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An Overview of Advanced Technologies for Instruments and Spacecraft on Several NASA Missions

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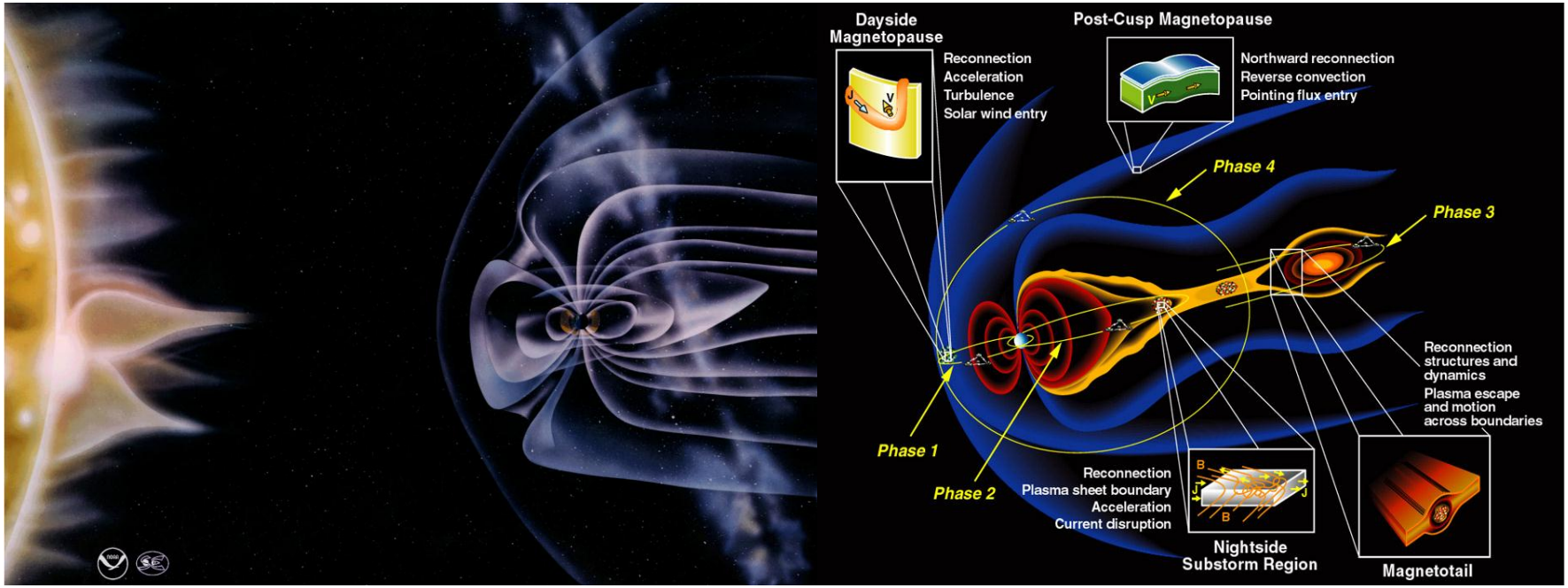
In Situe Experiments

In red flight missions with these instrument technologies

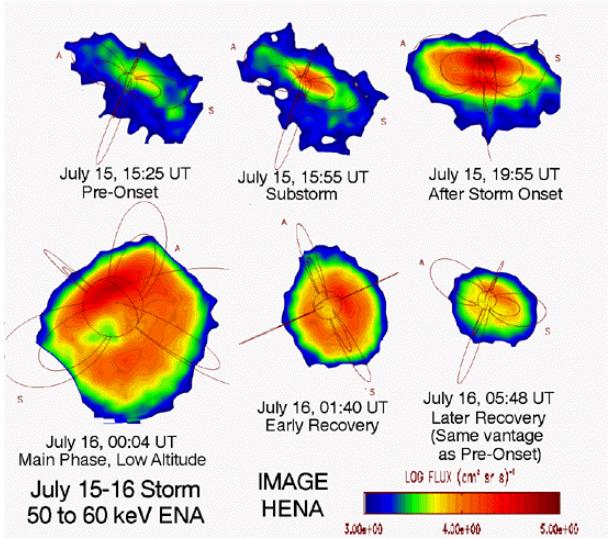


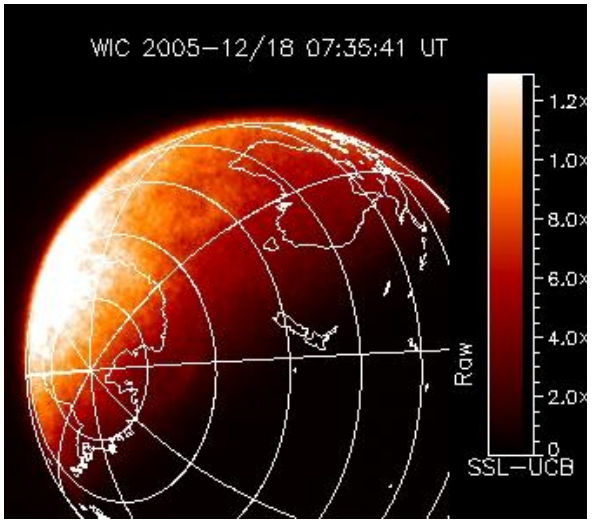
Particles and Fields

Fast Plasma,
Plasma Composition (MMS)
Energetic Particle Analyzers (Messenger, PLUTO, JUNO, RBSP, MMS, SP+)
High Energy Particles (Cassini)
Electric Fields, Magnetic Fields, Waves

Remote Sensing Experiments

In red flight missions with these instrument technologies





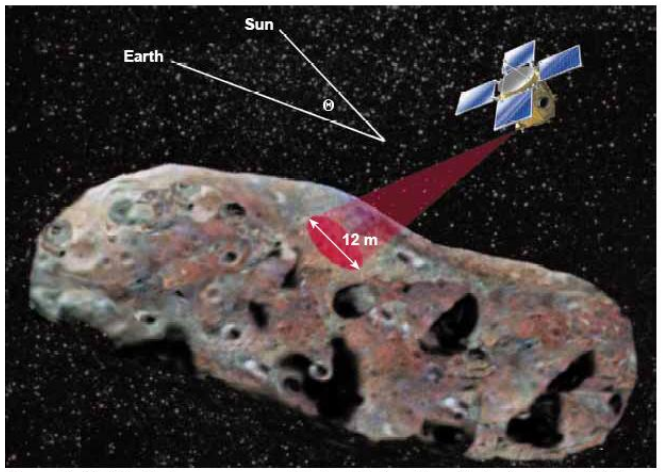


Figure 1. NEAR will place a spacecraft into orbit about the elliptical asteroid 433 Eros. The asteroid's dimensions have been estimated at 36 × 15 × 13 km. NEAR's optical instruments, including the laser radar, are continuously pointed toward the asteroid's

High Energy ENA of storm phases (left), and FUV wide-band imaging of the aurora from molecular nitrogen (middle), taken by the IMAGE satellite – passive remote sensing examples. Laser imaging altimeter of the Near mission (right) – active remote sensing.

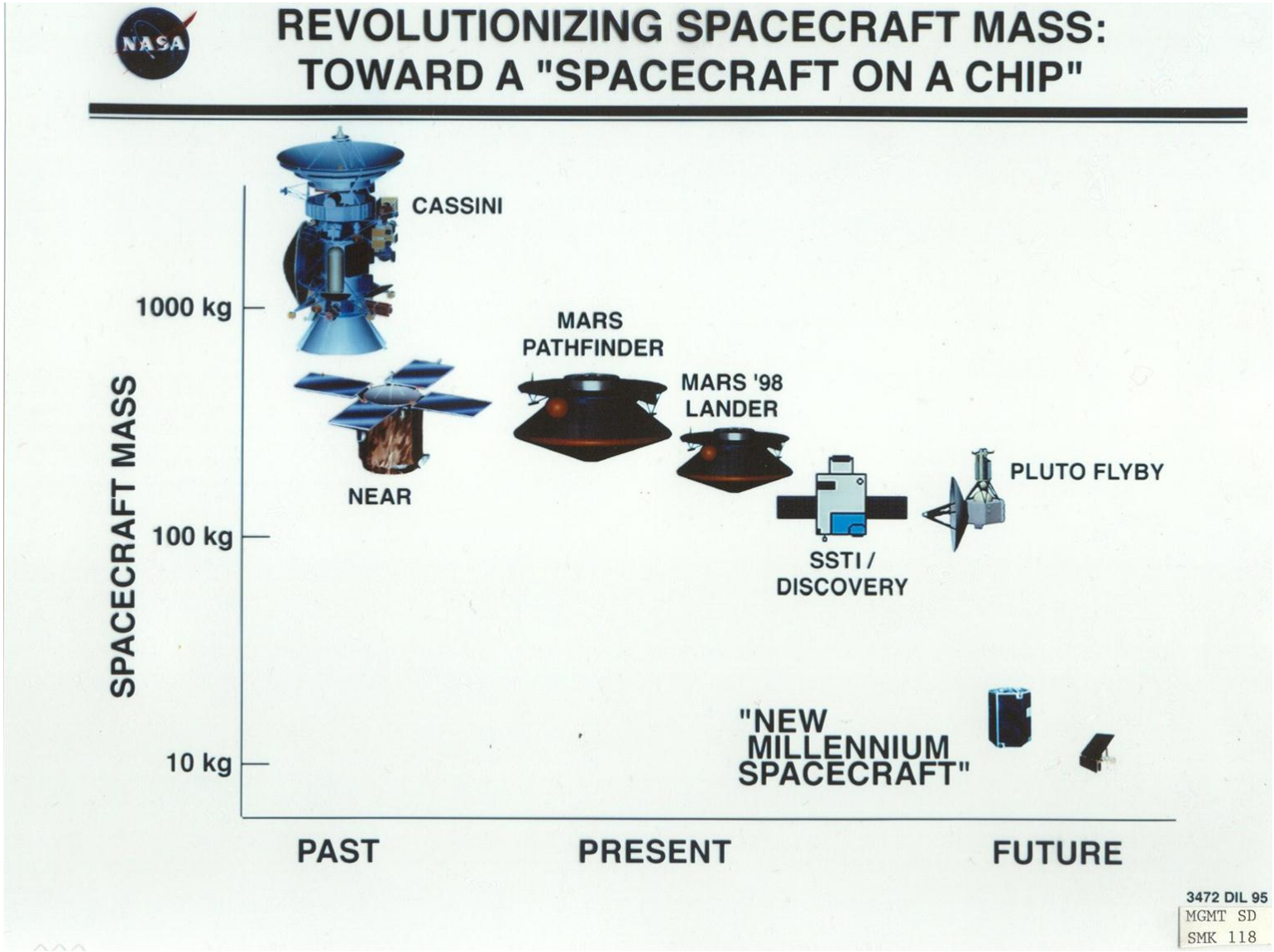
Passive remote Sensing

Neutral Atoms (Cassini, Image, Bepi-Colombo)
High, Medium and Low Energy
UV spectrographic Imagers
Visible multi-spectral imagers
IR imaging cameras
X-ray, gamma ray and neutron instruments

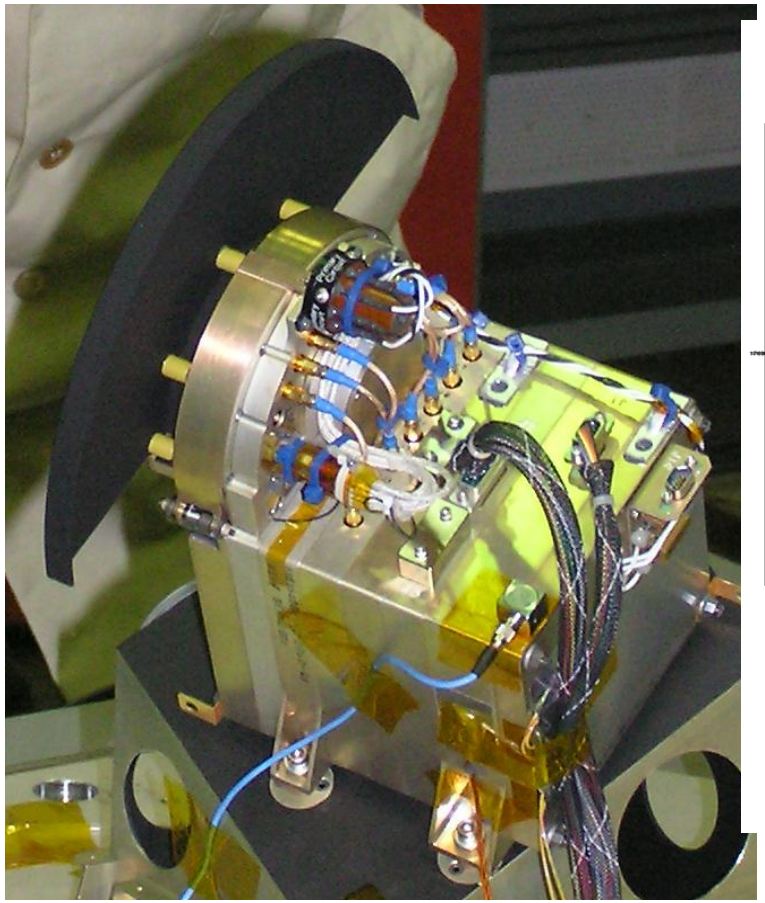
Active Remote Sensing

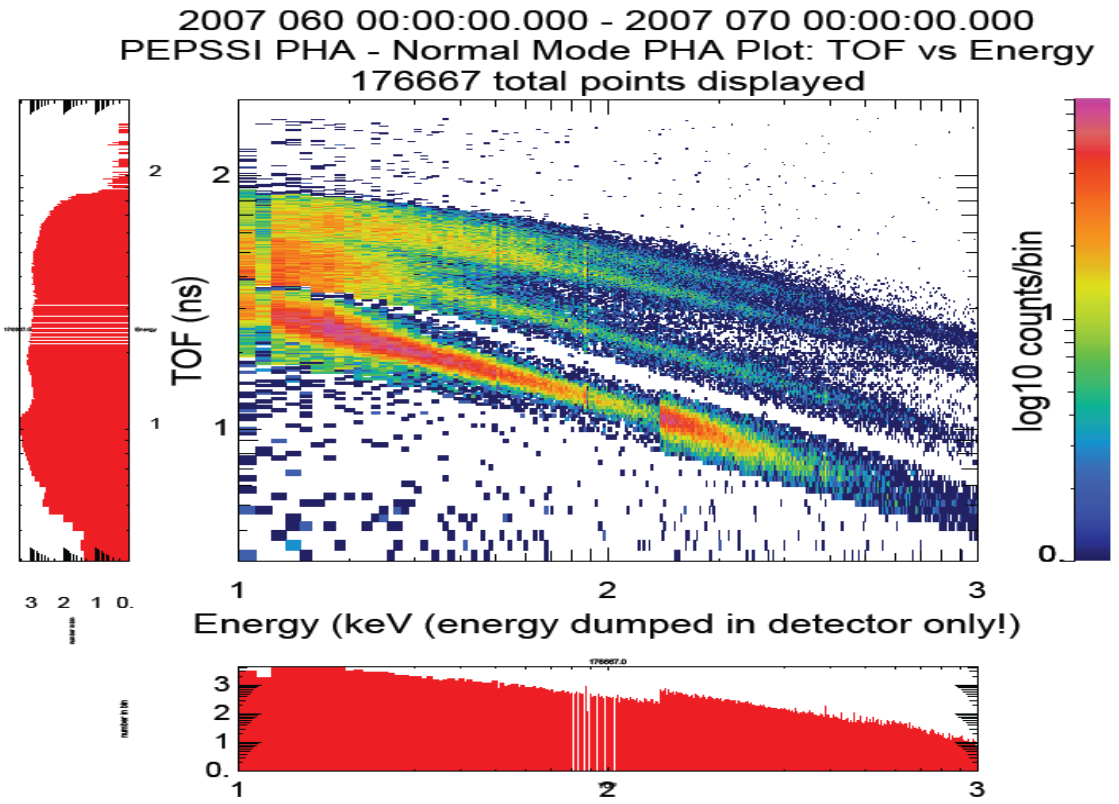
Laser altimeters (Messenger)
LIDAR imagers

Miniaturization of Spacecraft Poses Constraints to Instrument Resources



New Horizons PEPSSI
Time of Flight vs Energy Particle Spectrometer



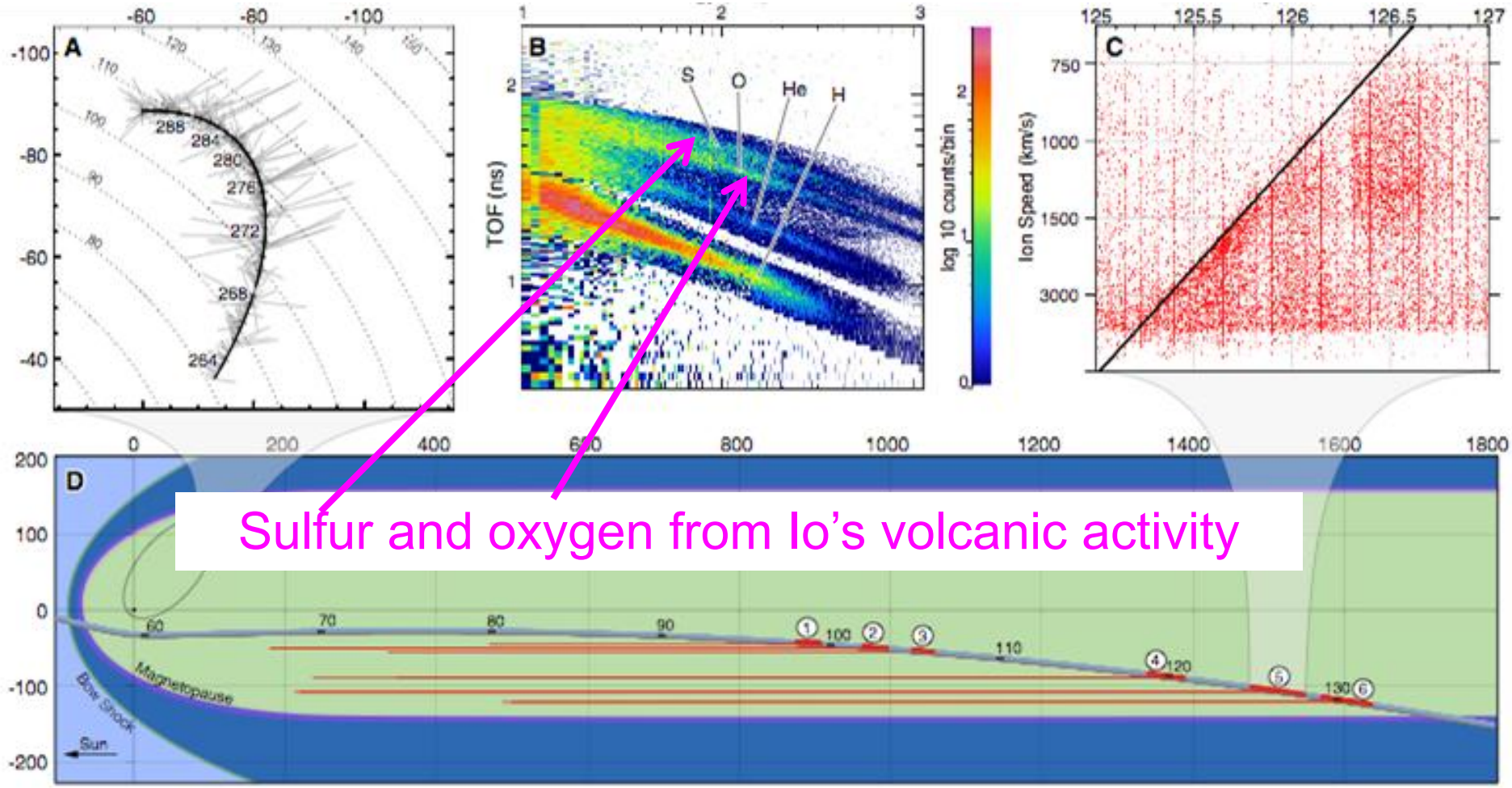


Energy range: ~20KeV to ~1MeV ions and electrons

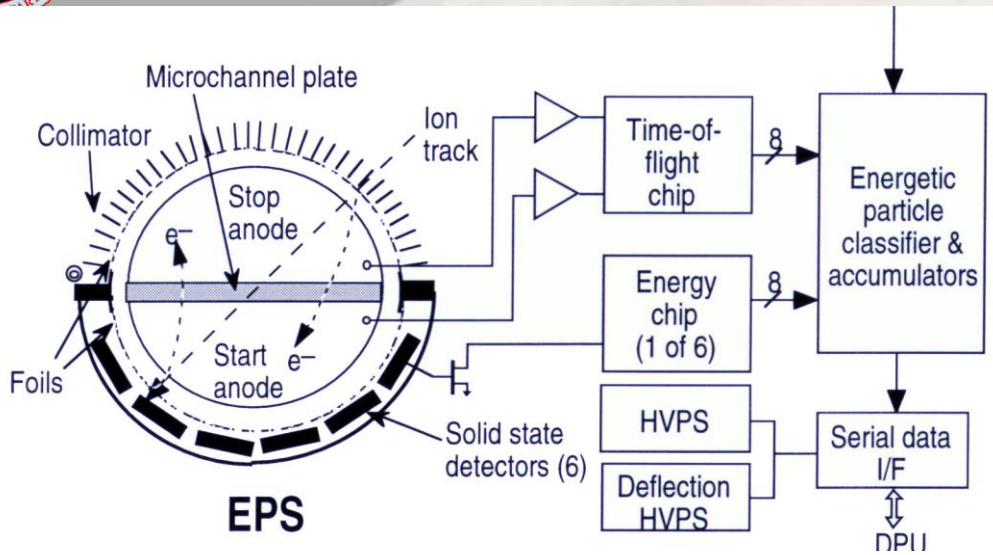
Mass and Power: ~1.5 Kg and ~2.5W
Before Miniaturization: >10Kgr, >10Watts

FOV: 160° x 12° solid angle divided into 12 sectors

Bursts of Energetic Ions Stream Down the Tail

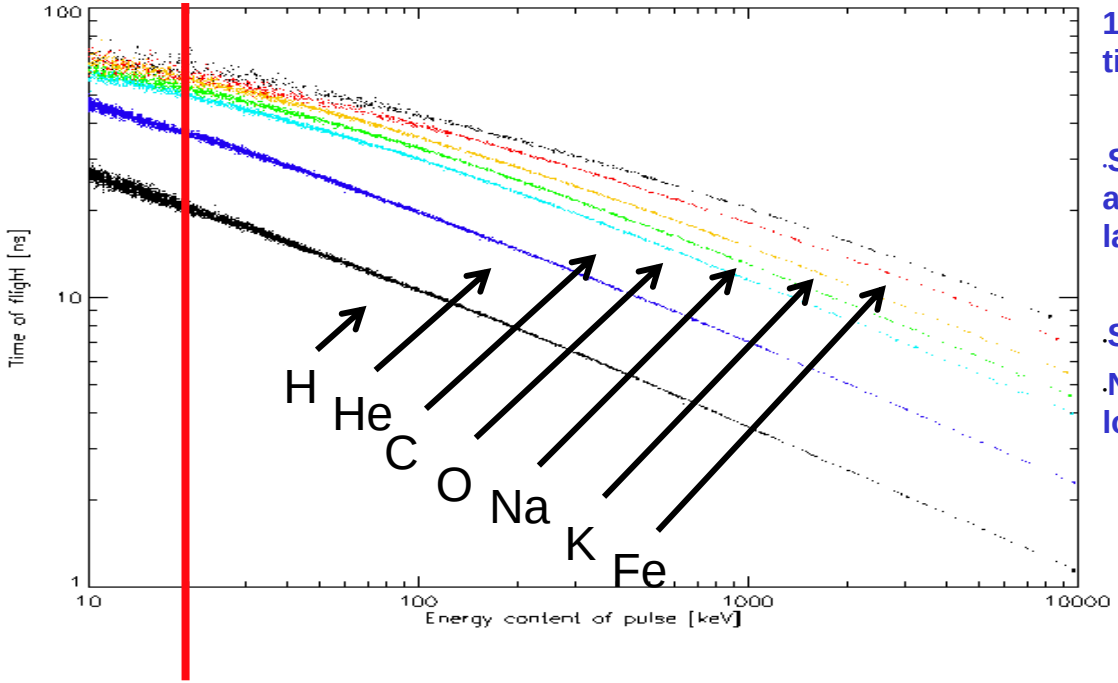


Simplified block diagram of APL's energetic particle sensor (EPS) on Messenger, Pluto, MMS, etc



- Energy range: ~5 keV/nuc to ~20MeV total
- Energy resolution ~2keV FWHM
- Time of flight range: 0ns to ~300ns
- TOF resolution: ~1ns sensor plus electronics
- FOV: 160 deg @ 6 sectors x 12 deg
- Front end counting rates: >1meg-cps

- Start and stop thin foils and single MCP
- Six start anodes and 6 stop anodes
- Note: start and stop anodes are replaced with 1D delay lines in the new versions for integral time and position sensing

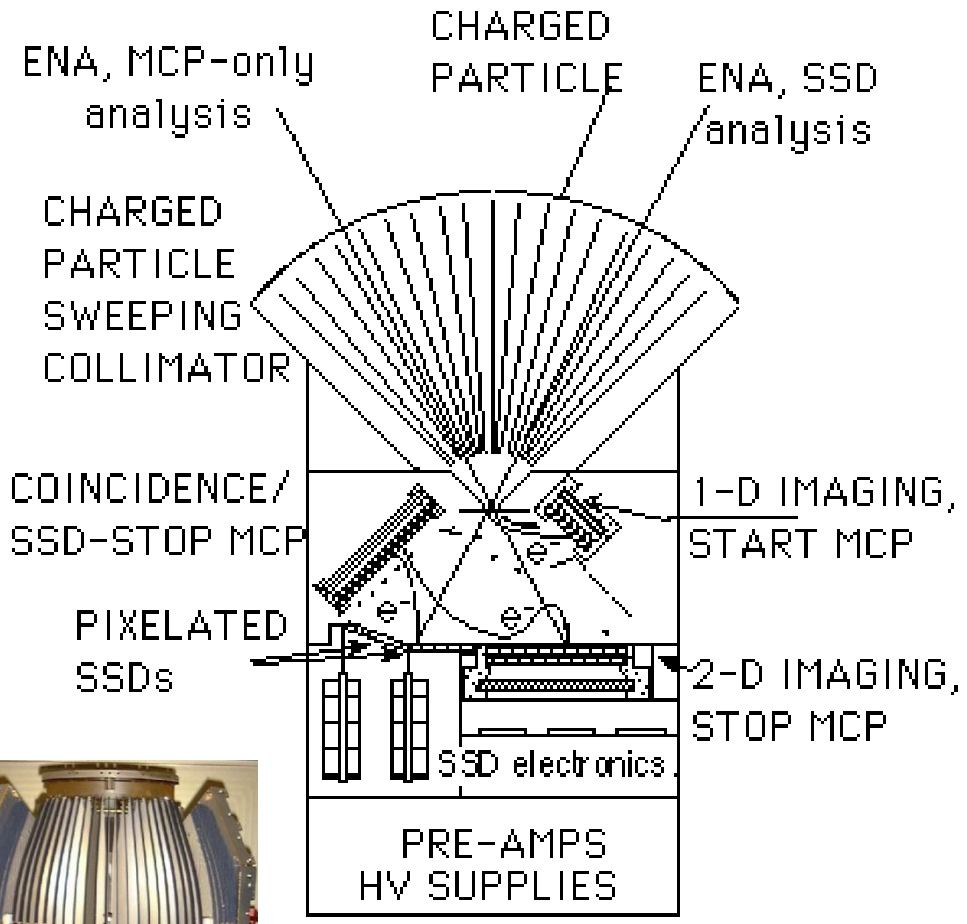


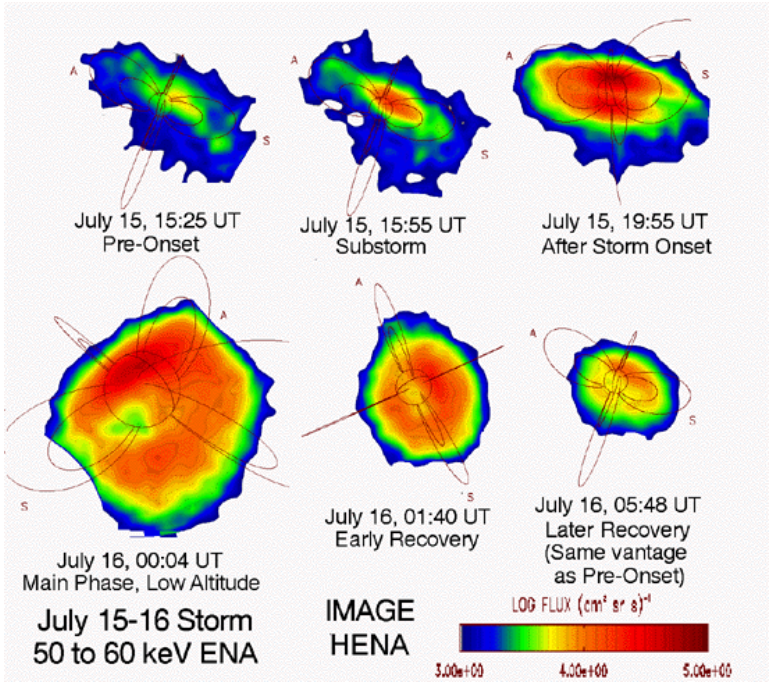
- Six SSD blocks, each block includes one large and one small ion pixel, and one small and one large electron pixel: total 24 channels.

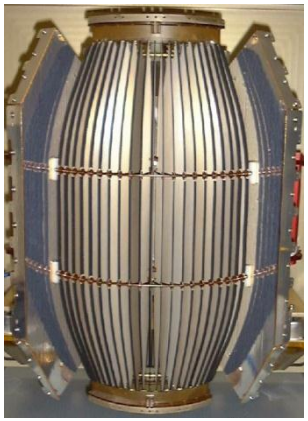
- Simulated TOF vs E ion species tracks
- Note: not fully accurate for actual foil and SSD loses

The High Energy Neutral Atom Imager on the IMAGE S/C

TOF versus Energy ENA imaging analyzer







Time of Flight vs Energy Particle Analyzers

Post Sensor Advanced Technologies

Micro – Channel Plate Detectors

1D and 2D detectors

Solid State Detectors (SSDs)

Single pixels and multi pixel
Strip Detectors
APD detectors
Pixelated Detectors

ASICs – Time of Flight Chips

TOF chips for precise time and position sensing at low power
Includes: CFDs, TDC, Valid Event Logic, PLL and I/O
Time resolutions as low as 20ps and time span up to 10us

ASICs- Energy chip

Multi channel SSD read out, each channel includes: CSA- Shaper- Active Baseline Restorer – output buffer
Low noise ~1 FWHM with small detectors, ~4keV with large detectors 10pf
Extra wide Energy Dynamic Range 10,000

ASICs- TRIO Smart sensor Chip

16 inputs multiplexed ADC

32 location memory

On chip voltage reference

Serial and parallel read outs

Used in instrument and spacecraft housekeeping such temperature, voltage and current monitoring

Aluminates lots of conventional electronic and wire harness

FPGA Based Even Classification and Memory Mapping

Time of Flight vs Energy processing

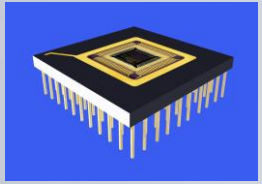
Species separation , energy binning and spectra accumulations

Science product generation

Compression and telemetry

The Time of Flight Chip

For Space Applications



Brief Specifications:

- Digitizes a Start–Stop time difference in one chip
- Two Constant Fraction Discrs (CFDs), one for start and one for stop
- One 11-bit Time to Digital Converter (TDC), 32-bit also available
- Analog input-digital output with CFD-TDC mode
- Digital Input–Digital output with TDC mode only
- CFD time walk <50ps at 40db input dynamic range
- CFD current dissipation 1.7mA/channel @3.3V
- TDC time digitization adjustable with external clock
- 50ps or 25ps with 40MHz clock, 500ps or 250ps with 4MHz clock
- TDC DNL <0.5LSB and INL <2LSB
- Current 0.5mA @10Kc/sec, 1mA @100kc/sec, 5mA @1Mc/sec
- Vdd 3.0V to 5.5V, Temp –70C to +150C, Rad Hard, no latch-up
- Package 84-pin flat-pack or PGA, also 20-pin
- Qualification u-electronics MIL-STD-883

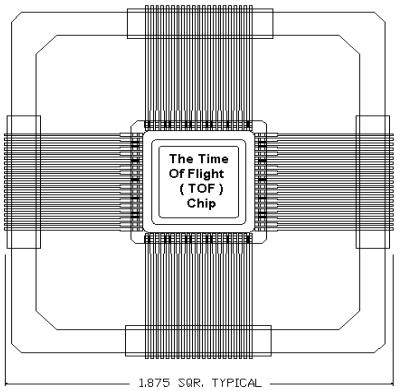
Missions

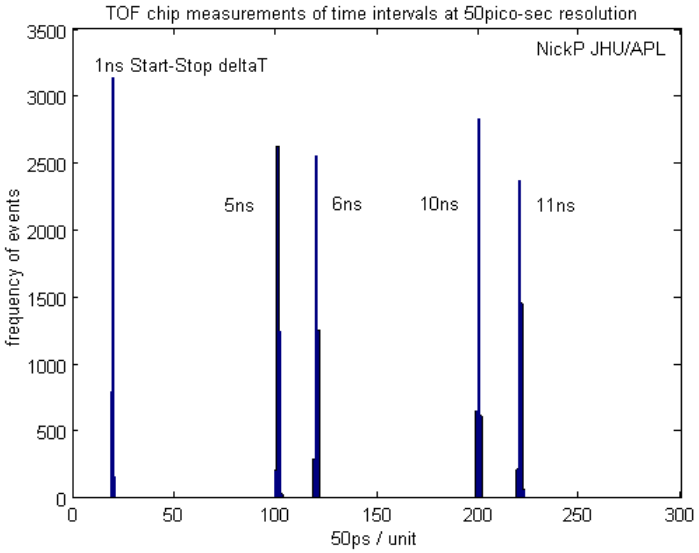
POC: nickP

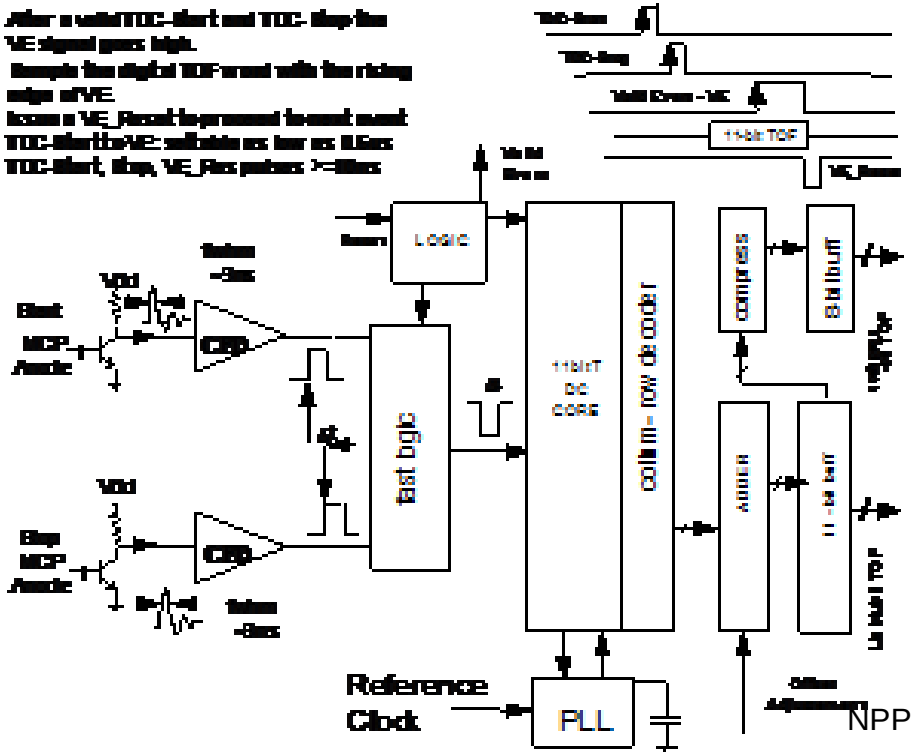
- NASA/IMAGE launched 03/00
  HENA neutral atoms
- MESSENGER launch 05/04
  MLA laser altimeter, EPS particles, FIPS plasma, XRS X-rays
- PLUTO/NH launch 2006
  EPS particles

Near Feature Funded Missions

- MMS
- IBEX
- JUNO
- Several instrument grants

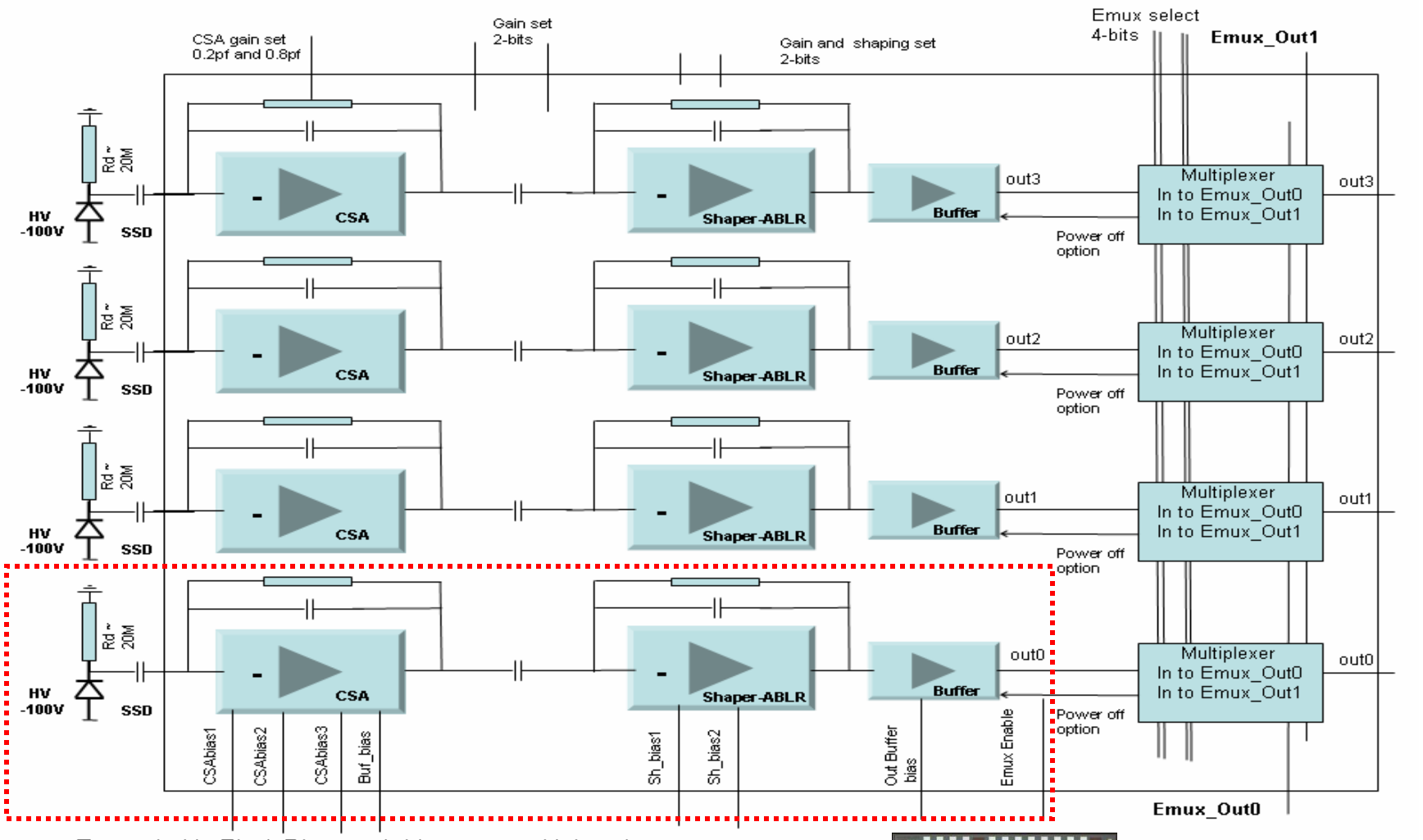




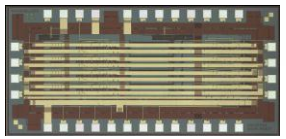


The Energy4M chip Block Diagram

Flight Missions: Pluto/NH, JUNO, RBSP, MMS

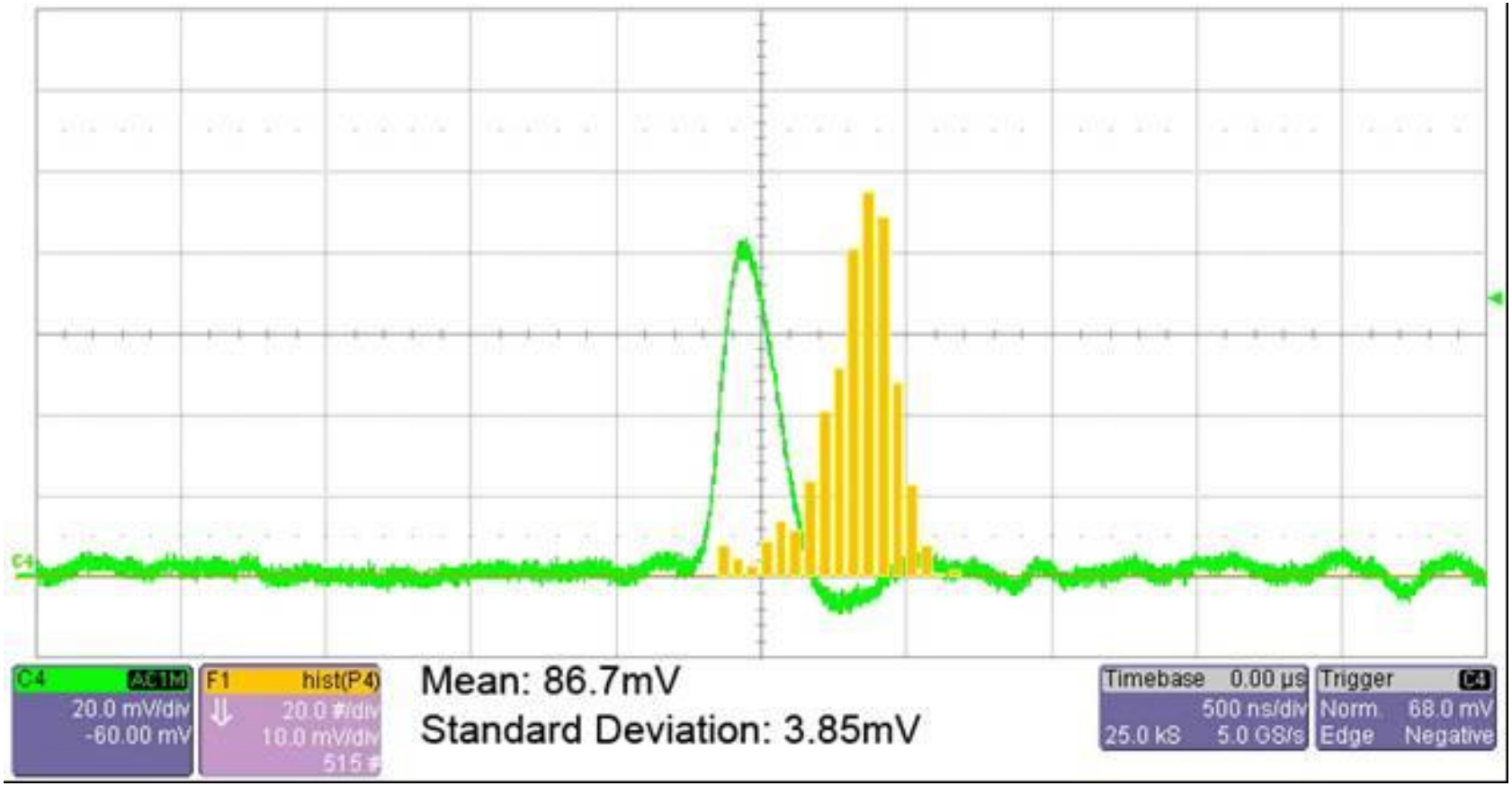


Energy4 chip Block Diagram (with output multiplexer)



nickP 12/03

.SSD-CSA-Shaper
Americium source ~60KeV gamma-rays
Standard deviation ~2.5 KeV



TRIOC Smart Sensor Chip Overview

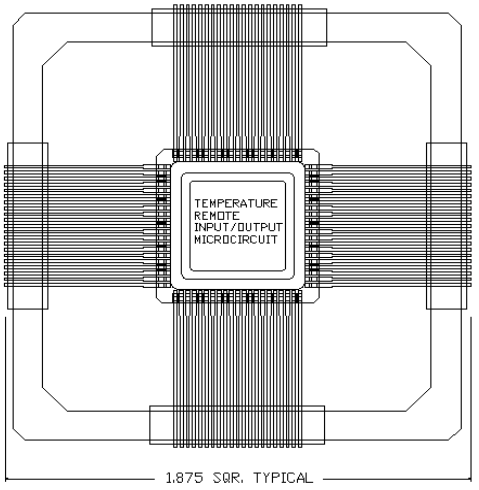
- 16 analog inputs (extendable to 32 with external MUX)
- 32 10-bit memory locations
- Temperature mode with passive or active sensors
- Voltage mode with single ended voltage sources
- Programmable front-end delay from 1us to 5msecs
- 10-bit ADC up to 100KSamples/sec (internal or external clock)
- ADC Vref+ and Vref- controllable (internal reference or user defined)
- ADC in voltage range 0.5V below GND and 0.5V above Vdd
- Built-in band-gap voltage reference and amplifier
- Standard parallel interface with 10-bit DB and 8-bit AB
- Standard I2C serial interface with 7-bit hard address select
- Built-in time out protection circuit in the serial interface on/off option)
- Fixed mode or scanning mode of operation
- 2.8-5.5V PS operation; power dissipation <10mW at all Vdds
- Technology: CMOS 0.8u, Class S qualification, 4 Mrad TID
- Latch-up free, SEU thresholds >120 LET MeV/(mg/cm2)

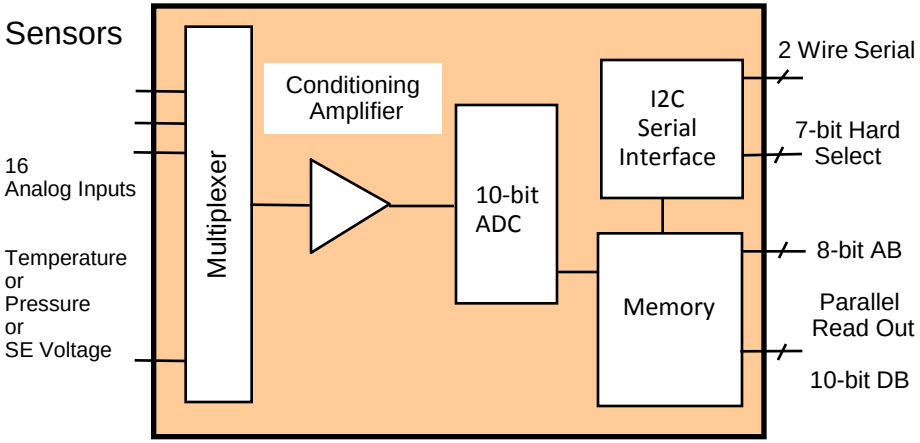
Some Space Missions

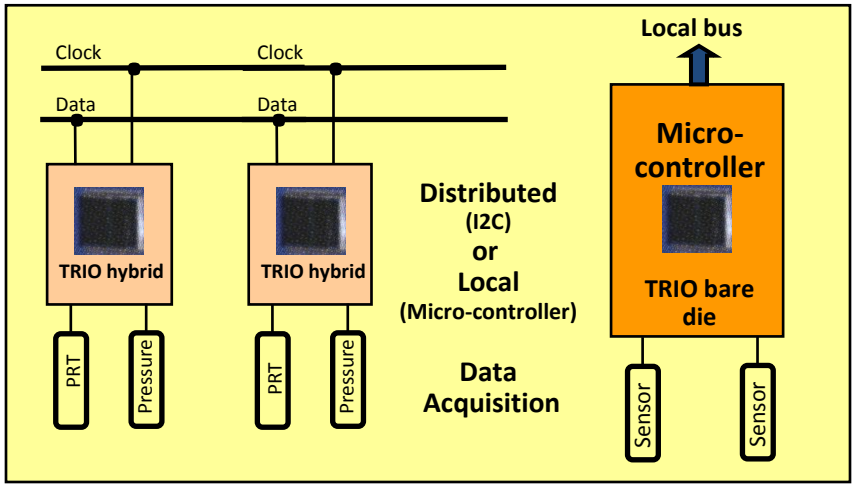
- CONTOUR
- MESSENGER
- STEREO
- PLUTO/ NEW HORIZ
- IBEX_LO
- MMS
- JUNO
- RBSP

- Applications
- TVI measurements
- Muxed ADC in instr

POC: nickP







Detector Description

MCP – 2D Delay Line Anode – Preamps – TOF Electronics

Micro-channel plates (MCP), two-stack or three-stack, with flexible active area, geometry and size.

A variety of 1D and 2D delay lines with active areas matching the MCP

Option of a photo cathode to enhance the efficiency of photon detection

Option of front foil(s) to increase the efficiency of particle detection.

TOF chip electronics for time of hit and position

Energy Chip Electronics for Charge Measurements

FPGA for data acquisition

Matlab SW for data analysis and visualization

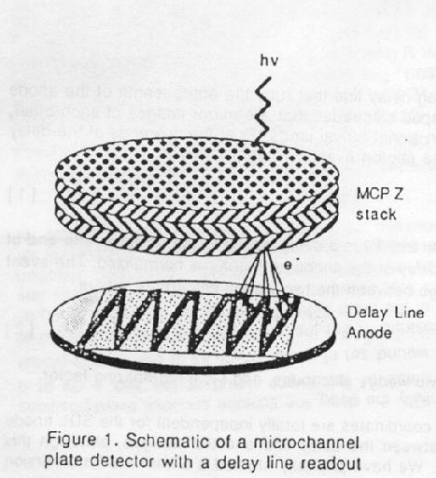
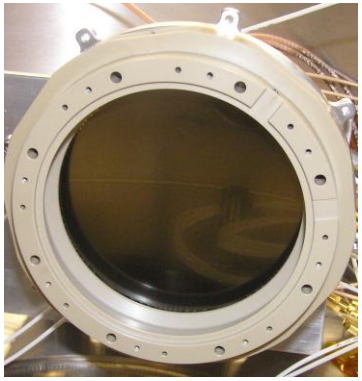


Figure 1. Schematic of a microchannel plate detector with a delay line readout

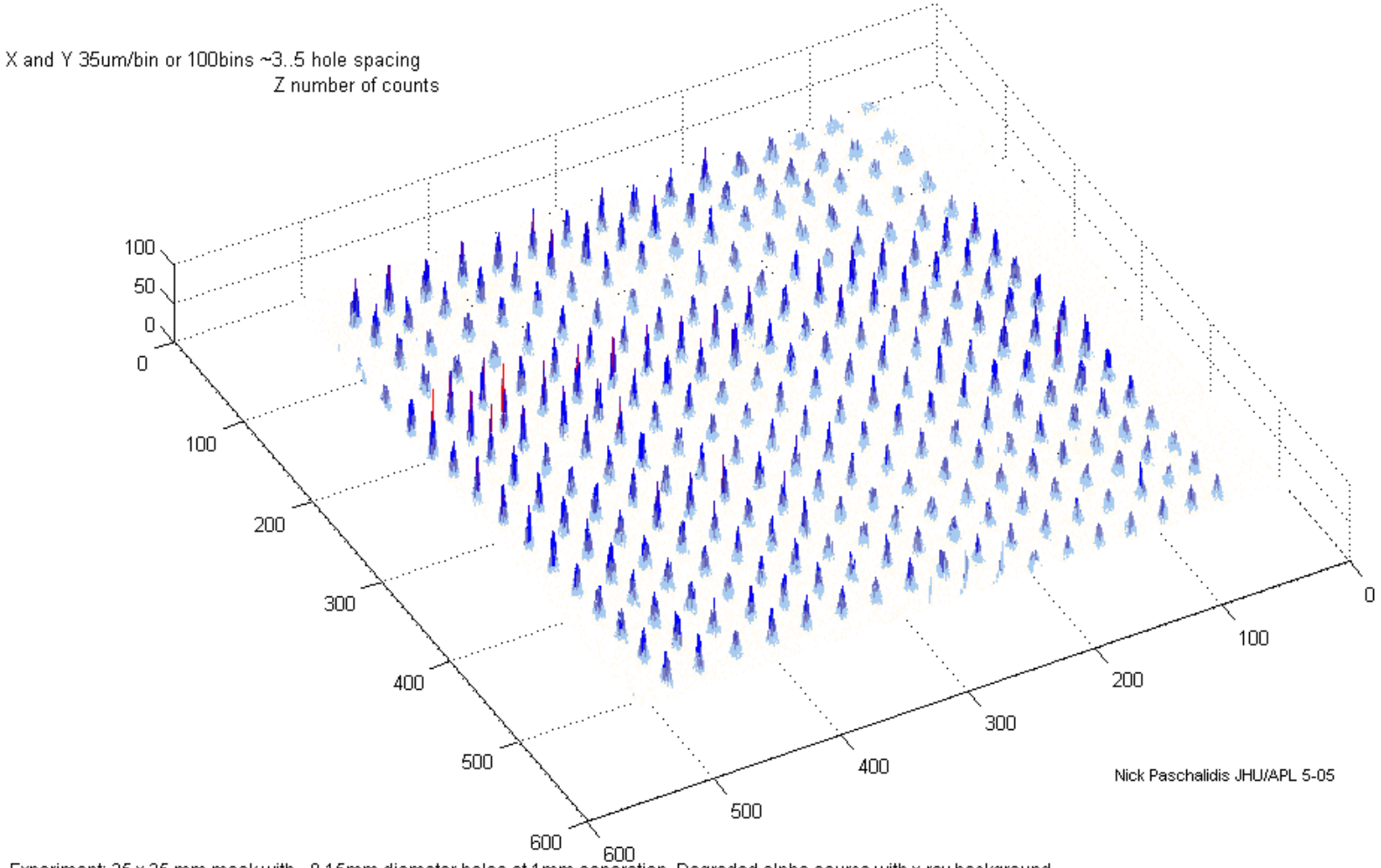


2D Delay Line anode
active area 8cm x 8cm
Position resolution ~0.1mm rms
Time resolution <50ps rms
Front focal plane and back components / preamplifiers

X-Y position measurements

Spacing of mask Holes 1mm

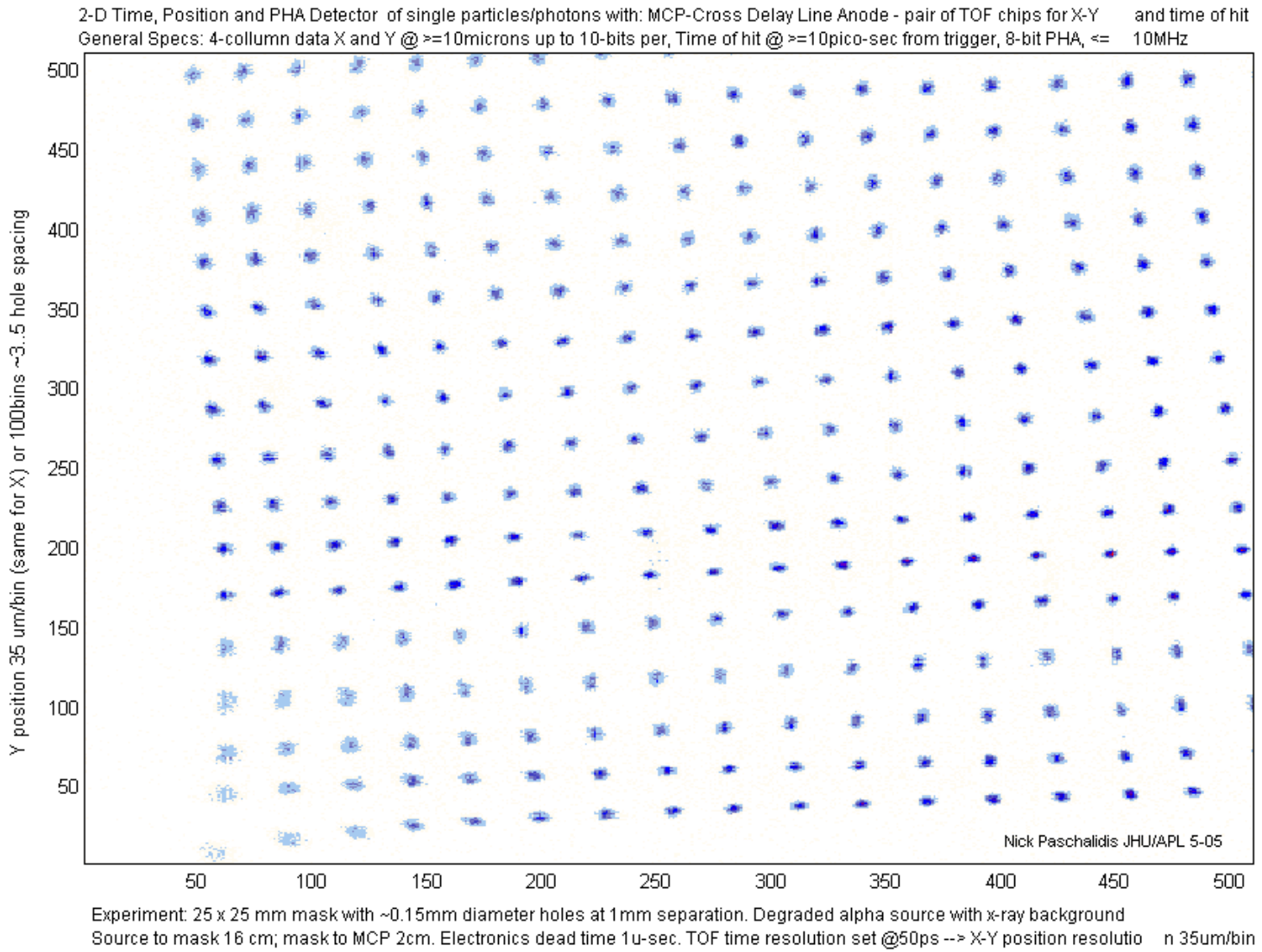
2-D Time, Position and PHA Detector of single particles/photons with: MCP-Cross Delay Line Anode - pair of TOF chips for X-Y and time of hit
General Specs: 4-collumn data X and Y @ >=10microns up to 10-bits per, Time of hit @ >=10pico-sec from trigger, 8-bit PHA, <= 10MHz



Experiment: 25 x 25 mm mask with ~0.15mm diameter holes at 1mm separation. Degraded alpha source with x-ray background
Source to mask 16 cm; mask to MCP 2cm. Electronics dead time 1u-sec. TOF time resolution set @50ps --> X-Y position resolutio n 35um/bin

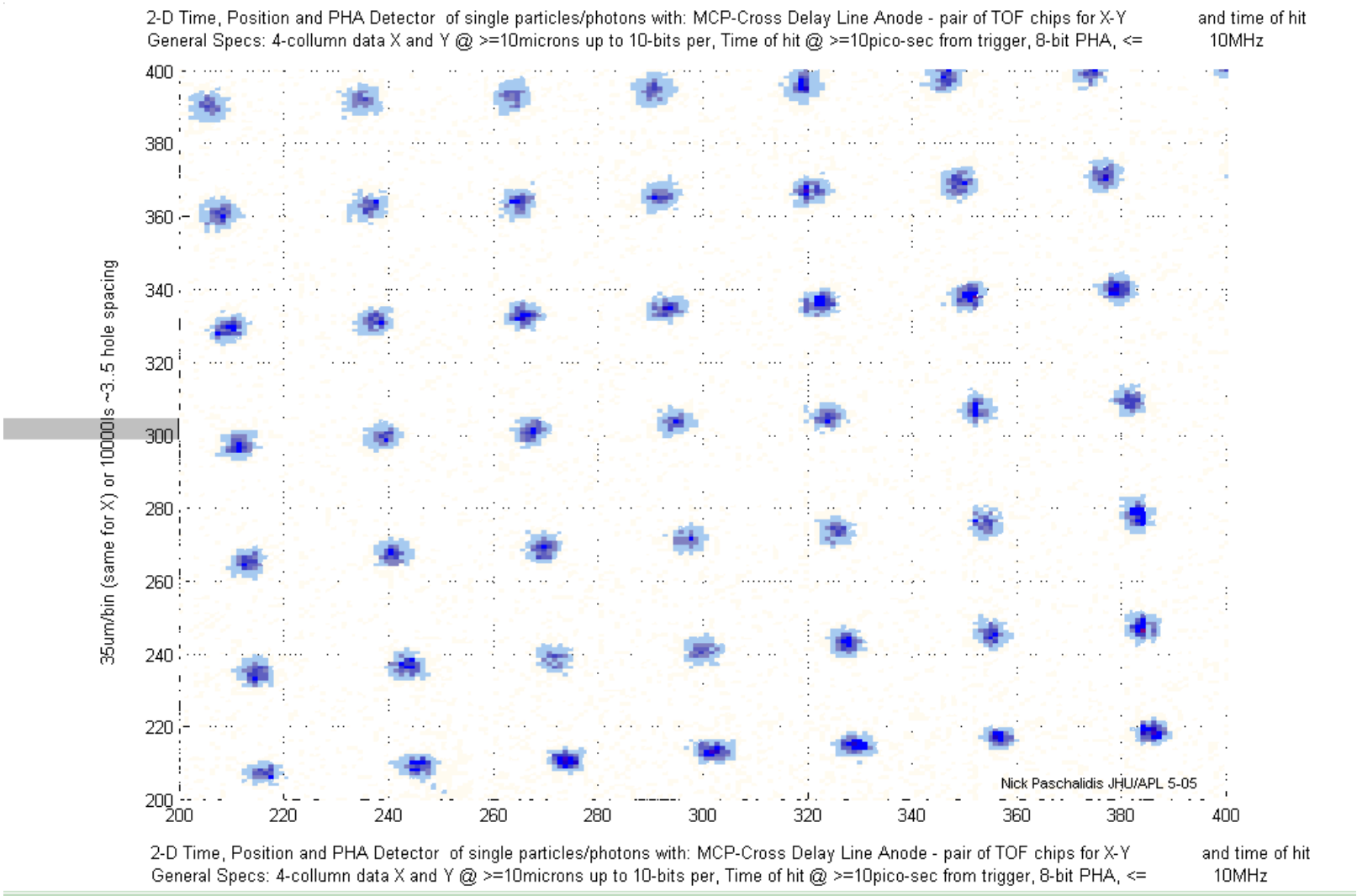
X-Y position measurements

Spacing of mask Holes 1mm

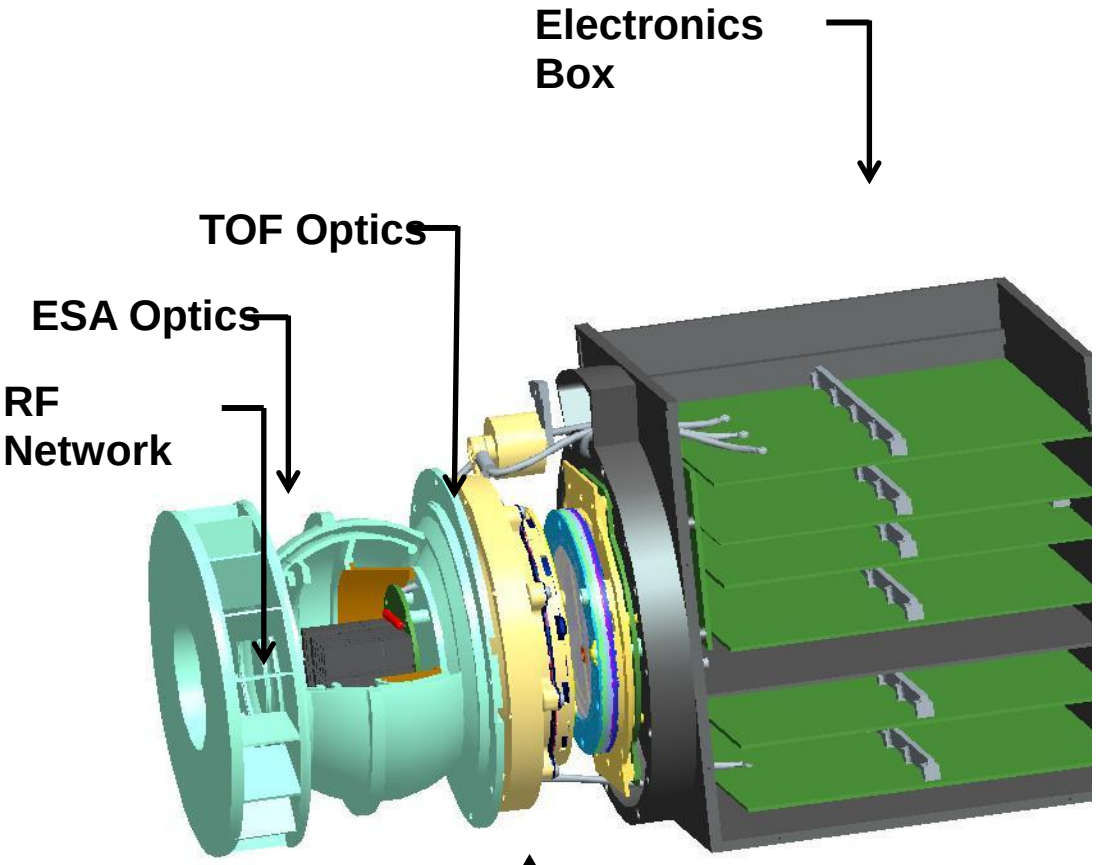


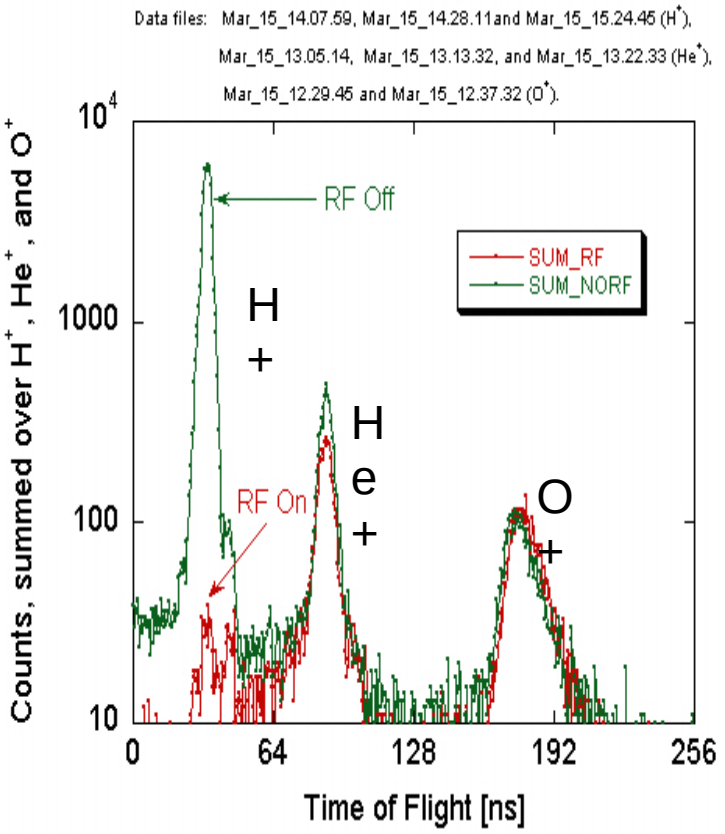
X-Y position measurements

Spacing of mask Holes 1mm

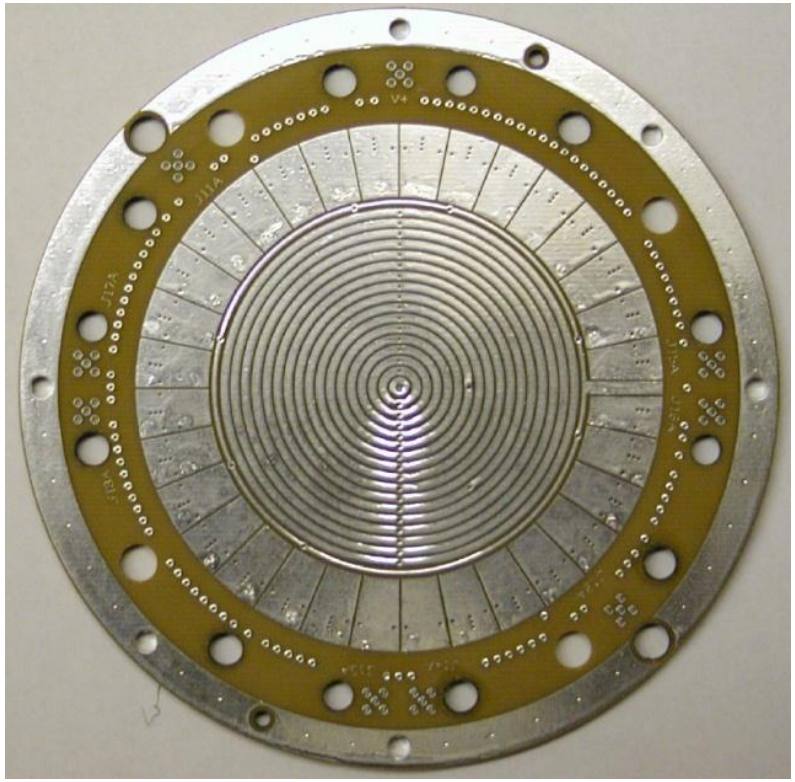


The Smart/HPCA Plasma Instrument
Lead Organization SWRI





Photos of the HPCA Anode / FEE board



Anode Side

APENDIX
Design and Space Qualification of ASICs

- Design approach for Micro-systems
  - VLSI technologies
  - Mixed signal Analog-Digital Processing
  - Low Noise analog and fast digital on the same chip
  - System on a Chip includes all necessary support circuits for signal processing, interfaces and command/telemetry
  - Design for testability
  - Chip-on-board implementation of systems
- Issues to be addressed
  - Total Radiation Dose
  - Single Even Upsets
  - Single Event latch-up
  - Space Qualification

- Radiation Effects in Semiconductor Devices and ICs
  - Total Ionizing Dose (TID) effects in MOS Devices
    - Transistor level
      - Threshold voltage shifts due to trapped holes in gate SiO2 layers
      - Drive current shifts
      - Carrier mobility reduction
      - Parasitic leakage currents due to NMOS subthreshold, and parasitic field NMOS transistor conduction
    - Circuit level
      - Performance degradation of analog functions
        - Voltage/current offsets, bandwidth, gain, and stability
        - Lost functionality
      - Performance degradation of digital functions
        - I/O parametric and noise margin shifts
        - Data loss and lost functionality