NSTX

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Lithium particle detector for fusion applications

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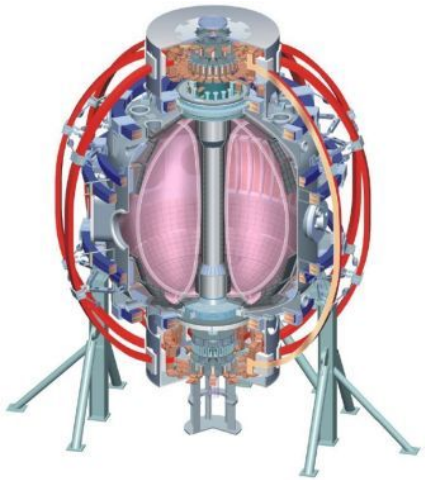

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Motivation

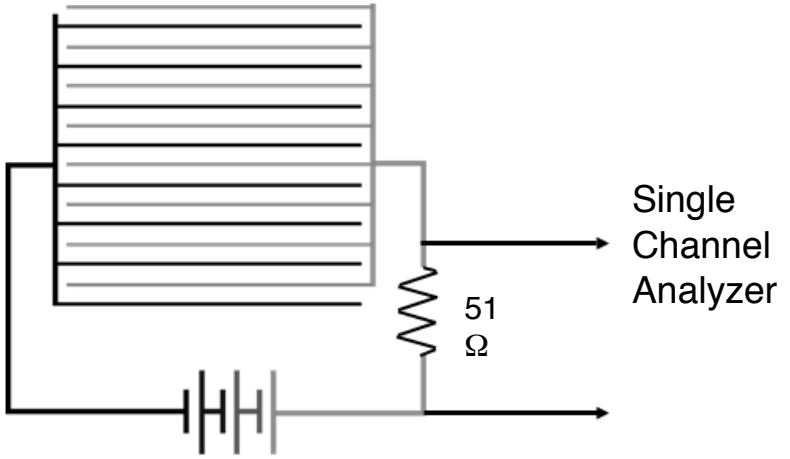
- Lithium coatings on the plasma facing components (PFCs) in NSTX has been used as a tool for density profile control and reducing the recycling of hydrogen.
- Injected lithium particles accumulate on interior vessel surfaces.
- Detection of beryllium dust is part of the ITER dust strategy and an absolute detection accuracy of 50% has been specified.
- Beryllium dust is highly toxic and difficult to handle.
- Lithium particles may be useful as a proxy for beryllium until beryllium measurements become available.

Lithium particles as a proxy for beryllium

	Beryllium	Lithium
Atomic number Z	4	3
Atomic weight ($g.mol^{-1}$)	9.01	6.94
Melting point (°C)	1278	180
Liquid density (g/cm^{-3})	1.7	0.5
Sp. heat capacity ($J.g^{-1}.K^{-1}$)	1.82	3.58
Th. Conductivity (W/m°C)	216	84.8
Electrical resistance (nΩ m)	36	93

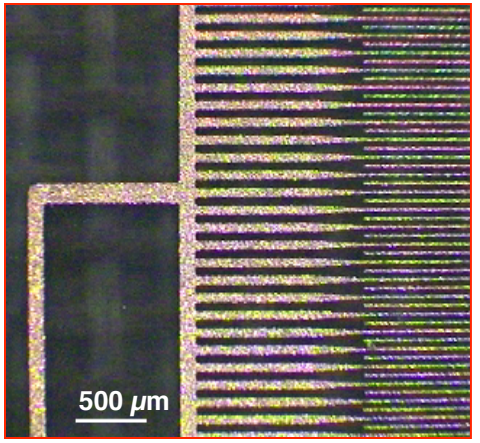
The electrostatic dust detector

- A 50 V bias is applied across a grid of interlocking traces on a circuit board.
- Impinging conductive dust creates a short circuit and current pulse.
- Current pulse is input to nuclear counting electronics and converted to counts.
- Number of counts is proportional to the mass of dust.
- Current also vaporizes or ejects dust from the circuit board restoring an open circuit.
- Device works in air or vacuum.



Schematic:

Electrostatic dust detector in action



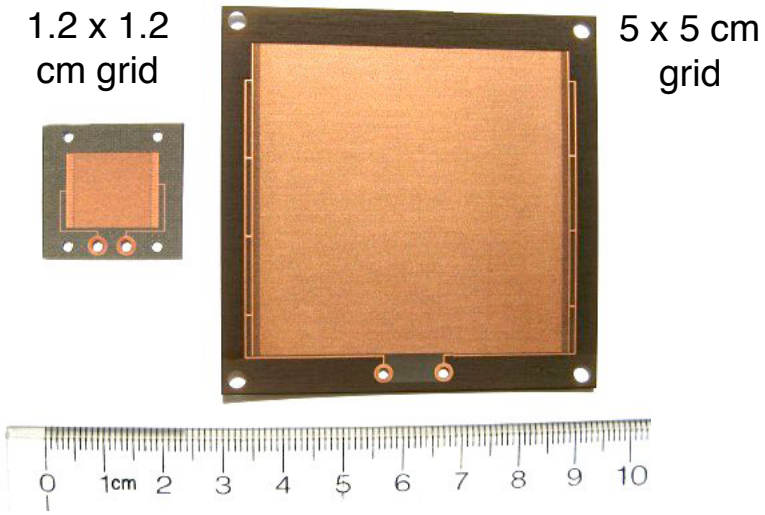
100 μm dia. of human hair

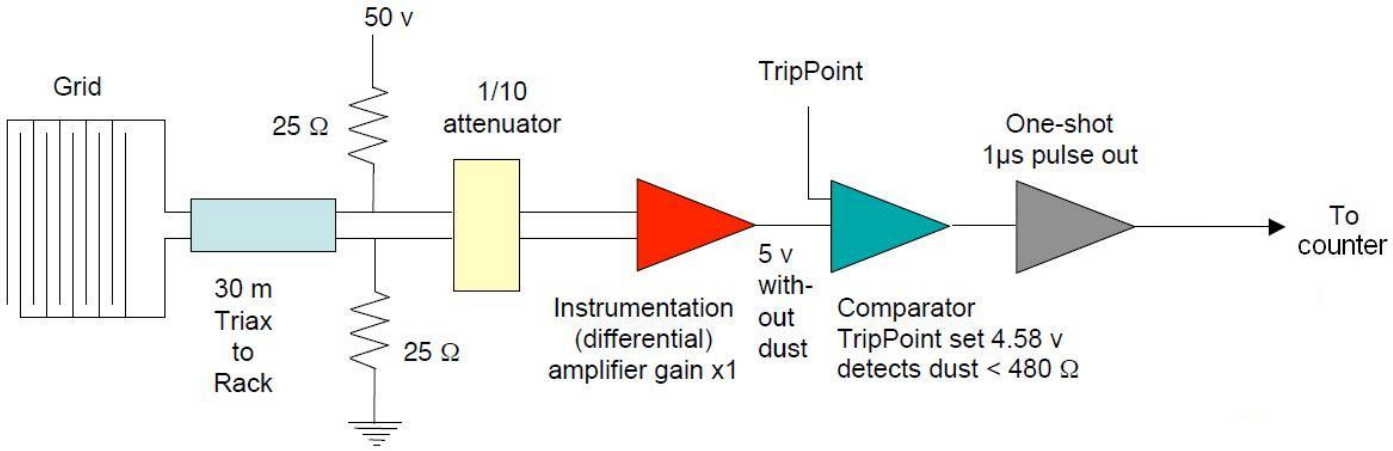
Partial view of grid with 25 micron spacing

The detector size and detection electronics

- Both grids have 25 μm trace spacing.
- 5x5 cm grid has 16x area and 50 m of 25 μm spacing !

- SPAs and RF antenna are a powerful source of noise a tokamak environment.
- A differential detection circuit has been implemented with high immunity from electrical noise pickup.

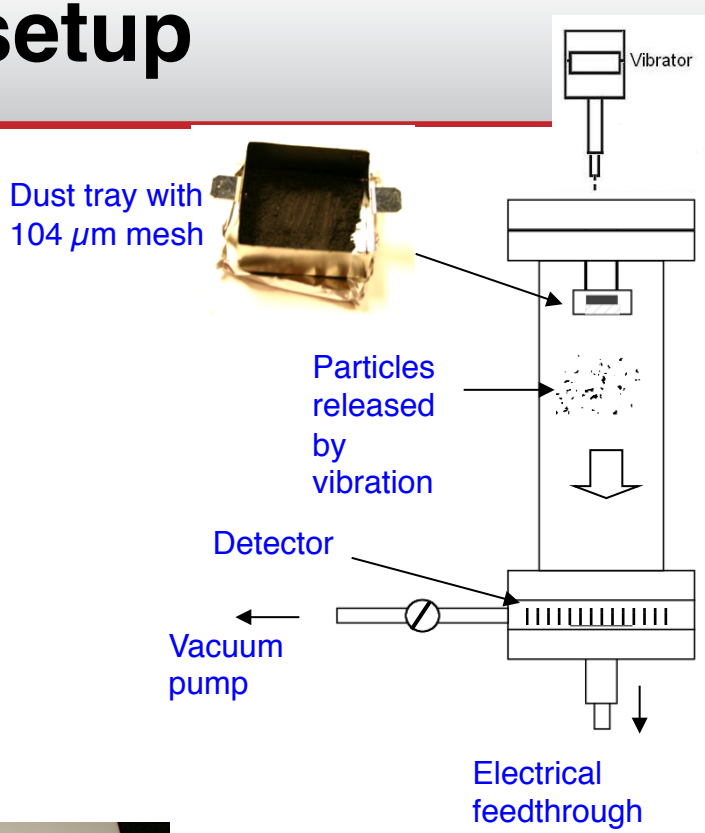




Differential detection electronics

Laboratory setup

- Dust particles were spread evenly over a dust tray
- The tray was weighed with a microbalance then moved to a tray holder
- Dust was released by mechanical vibration
- The mass loss of the tray was determined by measuring the mass of tray dust before and after dust delivery
- Lithium and carbon were used as test particles



Microbalance 5 g capacity 1 μg readability

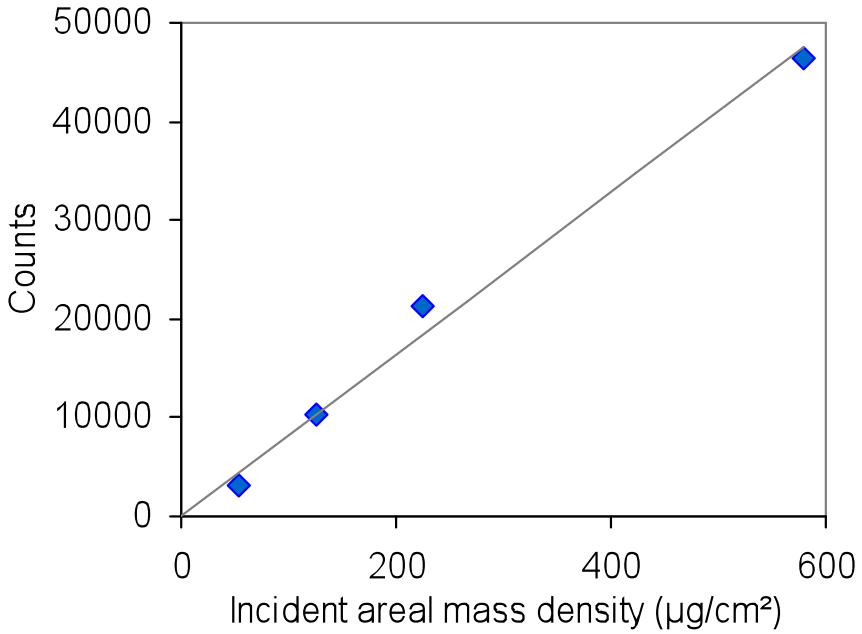
Special precaution for Li particles

- Lithium reacts violently with humid air resulting in spontaneous ignition.
  - → A mask, gloves, protection glasses and a fire-proof coat were used.
- Lithium oxidizes upon exposure to air changing the mass.
  - → To minimize mass changes due to oxidation the equipment was moved to an argon filled glove box.
- The change of mass due to exposure to residual oxygen (10% humidity inside glove box) was tracked for each measurement.
  - → A correction of order 9% was subtracted from the final mass.

- Lithium is known to react chemically with copper.
  - → A He gas puffing system has been implemented to periodically clear residual particles and successfully tested with carbon dust.

Calibration Results

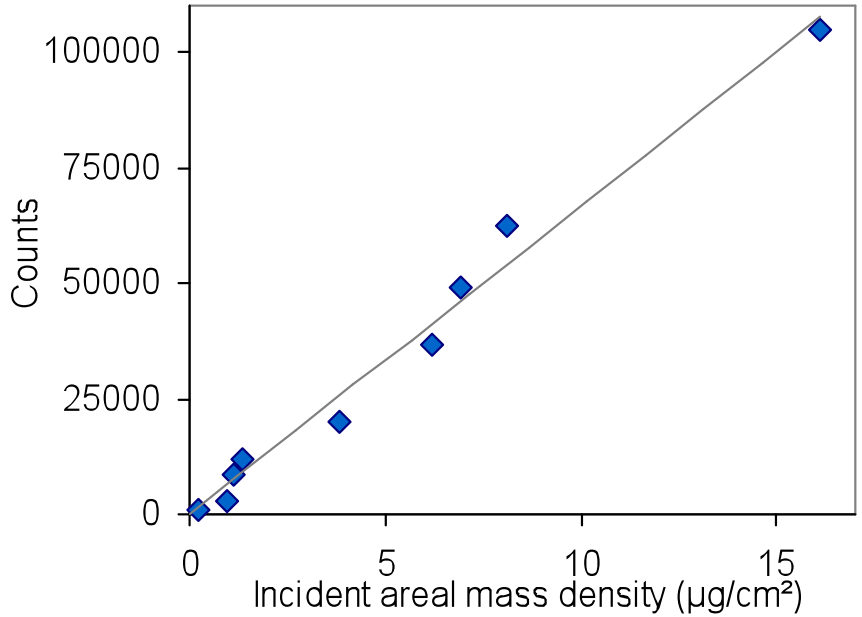
Lithium particles 40 μm diameter



Threshold Sensitivity: 14.5 ng/cm^2/count

12 mm detector, 25 μm spacing,
50 V bias in vacuum

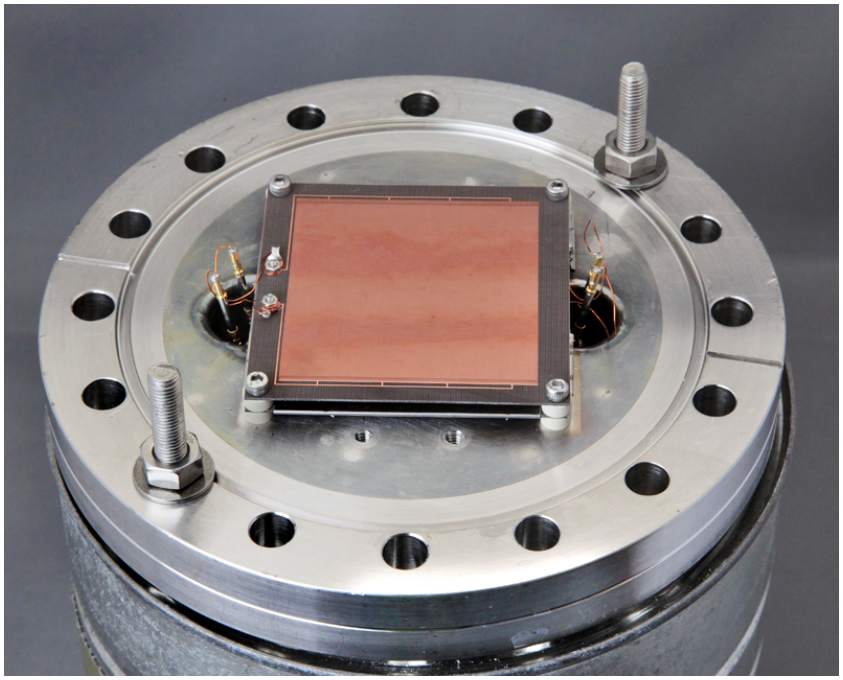
Carbon particles 2.14 μm diameter

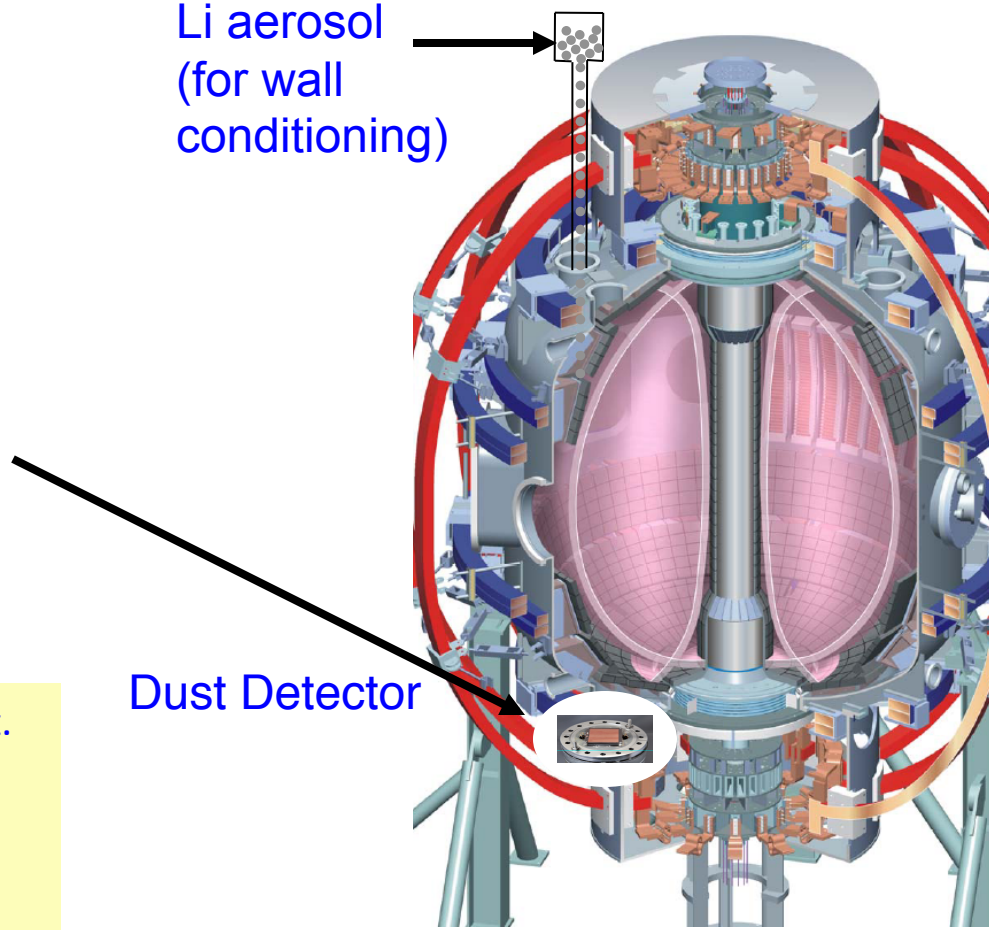


Extremely sensitive: 0.15 ng/cm^2/count
(larger number of particles than Li for a given mass)

51 mm detector, 25 μm spacing,
50 V bias in vacuum

NSTX Installation in lower port on NSTX





Two identical grids in same electrical environment.
upper grid (Ch.1) exposed to dust.
Lower grid covered with mica detects only pickup
Mesh cover (90 µm pore size) (not shown) shields from fibers and large particles that might cause a permanent short.

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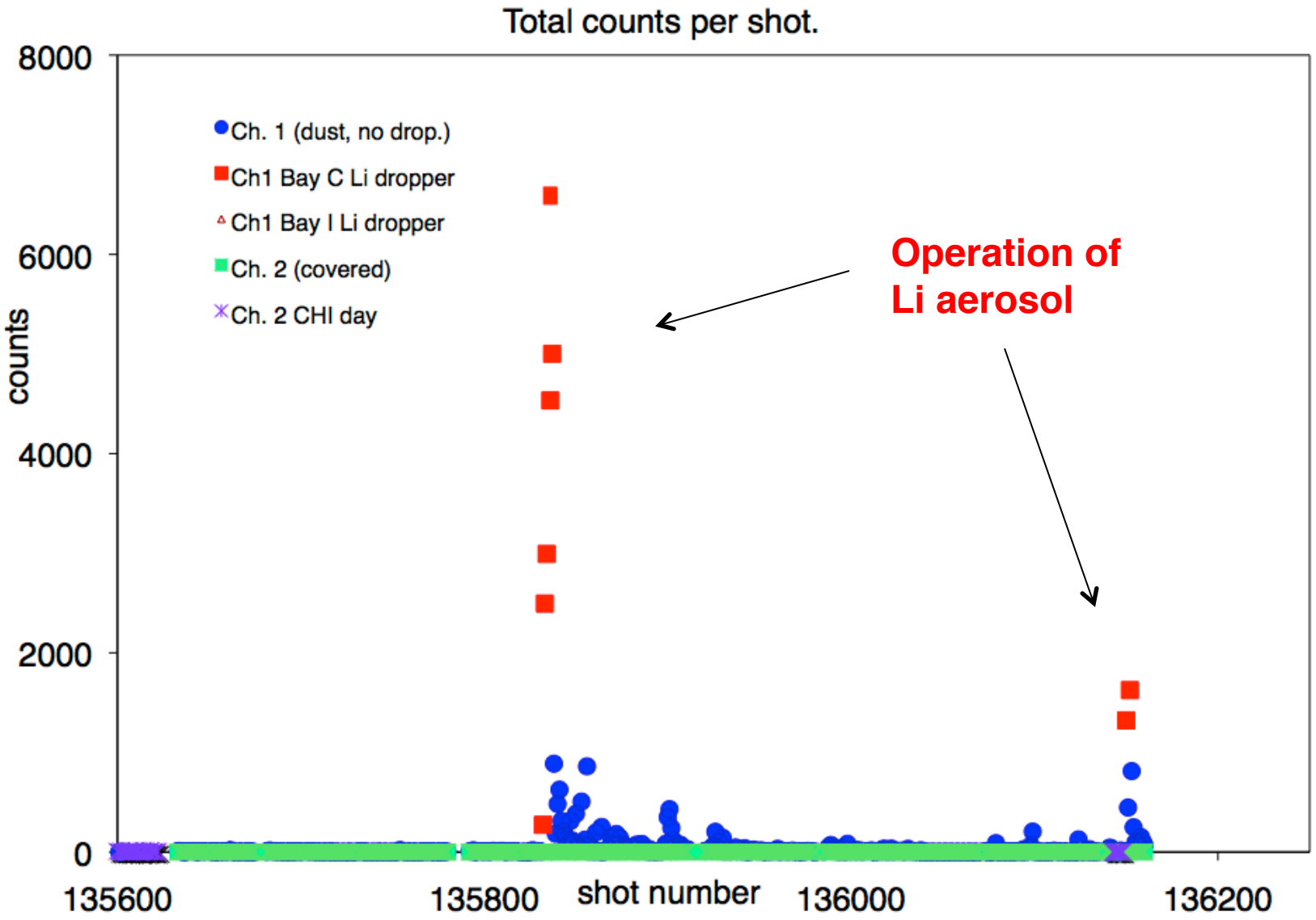
Li particle detection on NSTX



Summary

Lithium particle detector demonstrated on NSTX
(proxy for Be dust detection on ITER)

- Calibrated with lithium and carbon particles:
  - → Threshold Sensitivity for Li particles: 14.5 ng/cm^2/count
  - → High threshold sensitivity to carbon dust: 0.15 ng/cm^2/count
  - → Suitable for contemporary tokamaks.
  - → Radiation resistant materials required for ITER.

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