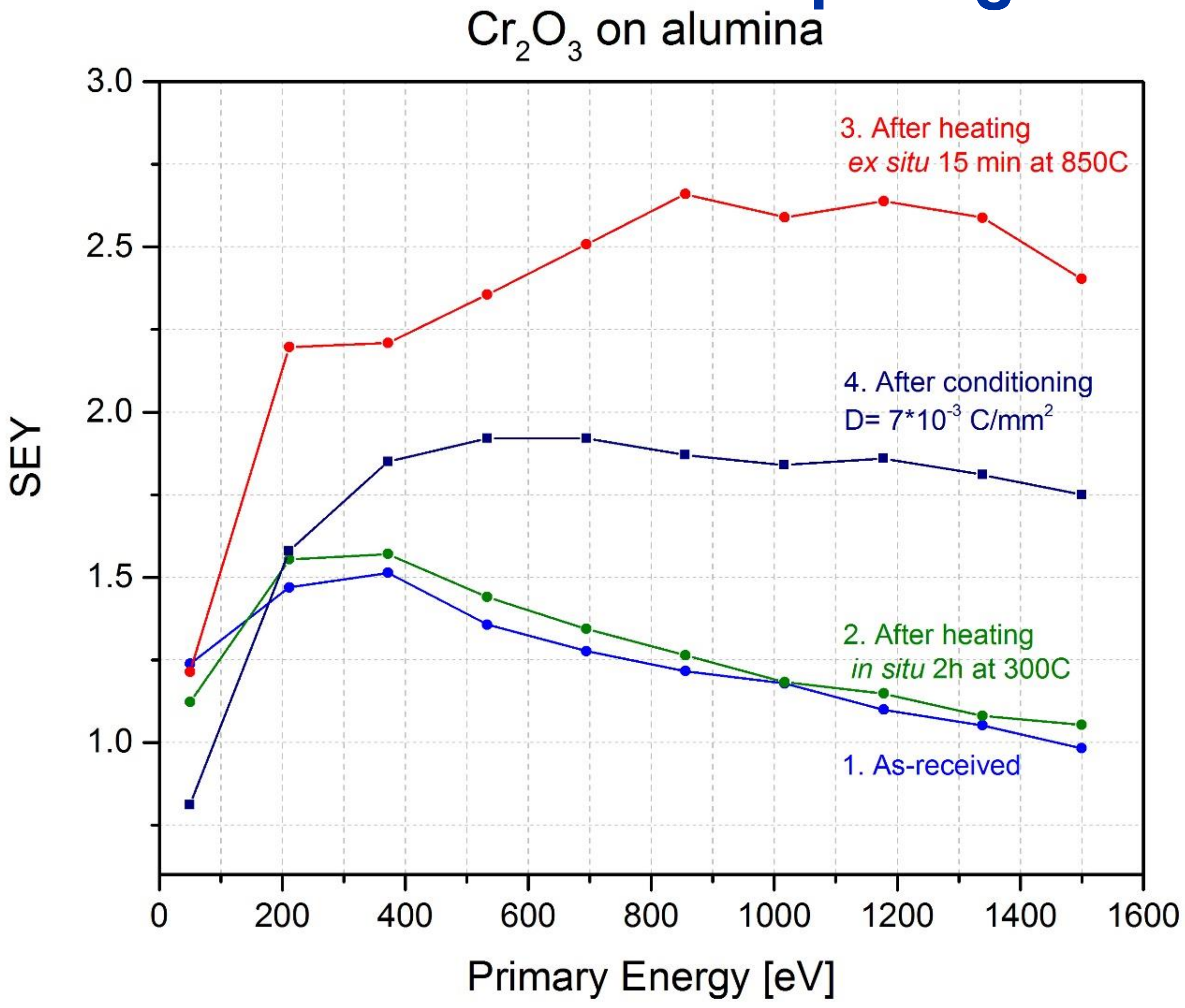
- A thin (~100nm) layer of amorphous carbon (aC) briefly considered - not (yet) further investigated due to concerns of aC ending up in HV regions, e.g. following an electrical breakdown of screen conductors
- Titanium layer not appropriate because of fast field rise time (need high resistance per square as, otherwise, induced eddy currents increase rise time)
- Laser Engineered Surface Structures (LESS) [University of Dundee, Scotland] gave low SEY, by trapping electrons – but concern re charging of alumina:





- Painted Cr2O3 samples from 2 companies – low SEY, but would have given dust (UFO's) in vacuum system
- Polyteknik applied Cr2O3 by magnetron sputtering – low SEY and no dust (several thicknesses tested)
- Polyteknik developed magnetron sputtering equipment to apply Cr2O3 coating to 3m+ long tube
- Alumina tube has 50 nm thick Cr_2O_3 coating – (low SEY, no increase in UFOs, compatible with both the vacuum and high voltage environments)

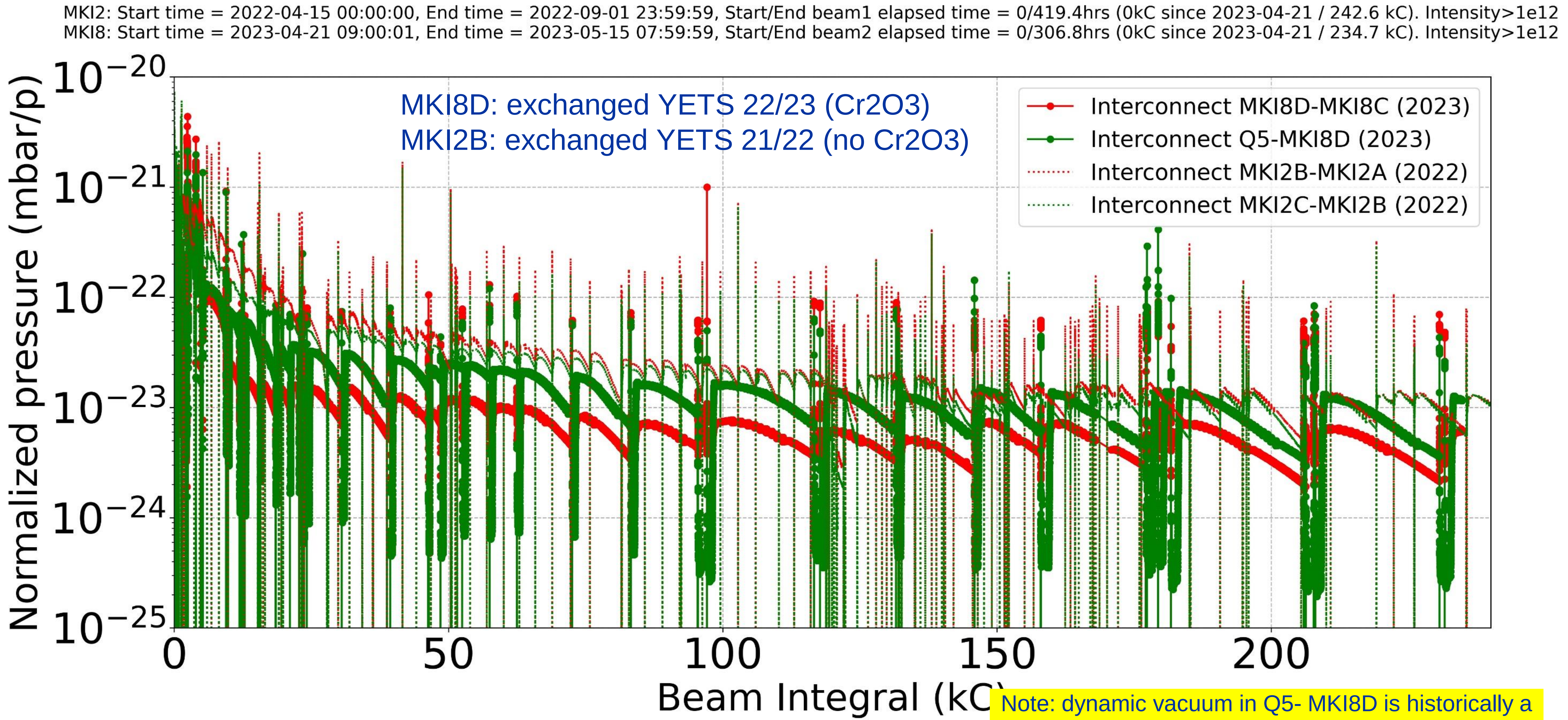
MEASURED SEY OF Cr_2O_3 COATING ON ALUMINA



Measurements courtesy of Holger Neupert

Measurement of SEY of 50 nm coating of Cr_2O_3 on alumina: (1) as received; (2) after heating in vacuum for 2 hrs at 300C; (3) after heating in air for 15 mins at 850C; (4) as per (3) but following bombardment (conditioning) with an electron dose of 7 mC/mm^2

NORMALIZED PRESSURE: MKI2 2022, MKI8 2023



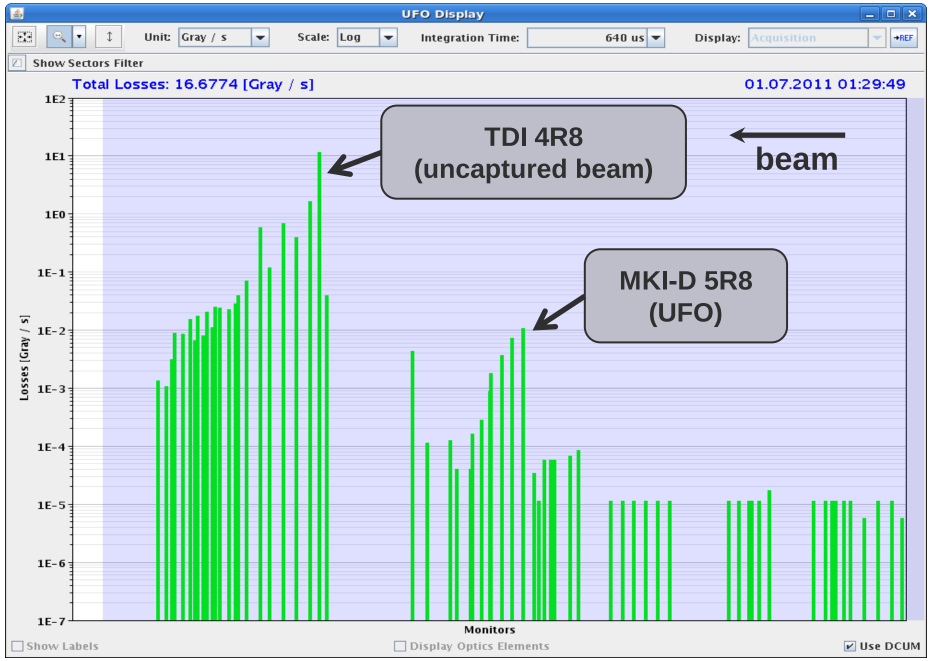
Note: dynamic vacuum in Q5- MKI8D is historically a factor of 3-12 worse other interconnects

2012 Knowledge re MKI UFOs

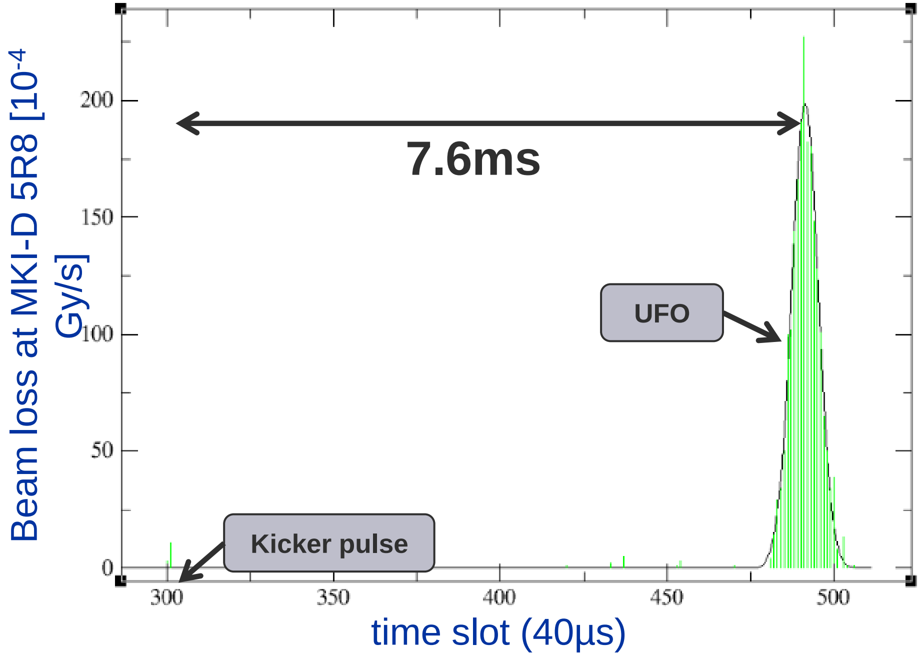
- MKI UFOs can be produced by pulsing the MKIs [1];
- At point 2, most UFO events occur around MKI2-D [5]: FLUKA simulations of the UFOs at the MKIs in point 2 show that the UFO location must be in, or nearby upstream, of MKI2-D [2];
- Measurements in the lab show that pulsing the MKI magnets at 25 kV leads to mechanical vibrations and displacements of ~10 nm [3, 4];
- The temporal distribution of UFOs is mainly from a few ms up to several hundred ms after a pulse [5];
  - UFOs occurring before ~60 ms after a pulse cannot be explained by gravitational effects, but could be due to charged particles being accelerated by the electric field of the MKIs [6];
- An MKI, removed from LHC in a TS 2010/11, was opened and inspected for macro particles [7]:
  - Energy-dispersive X-ray spectroscopy of the particles showed that they mainly consist of Al and O, leading to the conclusion that the macro particles originate from the alumina tube.
  - *clean room air: 100 particles on filter; new alumina tube: 10‘000 particles on filter*; sample from alumina tube from removed MKI: **5,000,000 particles** on filter.
- UFOs were not produced by pulsing the MKQs [5];
- Energy dependence means that UFOs could limit LHC performance after LS1 [8];
- There is a positive correlation between vacuum pressure and UFO rate [9];
- No correlation identified between UFO signal magnitude and time after the MKI pulse [5].

MKI UFO MD

Tobias Baer, UFO Update, Mini-Chamonix Workshop July 15th 2011



Peak loss 640µs integration time in the second of the kicker pulse



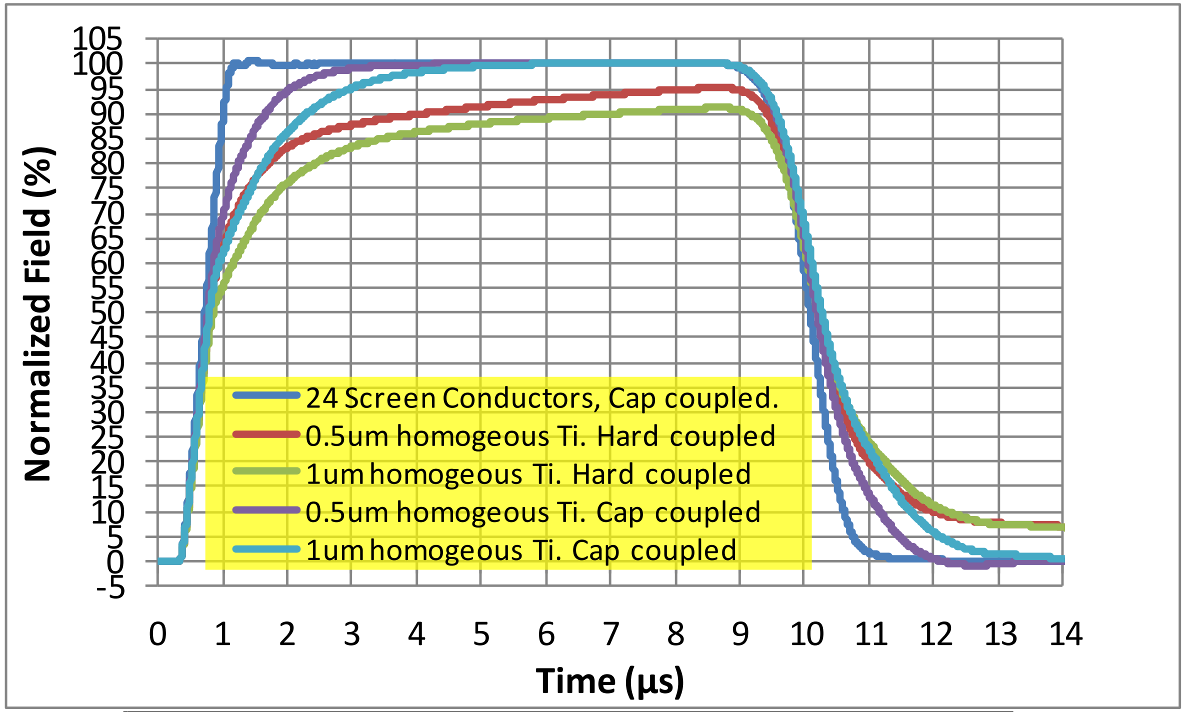
BLM injection capture buffer (512·40µs)

During the MD the MKIs were pulsed without injecting beam (1236b)

Several UFOs were observed directly after pulsing the MKIs.

SIMULATION OF METALLIZATION OF MKI ALUMINA TUBE

- UFOs were not produced by pulsing the MKQs [5]: the MKQs have a metalized alumina chamber.
- Simulations have been carried out to assess the effect of metalizing the MKI alumina chamber:



Configuration:	Rise-time [ns] (0.5% to 99.5%)
24 Screen Conductors, Cap coupled	805
0.5µm homogeous Ti. Hard coupled	-
1µm homogeous Ti. Hard coupled	-
0.5µm homogeous Ti. Cap coupled	2960
1µm homogeous Ti. Cap coupled	4540