Development of Cosmic Dust Detectors Onboard Spacecrafts

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Introduction

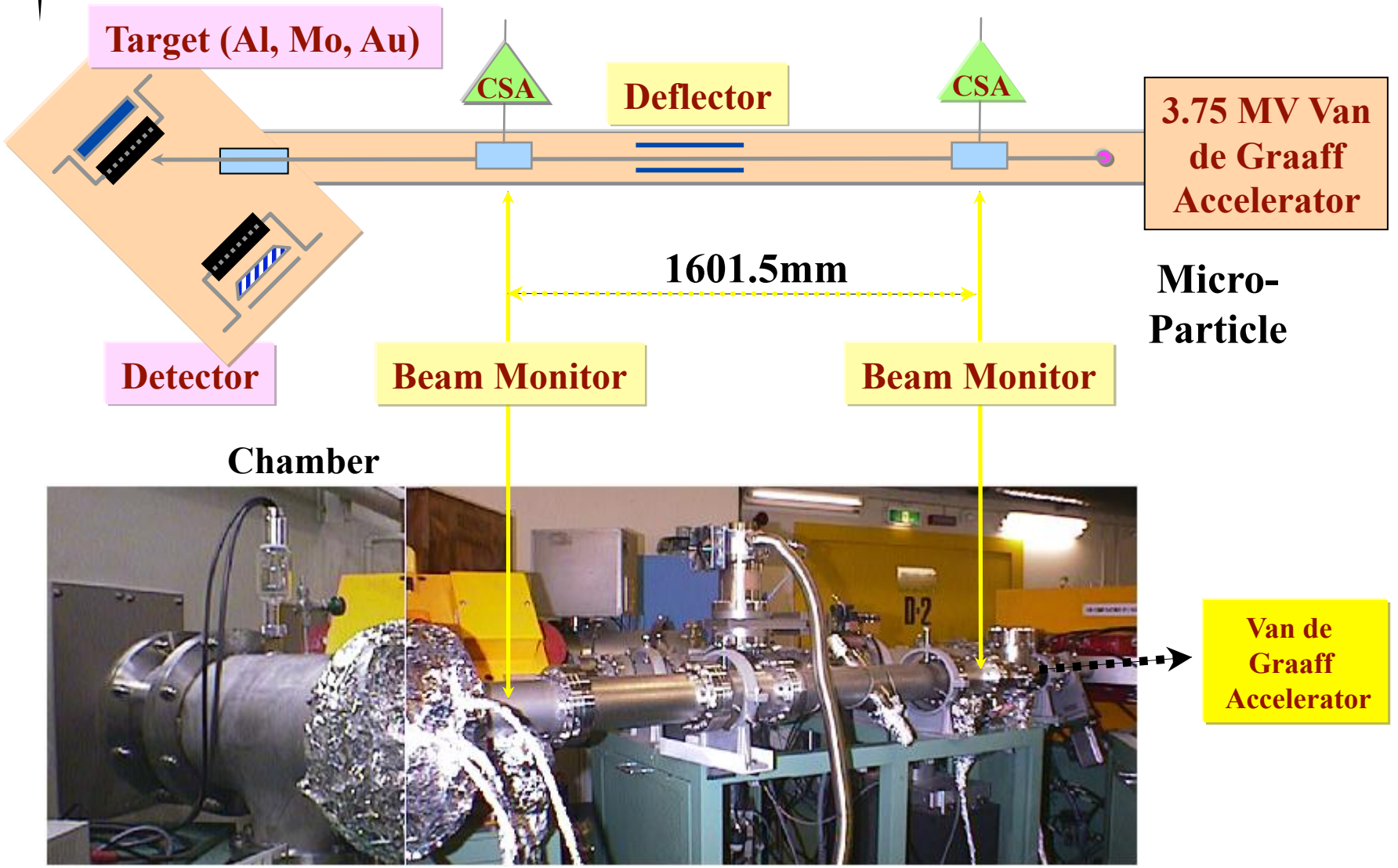
Cosmic dust composed of small (submicron- ~ micron-sized) solid particles pervades interstellar space.

In order to investigate the flux, mass, velocity and chemical component of cosmic dusts, we have been developing three types of cosmic dust detectors for *in situ* measurement onboard spacecrafts.

1. IID (Impact Ionization dust/debris Detector)
2. Piezoelectric (PZT) impact detector
3. TOF (Time of Flight) mass spectrometer with IID or PZT

These instruments are calibrated by ground based experiments using with *Electrostatic Dust Accelerators*.

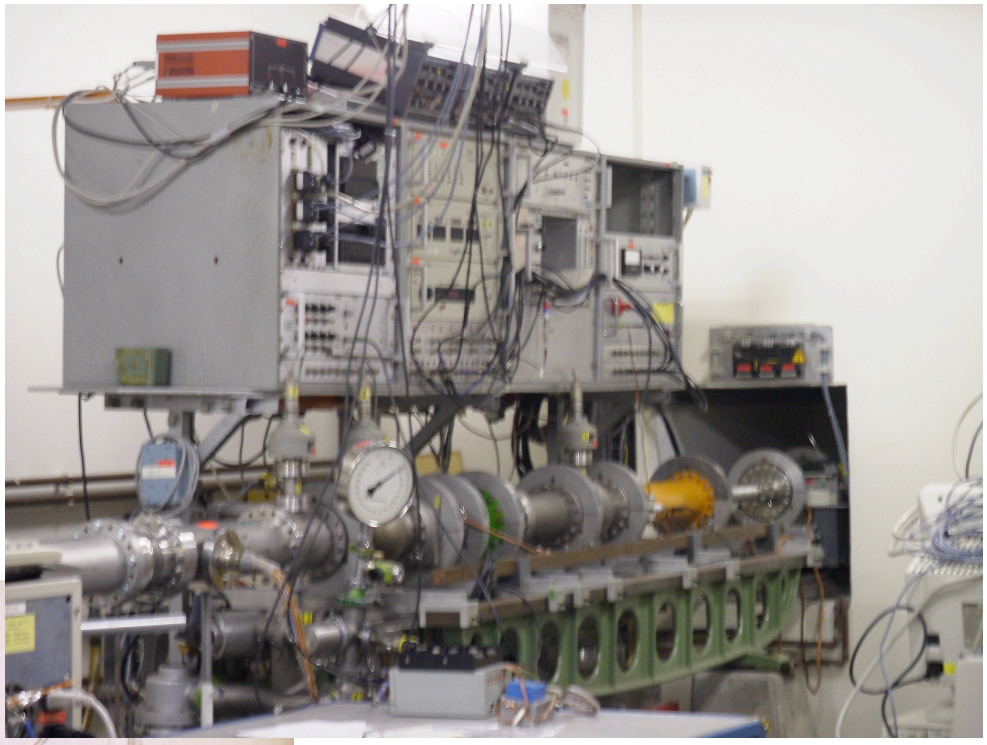
Dust Accelerator (HIT, Univ. Tokyo)



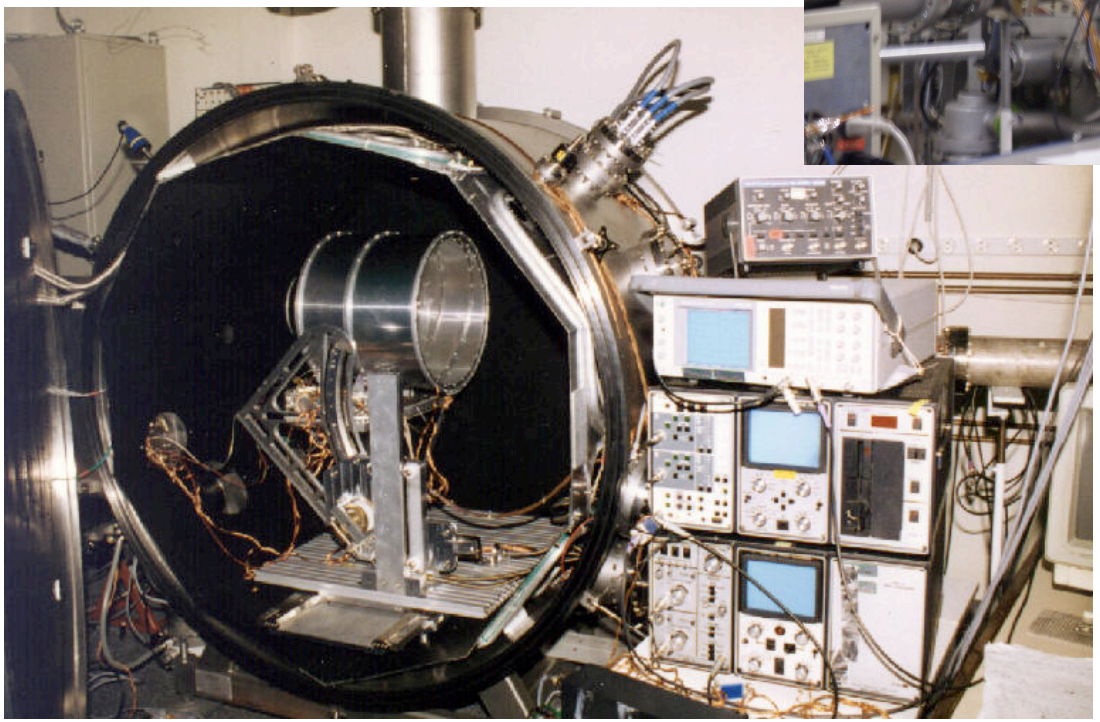
Max-Planck-Insitut für Kernphysik

Heidelberg, Germany

2MV Van de Graff accelerator



Beam line

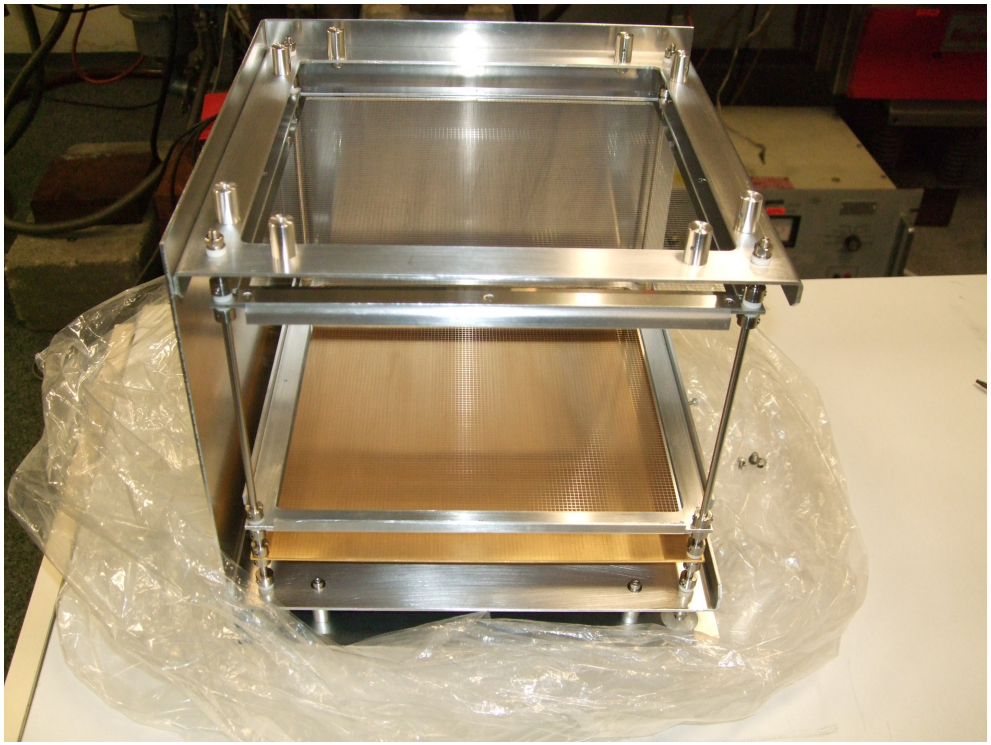


Target chamber

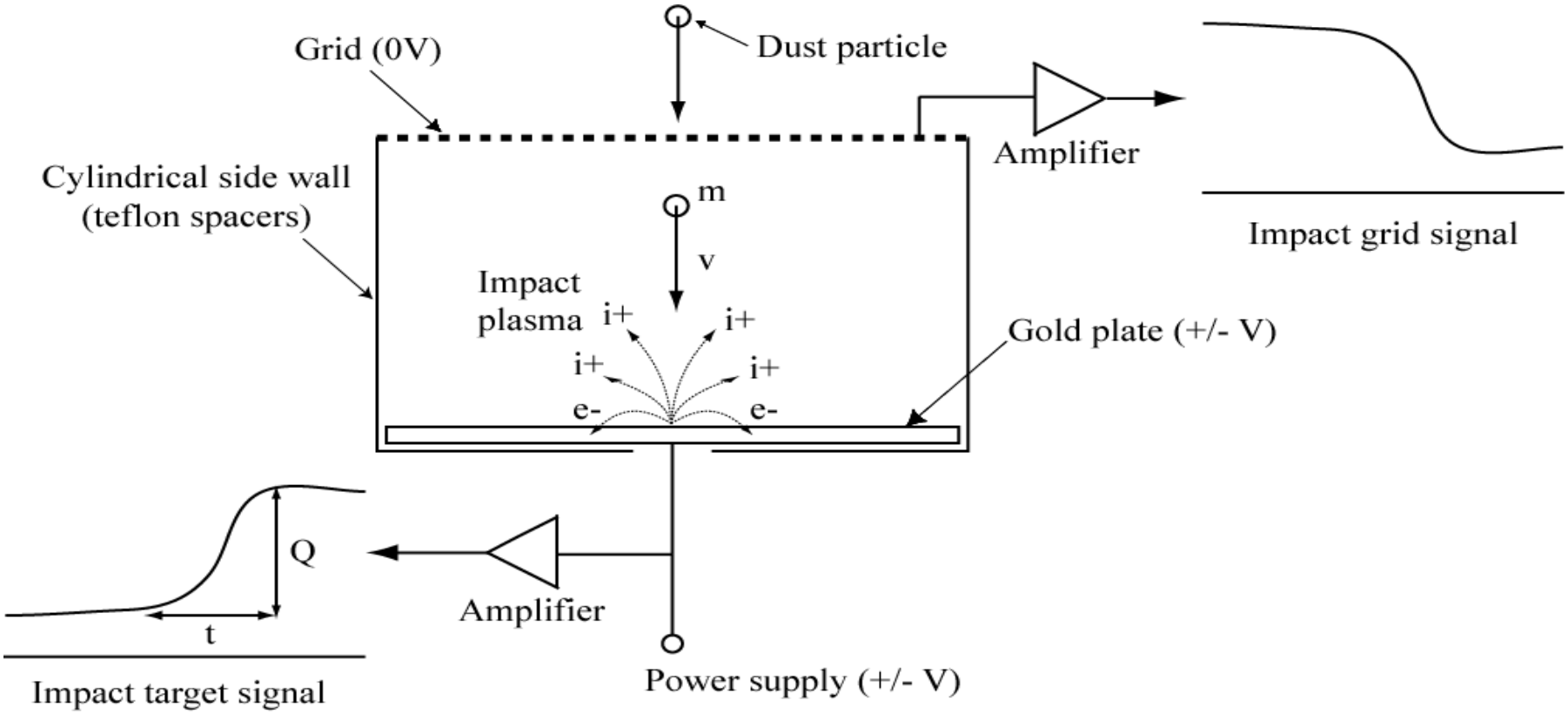
1. IID

(Impact Ionization dust/debris Detector)

- Gold plated metal target
- Double entrance grids
- Large impact area (20cm x 20cm)
- Light weight



Principle of Impact Ionization Dust Detector



Charge Signal ⇨ Particle Mass , Velocity

$$t = c_g v^{\alpha}$$

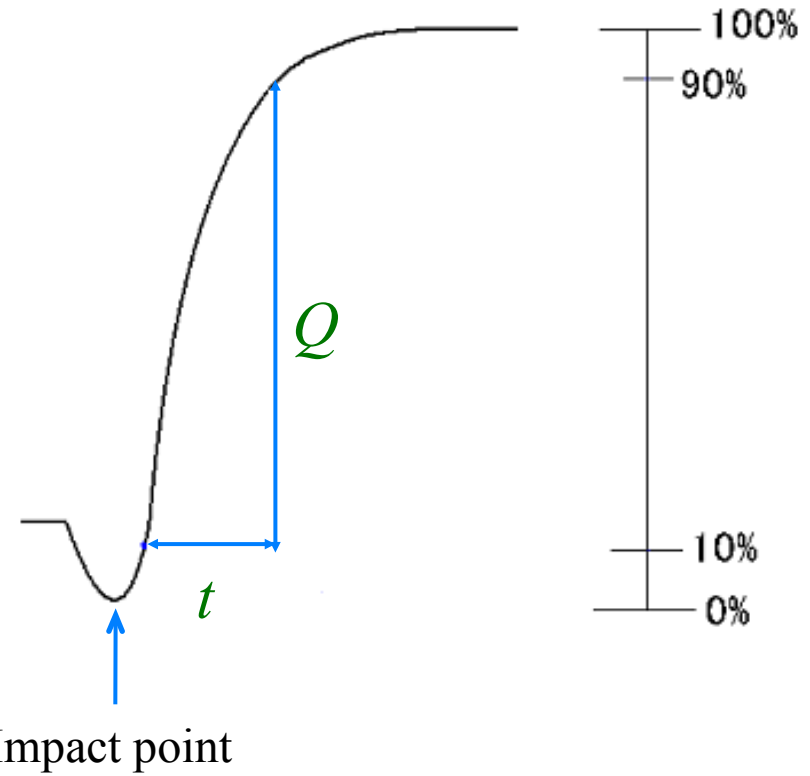
$$\pm Q/m = c_r v^{\beta}$$

t : Rise time v: Velocity

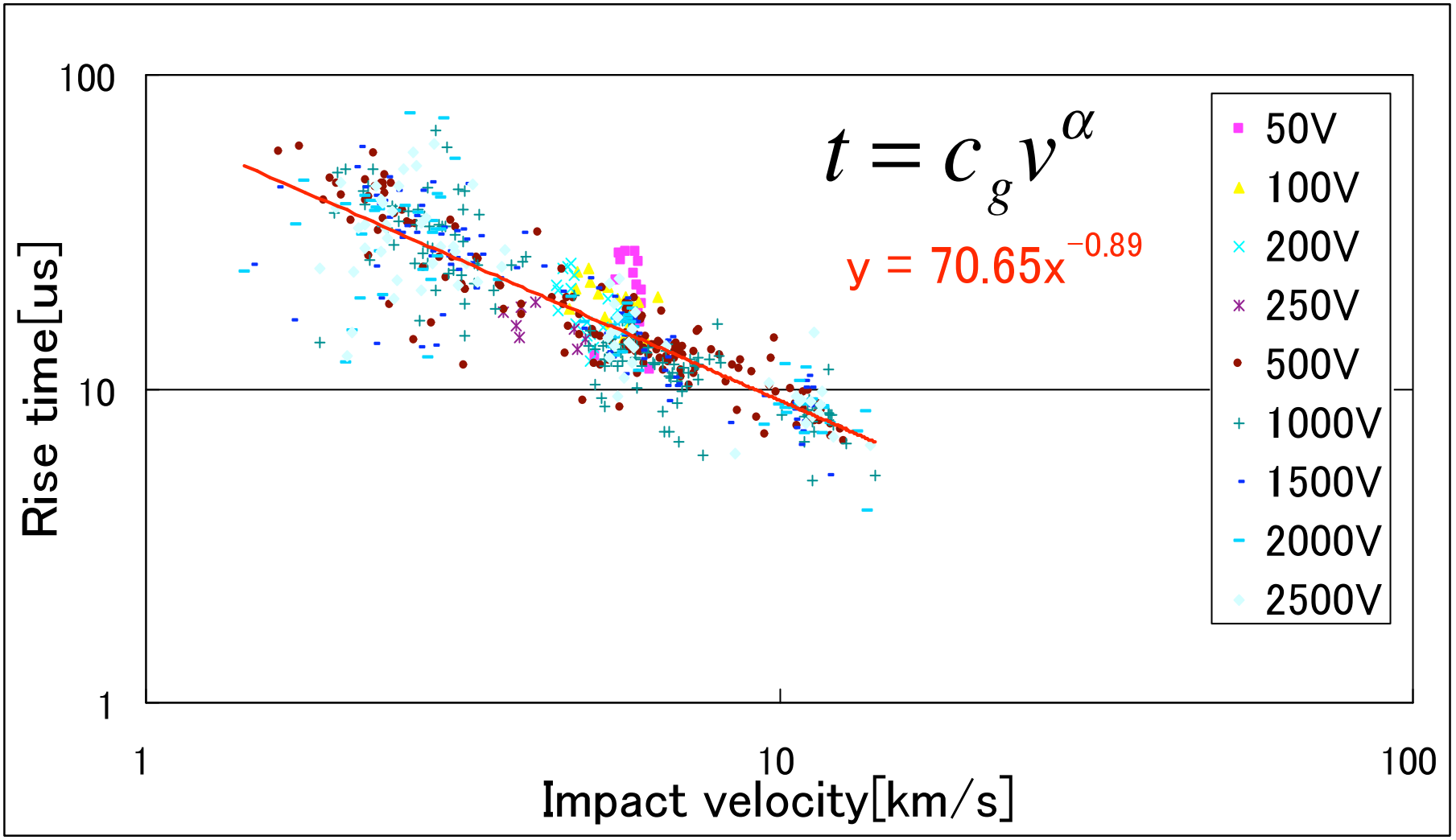
Q : Charge m : Mass

C_g, C_r, α, β : Constants

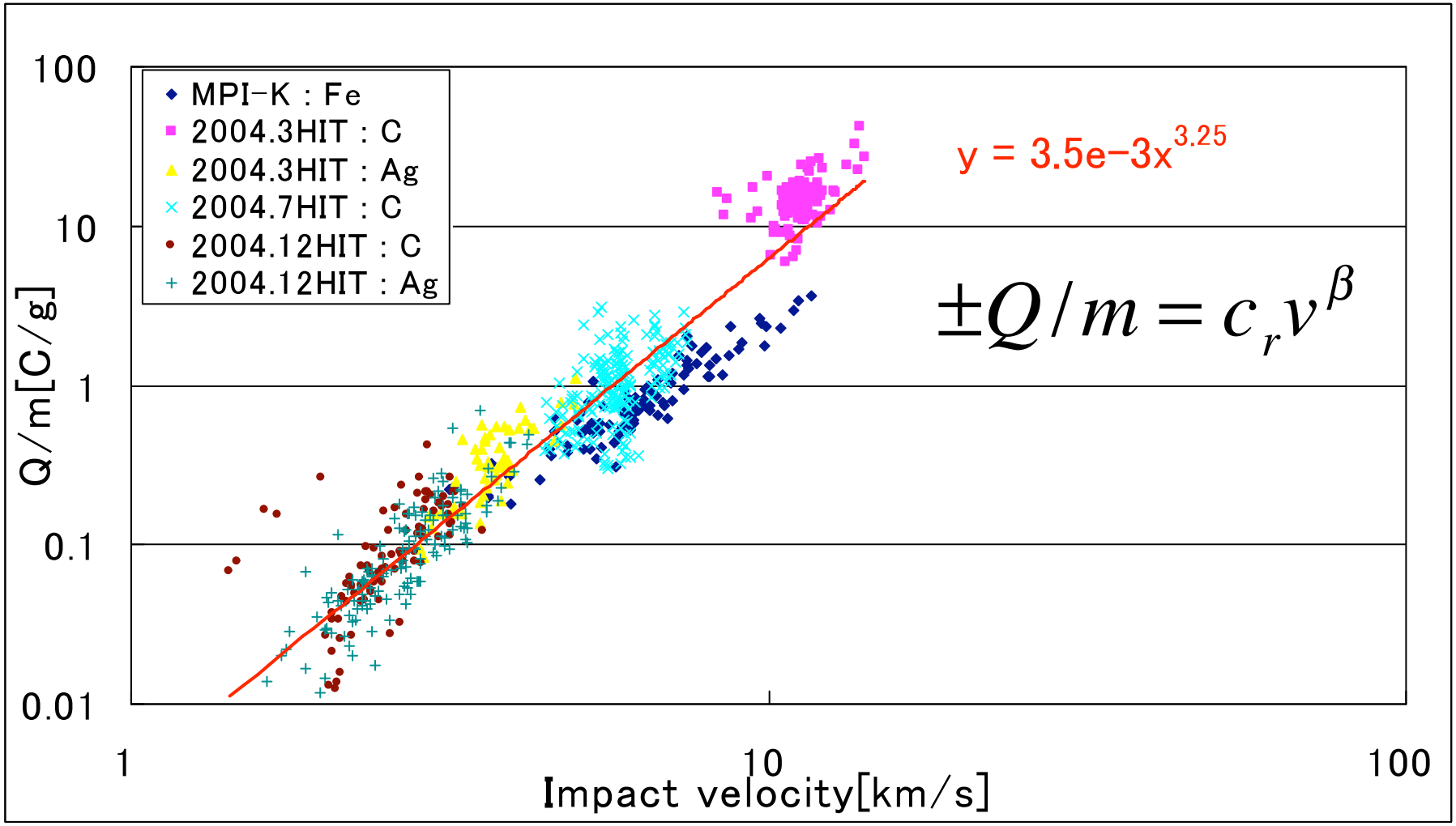
[D.K.Bedford, 1970]



Impact velocity vs Rise time



Impact velocity vs Charge/mass



2. Piezoelectric Impact Detector

MDM (Mercury Dust Monitor)

PZT (piezoelectric lead zirconate titanate) element as an impact target

Measurements of dust particle

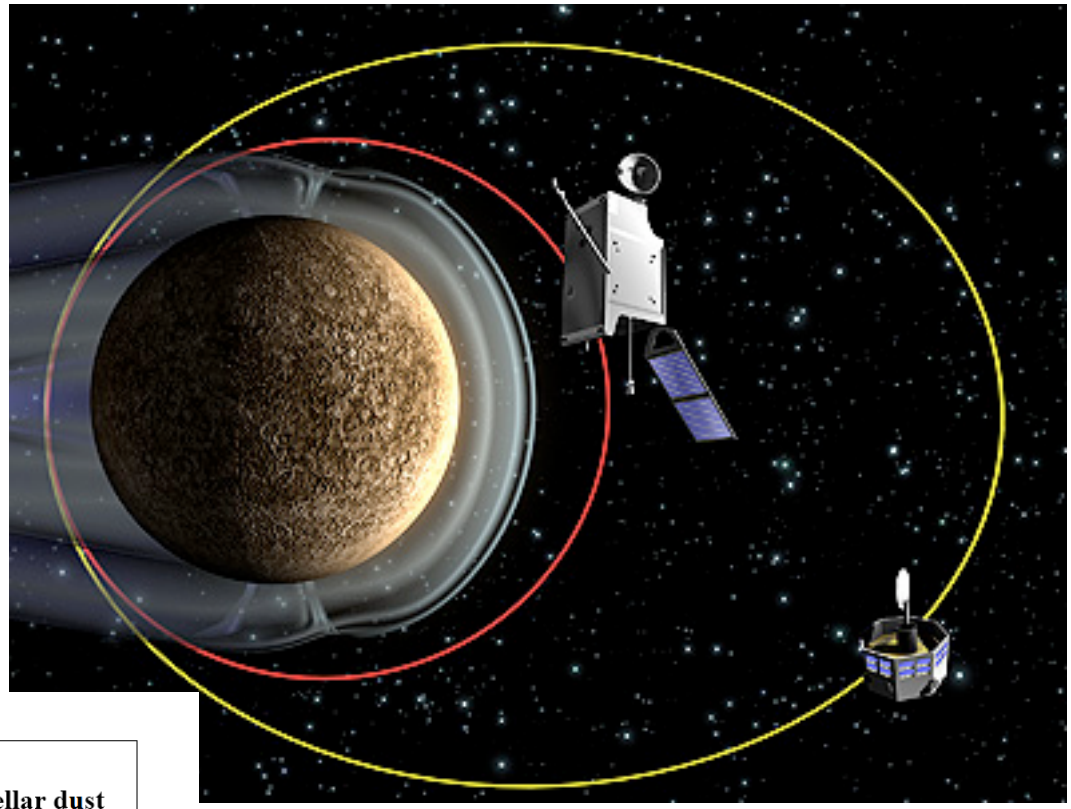
1) Number of incoming dust particle with crude direction
2) Momentum or velocity of particle

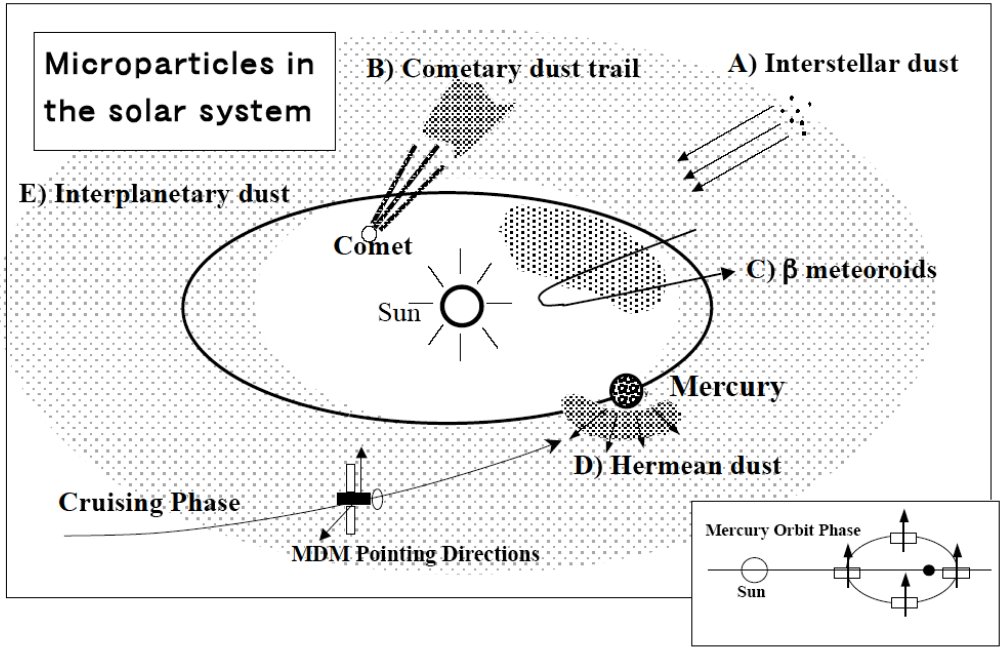
BepiColombo

MPO (Mercury Planetary Orbiter) (ESA)

MMO (Mercury Magneto-spheric Orbiter) (JAXA)

ESA /JAXA joint mission

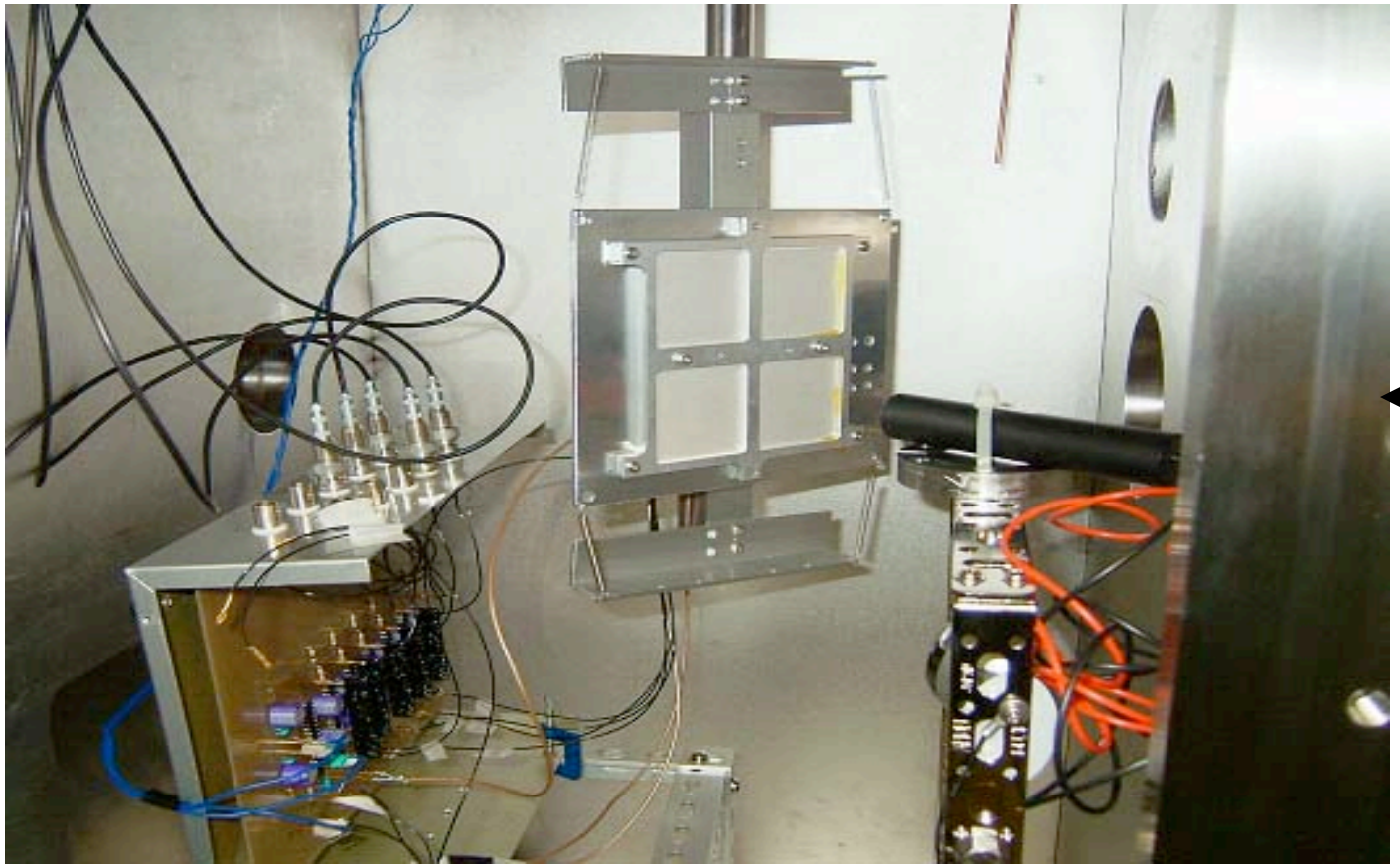




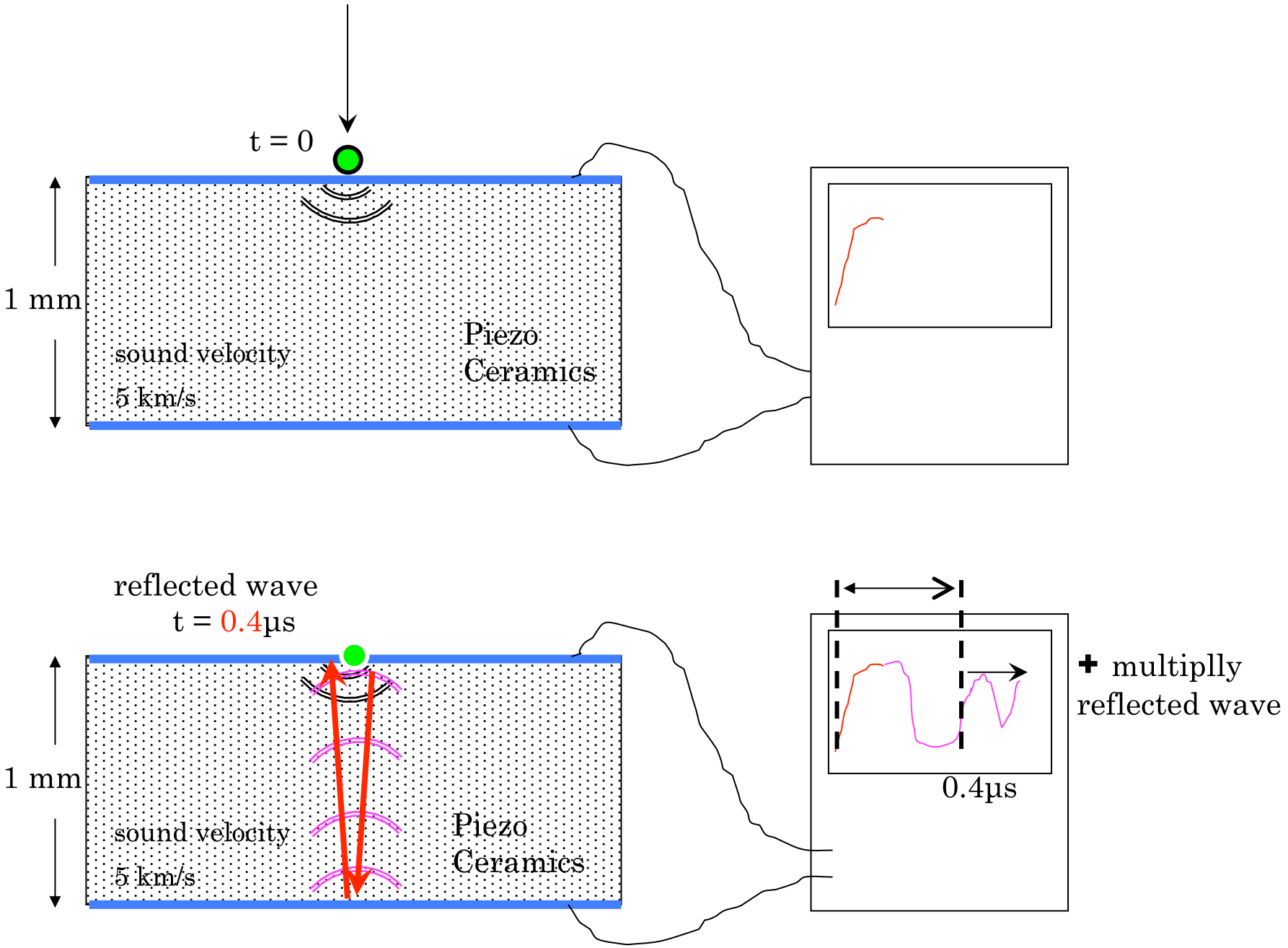
Launch July 2014 Ariane 5
Arrival May 2020
One year research

MDM (Mercury Dust Monitor)

PZT sensor in the dust accelerator chamber

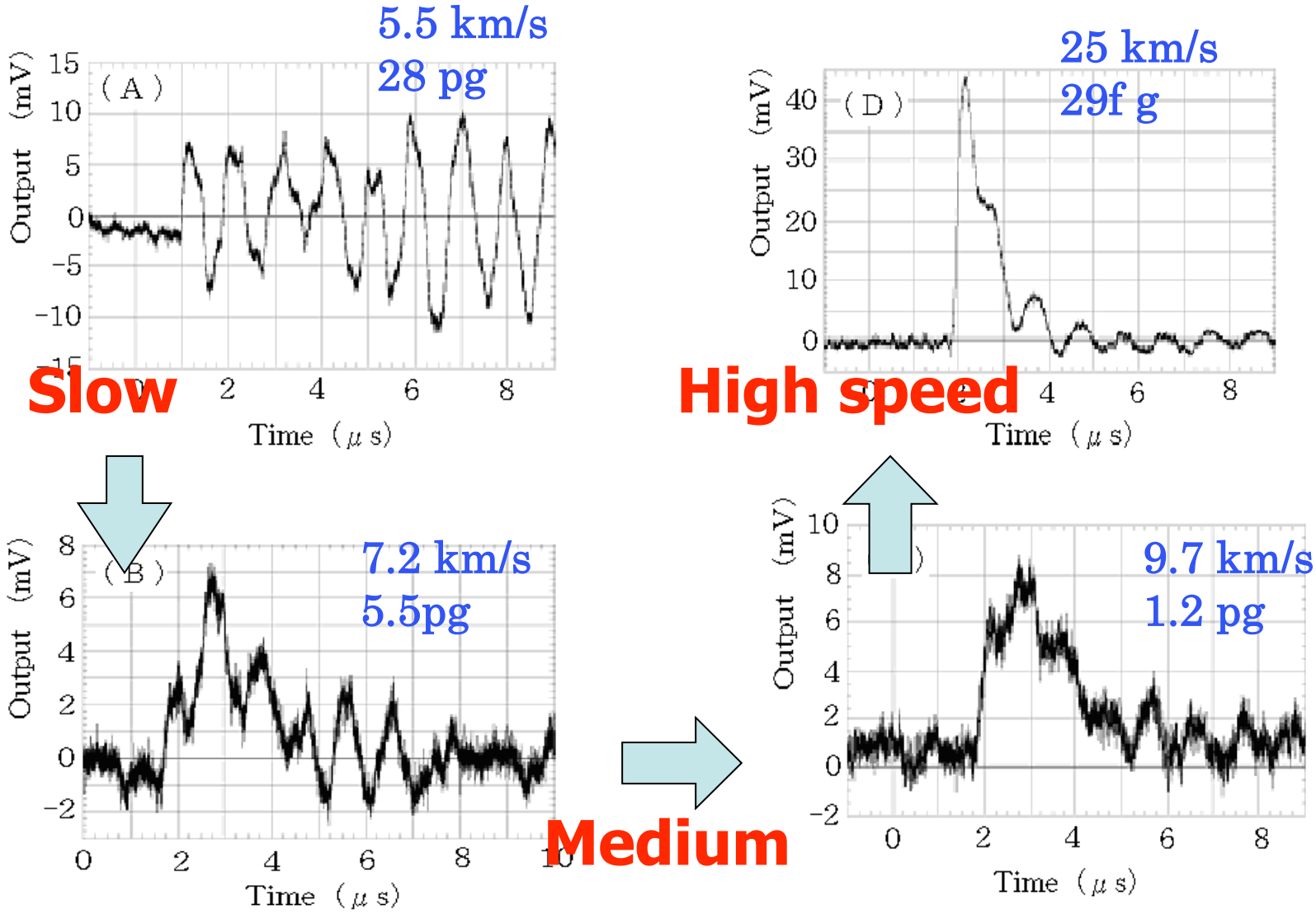


Dust Particles


t = 0
1 mm
sound velocity
5 km/s
Piezo
Ceramics
reflected wave
t = 0.4µs
1 mm
sound velocity
5 km/s
Piezo
Ceramics
0.4µs
+ multiplly
reflected wave

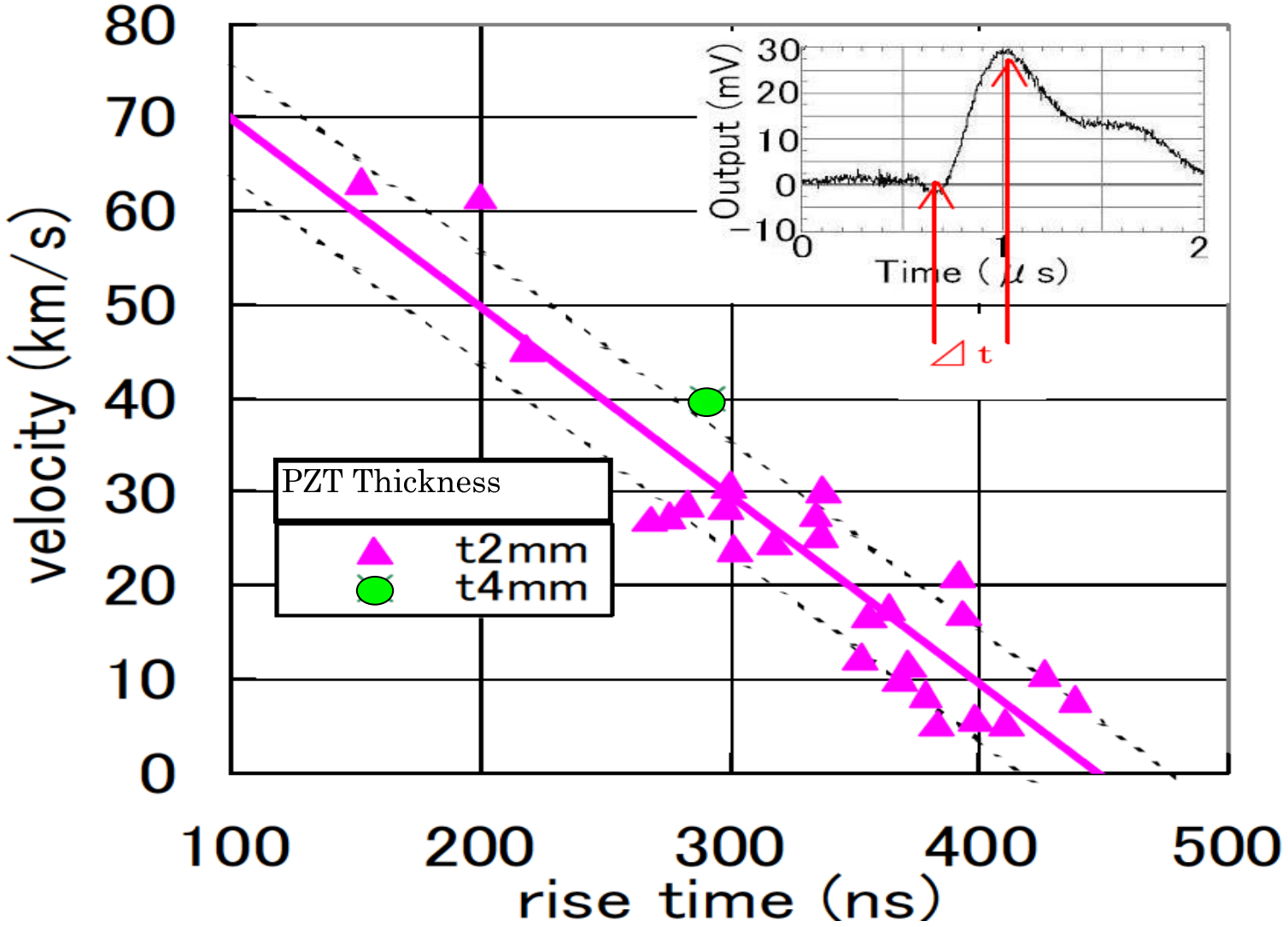
Typical waveform (MPI-K)

Velocity dependent (Iron particles)



Rise time vs. velocity of single peaked pulse

High speed impact (> 8 km/s)

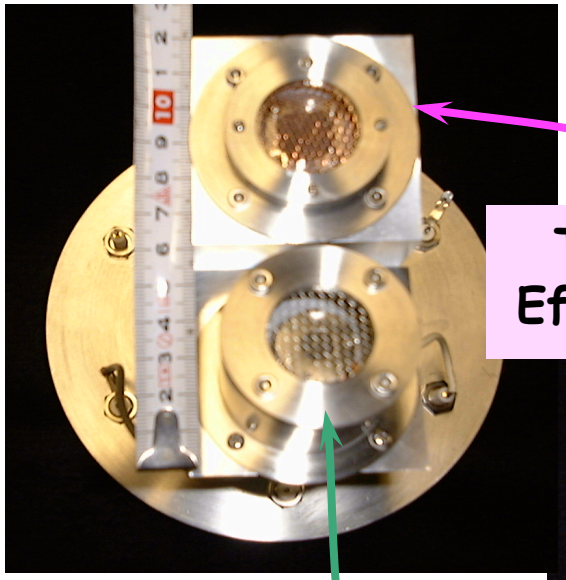


3. TOF-MS with IID or PZT

- Impact Induced Plasma (Particle mass and velocity)
- Chemical Analysis (Secondary ion mass analysis)
  - TOF (Time of Flight) mass spectrometer

Target	Signal analysis	Feature
Metal plate	Mass, velocity	Moderate signal
PZT	Mass, velocity	Velocity from waveform
MicroPZT	Mass, velocity	Large signal

Reflectron (Prototype)

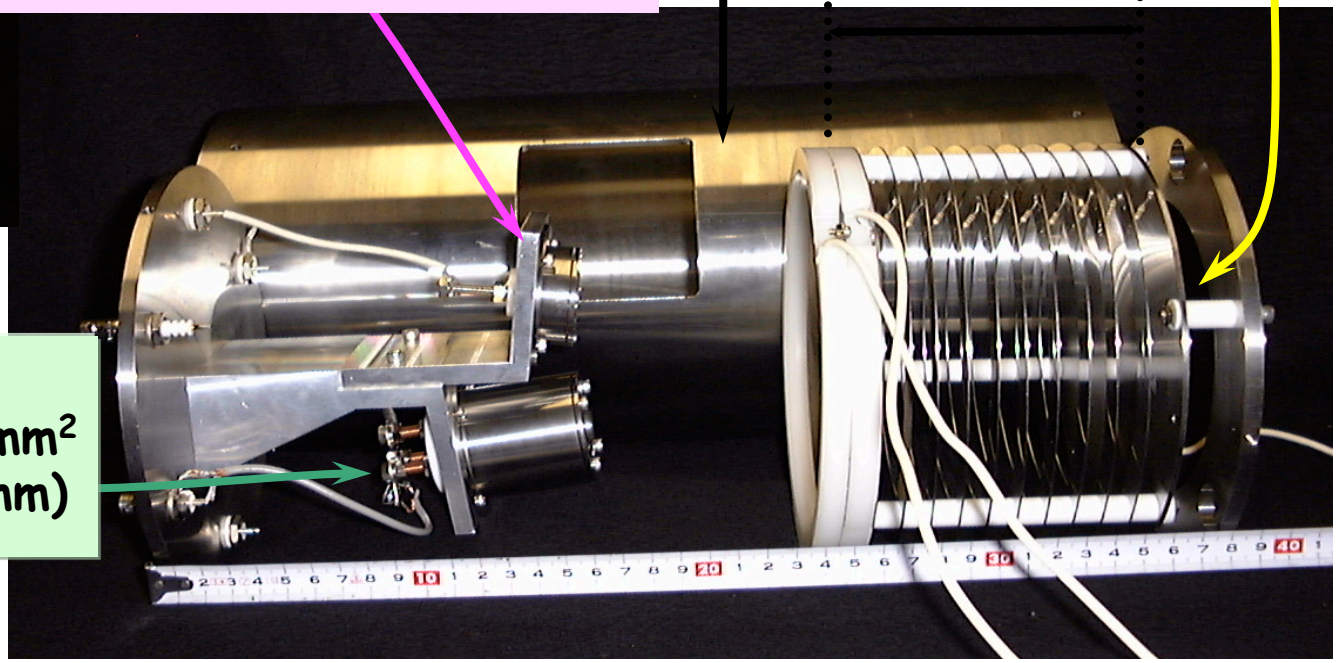


Protective Tube

Reflection Plate
(1000 – 2500 V)

Target (800 – 1200 V)
Effective Area : 18×18 mm

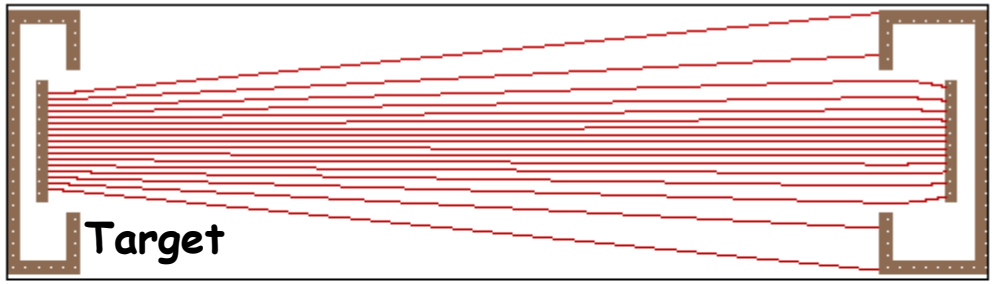
Reflecting Region
(Potential Ring)



Detector (MSP)
Effective Area ~ 57 mm^2
(Diameter = 8.5 mm)

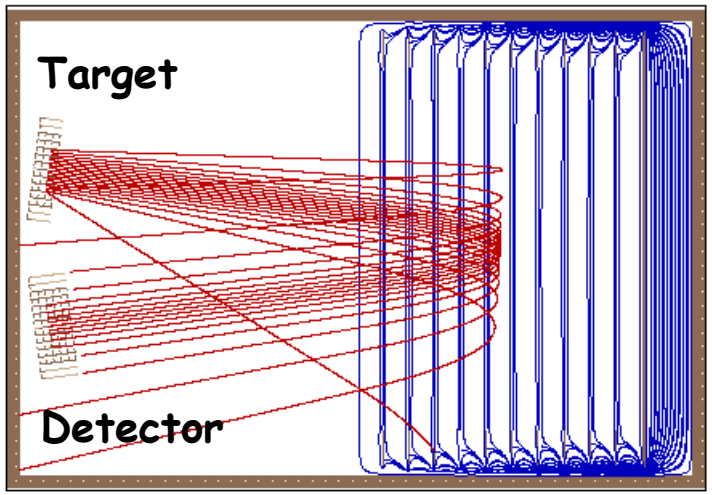
Curved Potential TOF-MS

Linear Type

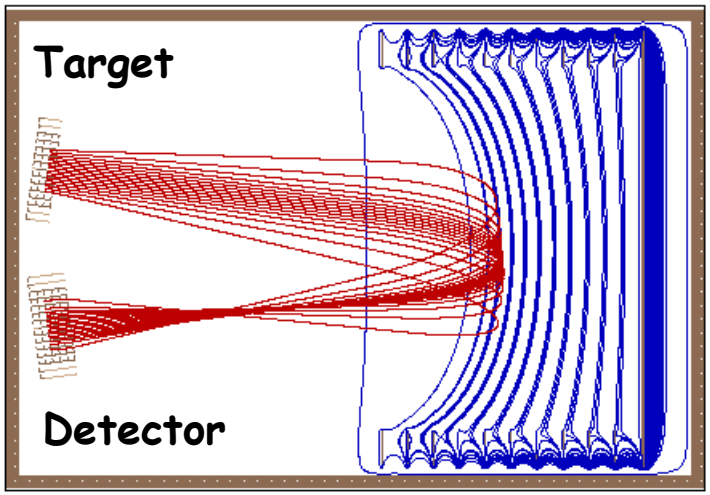


Impact Point :
Y = ± 4 mm
Initial Energy : 0.1 eV

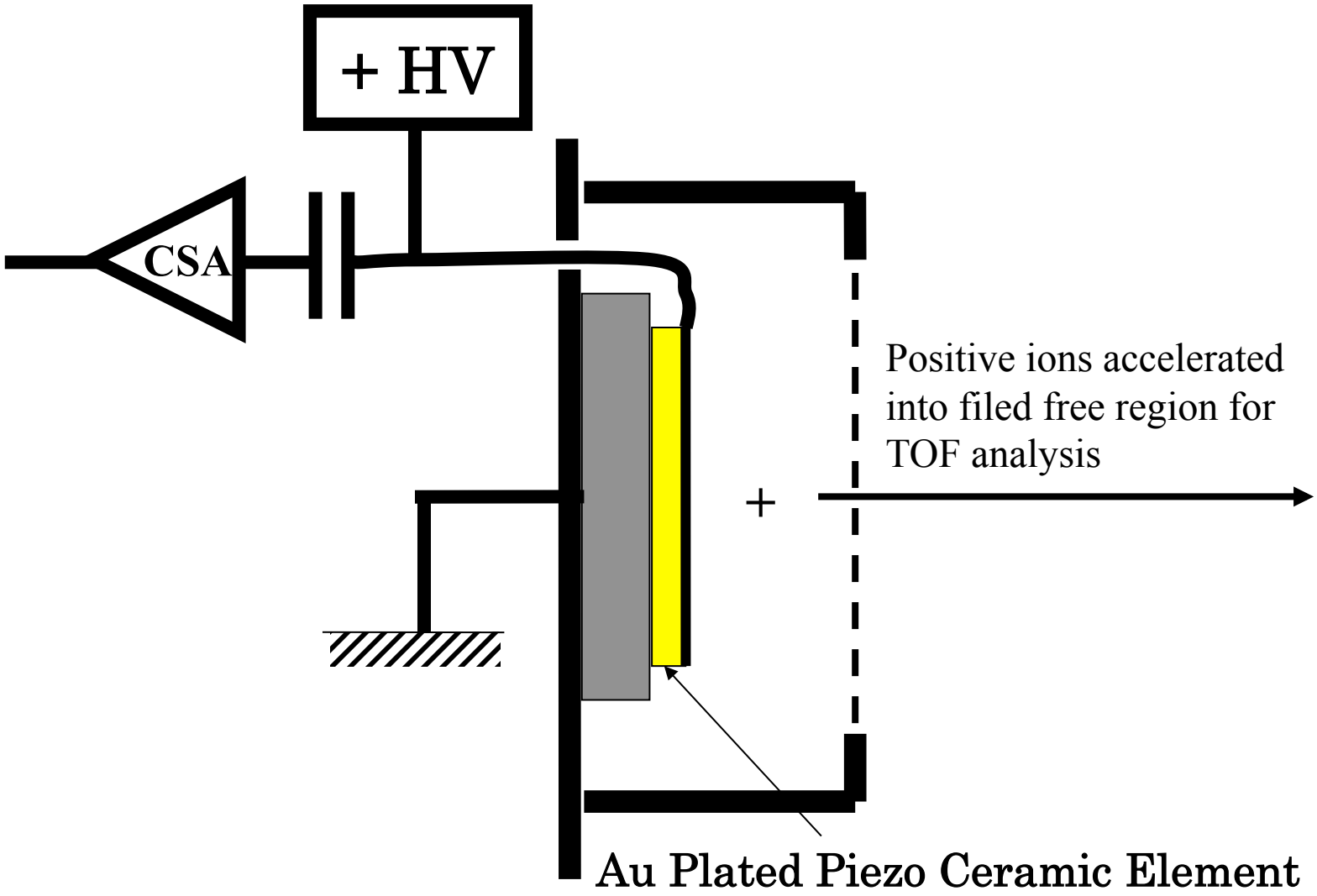
Parallel Potential Type



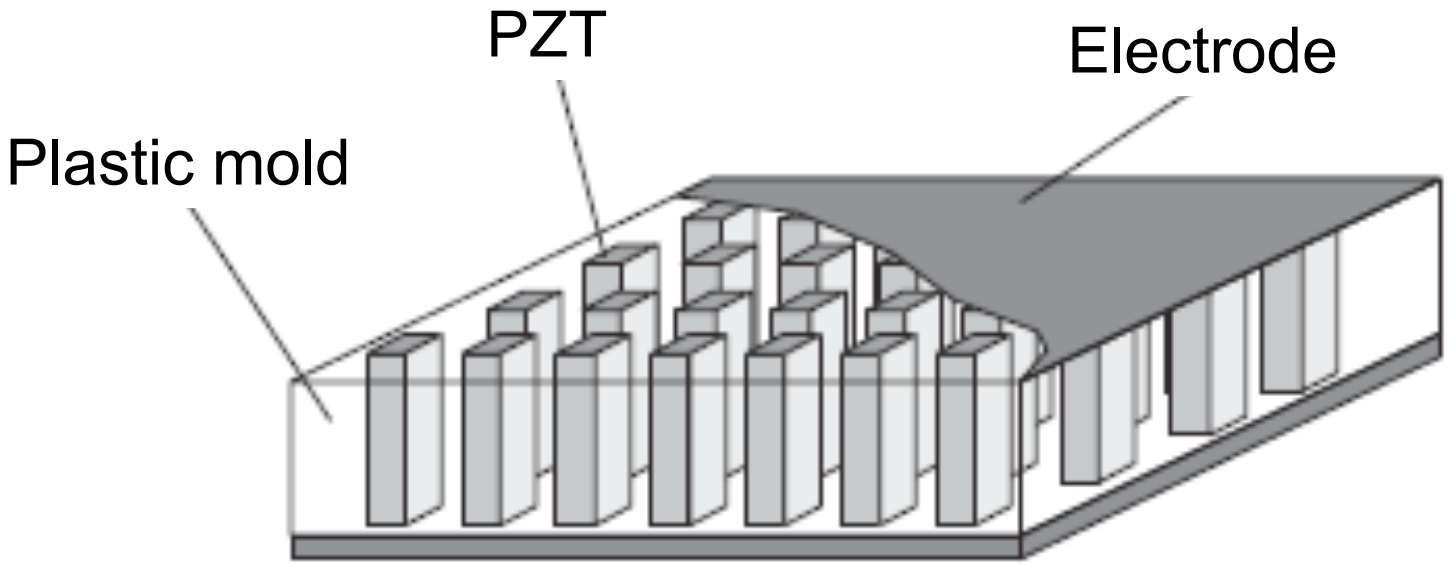
Curved Potential Type



Schematics of target setup



Micro Piezoelectric Element



Micro-PZT 25micron square, 250micron high