UNIVERSITY OF HOUSTON

Learning. Leading.

Summary of HIMAC Measurements with the TimePix version of the Medipix2-Based Detectors and Preparation for the First Flight of Medipix in Space

Lawrence Pinsky

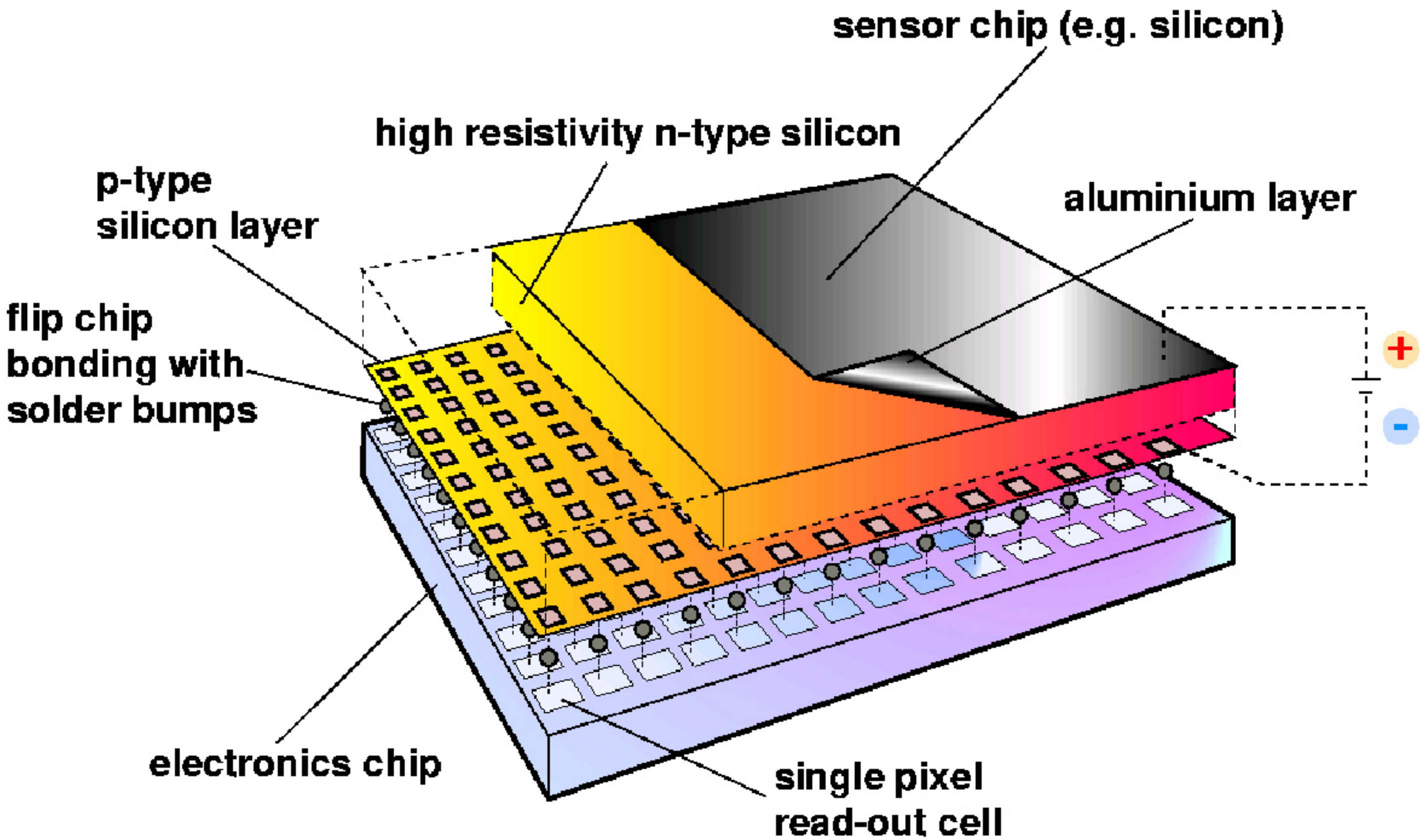
Physics Department

University of Houston

L. S. Pinsky [1*], A. Empl, J. Jakubek [3], H. Kitamura[4], C. Leroy[2], N. Stoffle[1], S. Pospisil[3], Y. Uchihori[4], N. Yasuda[4]

[1] University of Houston, USA.
[2] University of Montreal, Canada.
[3] Institute of Experimental and Applied Physics, Czech Technical University in Prague, Czech Republic.
[4] National Institute for Radiological Sciences, Chiba, Japan.

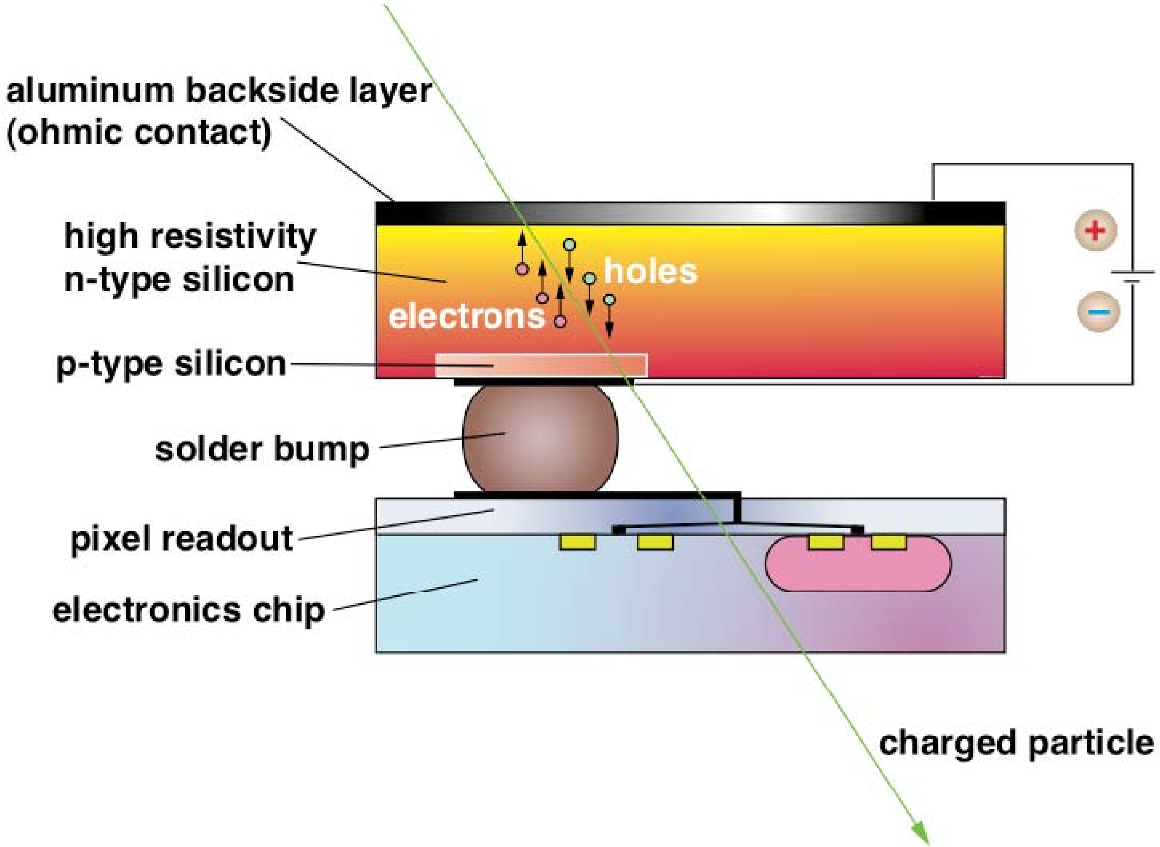
Hybrid Pixel Detector



Detector and electronics readout are optimized separately

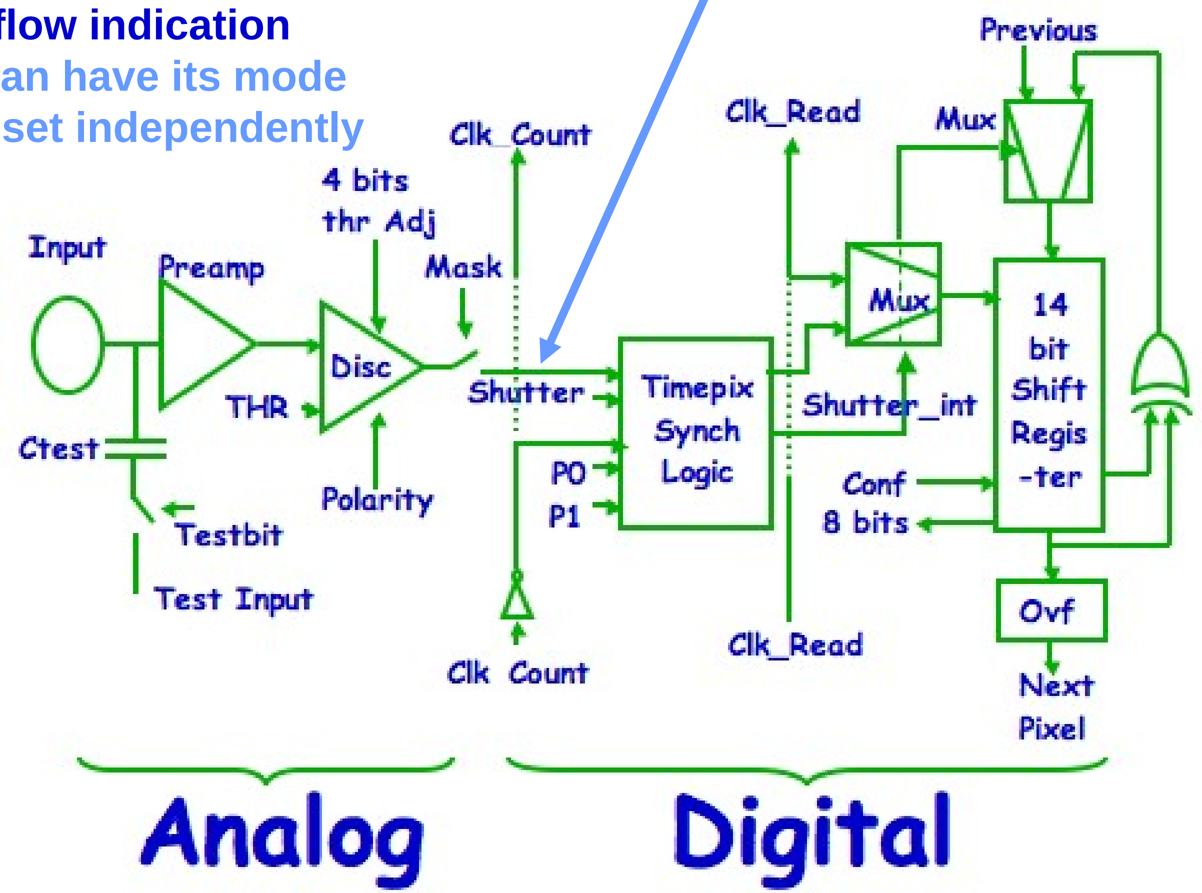
Hybrid Pixel Detector - Cross Section

UH is currently working on epitaxial deposition techniques that will facilitate the creation of high efficiency Embedded-Neutron-Converter detectors

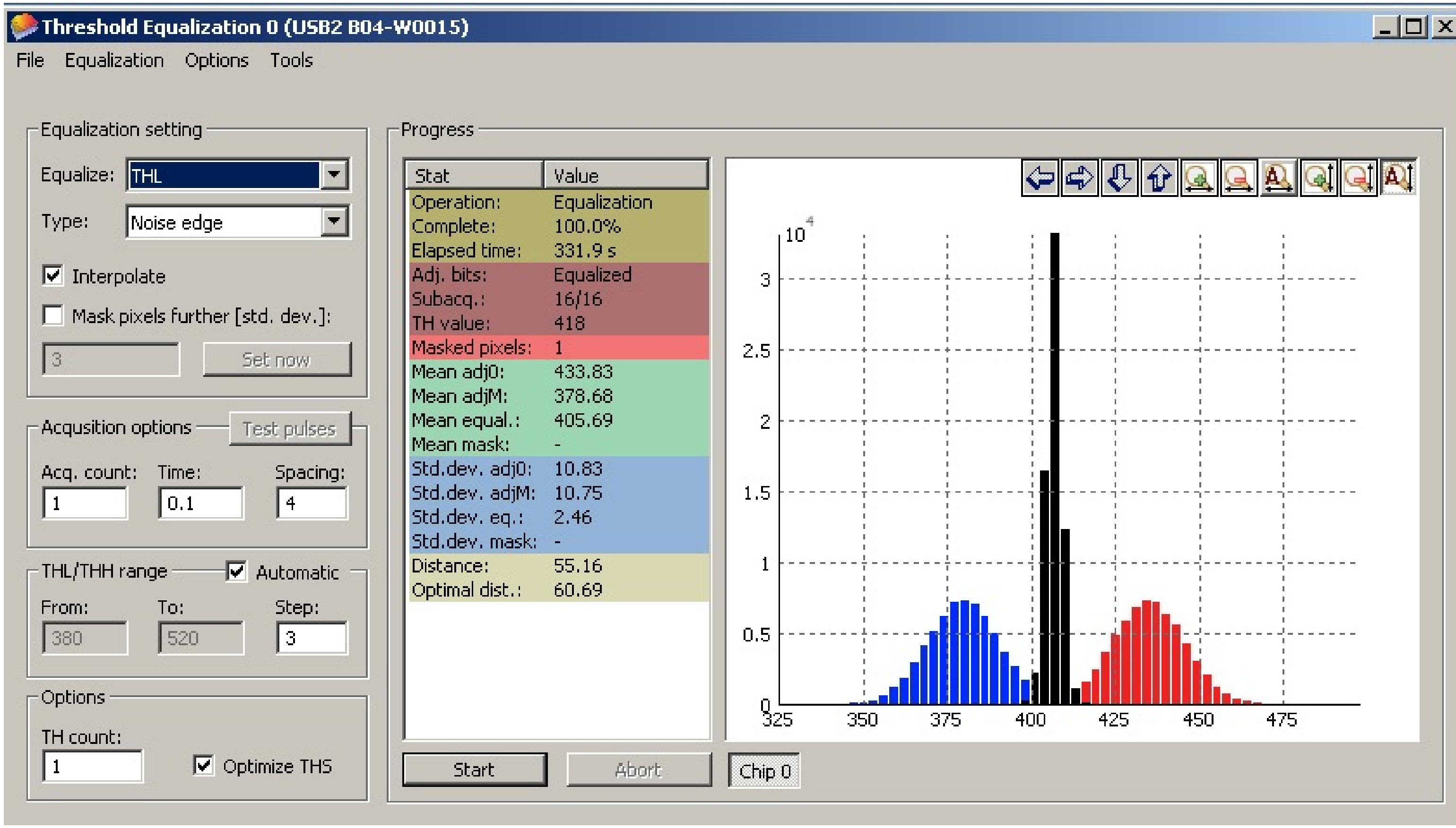


TimePix Cell Schematic

- **Charge sensitive Preamp/Shaper w/ individual leakage current compensation**
- **Discriminator with globally adjustable thresholds & individual 4-bit fine tuning offset**
- **Individually settable test and mask bits for each pixel**
- **External shutter activates the counter (can be as short as 10 ns,**
- **but 100 ns is the practical limit)**
- **14-bit output register (11,810 decimal)**
- **…with Overflow indication**
- **Each pixel can have its mode (ADC or TDC) set independently**



TimePix Threshold Calibration

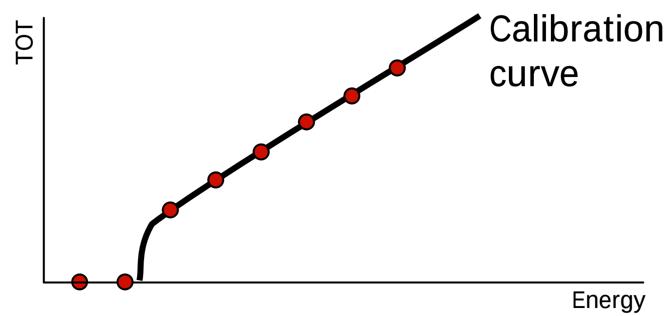


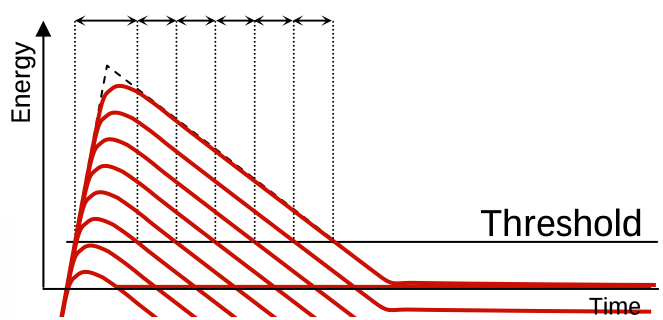
- Calibrates the 4-bit (16 level) Threshold Offsets for each pixel. The RED histogram is the distribution of noise turn-on points with all bits set to high. The BLUE histogram is the corresponding low setting. The BLACK histogram is the corrected result. Each channel is ~20 e$^-$…

TimePix and its TOT mode

Counter in each pixel can be used as

- **Timer** to measure detection time => TOF experiments, TPC detectors, ...
- Wilkinson type **ADC** to measure energy of each particle detected.

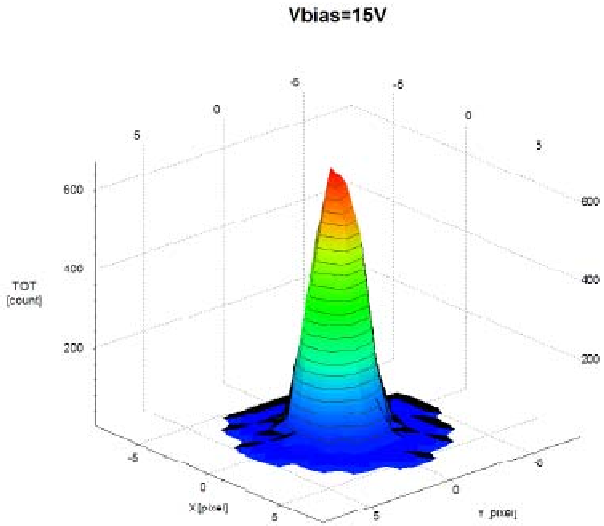


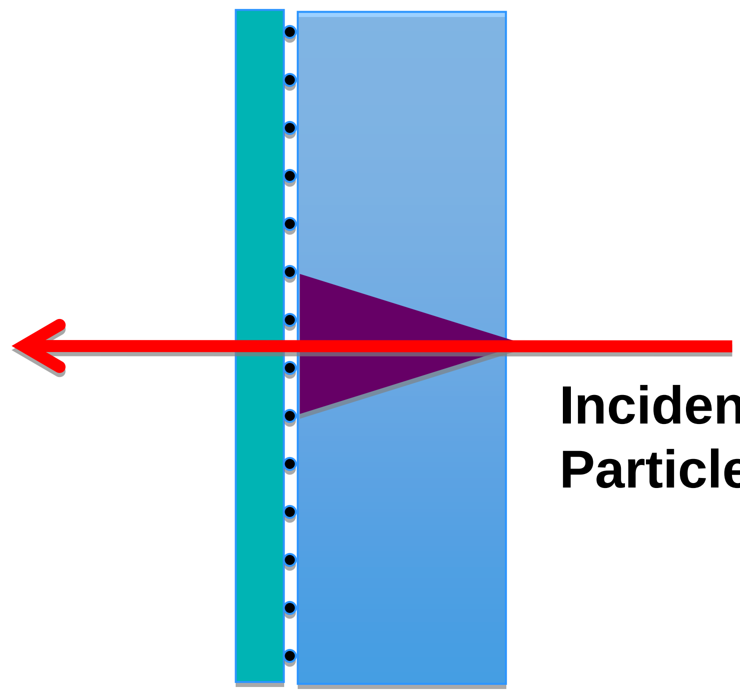


- **If the pulse shape is triangular then Time over Threshold is proportional to collected charge i.e. to energy.**
- **Due to limited bandwidth the pulse can be NEVER perfectly triangular.**
- **Non-linear TOT to energy dependence**

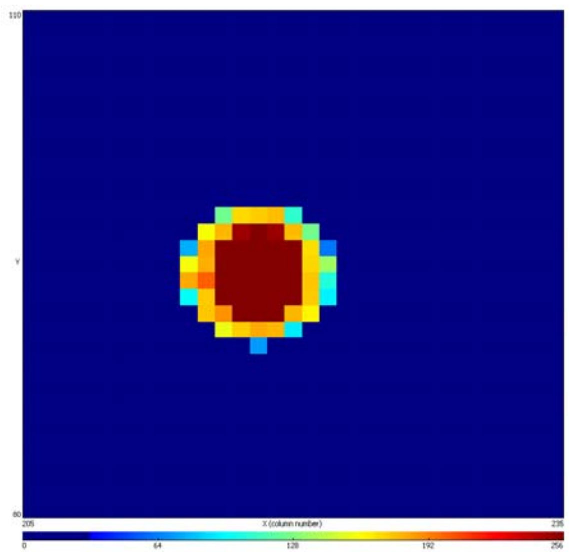
Charge Clusters

The electron-hole pairs liberated by traversing moving charges drifts in the bias voltage and also diffuses during the process, creating a multi-pixel cluster.





“PIXELMAN” Image



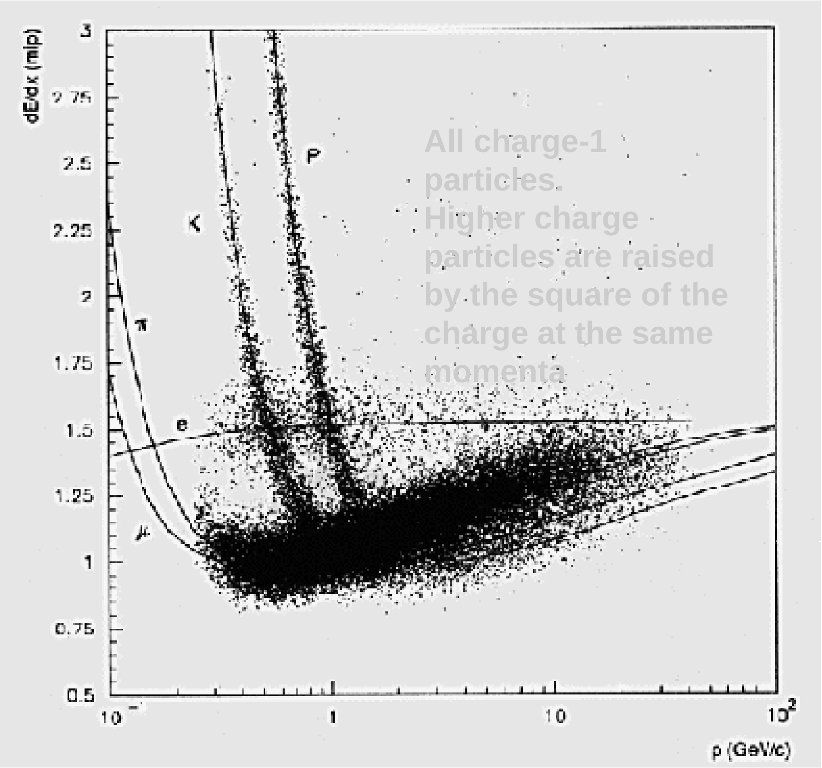
Dosimetry in Space

- Our approach is to try and Characterize the Radiation Field as precisely as possible as a function of time.
- To do that, we need to assess the radiation environment in terms of the Charge AND Energy of the individual particles that are present.
- …HOWEVER, because of the "Z^2 effect" and the shape of the energy-loss curves, it is possible for different ions to have the same dE/dx in a thin detector…
- Slow lower-Z particles seen in the dosimeter will not penetrate deeply into the body, and can be mimicked by higher-Z faster particles, which CAN penetrate deeply…
- SO, again, "Our approach is to try and Characterize the Radiation Field as precisely as possible as a function of time."

Measuring Charge AND Energy

- **If you know β then measuring the charge is reasonably simple because of the Z^2 dependence.**
- **In accelerator experiments the interaction fragments from the projectile particle is generally moving at close to the projectile's original velocity, at least for forward fragments.**
- **However, if you have no *a priori* velocity information, the problem is the *BETHE-BLOCH Equation*… (One can observe the behavior over a longer distance, or look for track structure differences…)**

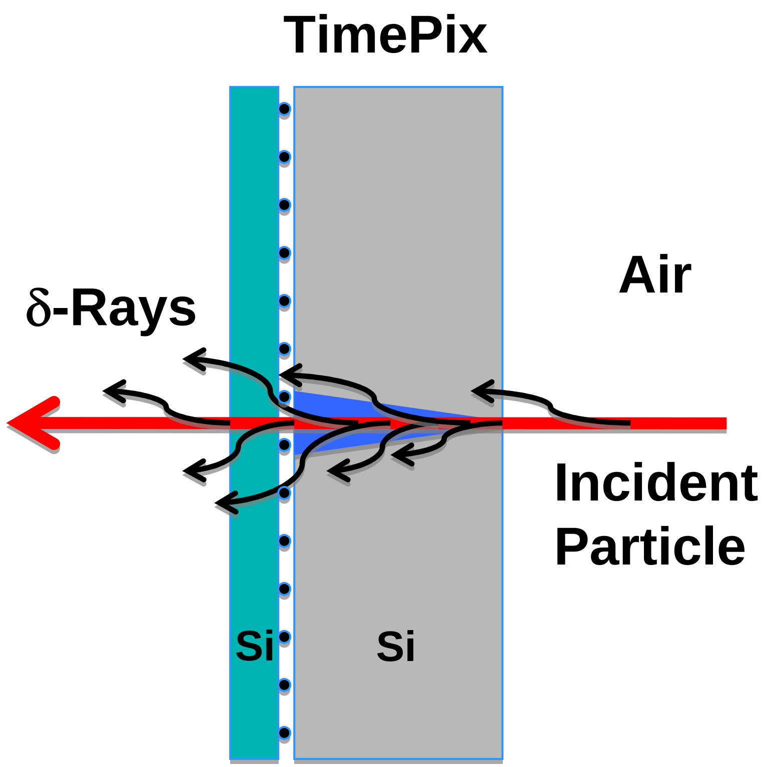
$$-\frac{dE}{dx} = \frac{4\pi}{m_e c^2}\cdot\frac{nz^2}{\beta^2}\cdot\left(\frac{e^2}{4\pi\varepsilon_0}\right)^2\cdot\left[\ln\left(\frac{2m_e c^2\beta^2}{I\cdot(1-\beta^2)}\right)-\beta^2\right]$$



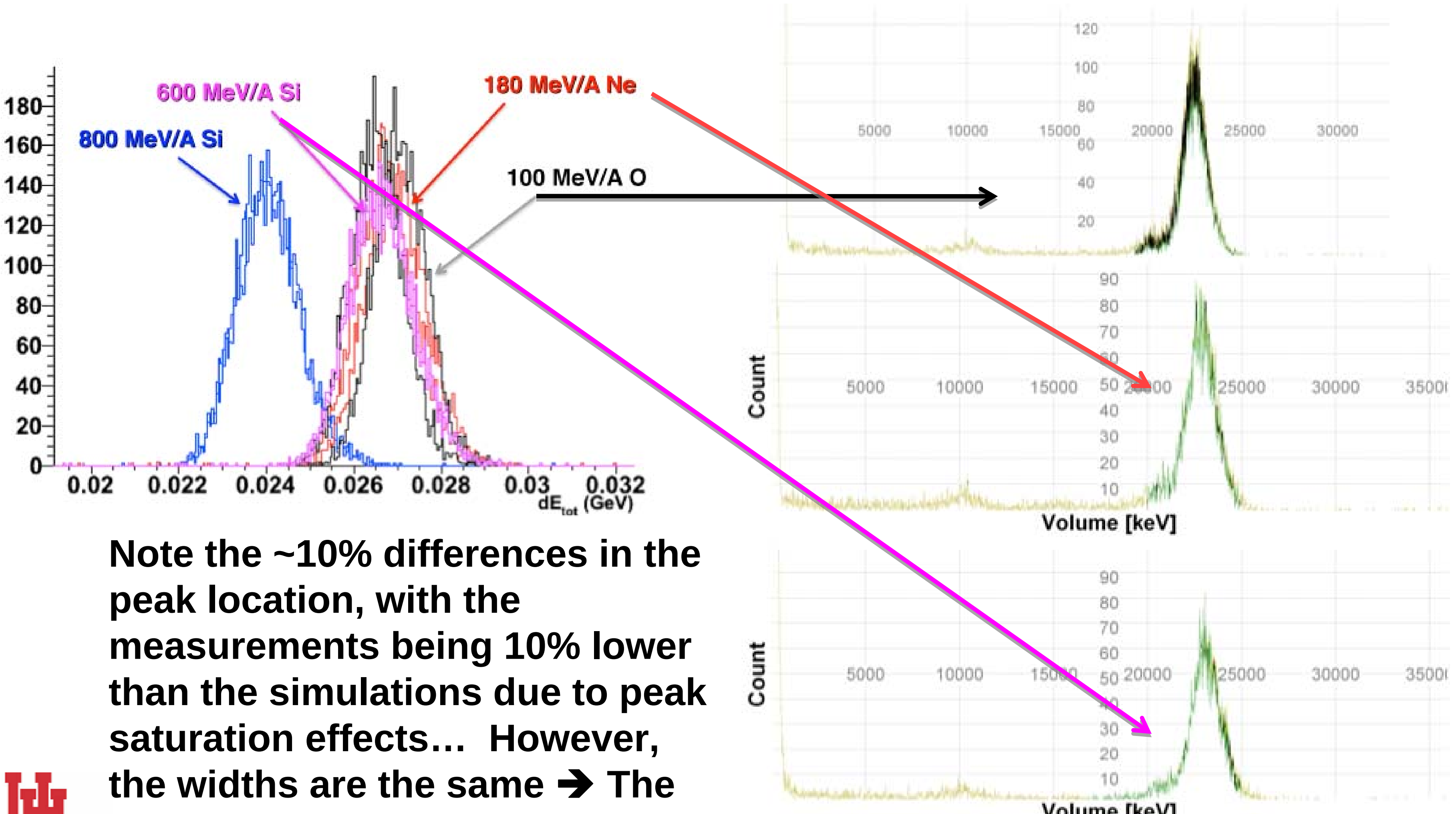
UNIVERSITY OF HOUSTON
Learning. Leading.

Also, dE/dx ≠ LET (High Energy δ-Rays)

- Because the number of δ-rays produced per unit track length in the Air prior to entering the Si is much less than in the the Si…
- …The highest energy δ-rays carry away more energy from the Si than enters from the air.
- HOWEVER—It is the High Energy δ-rays that offer the prospect of telling the difference between the different particle velocities with the same dE/dx…

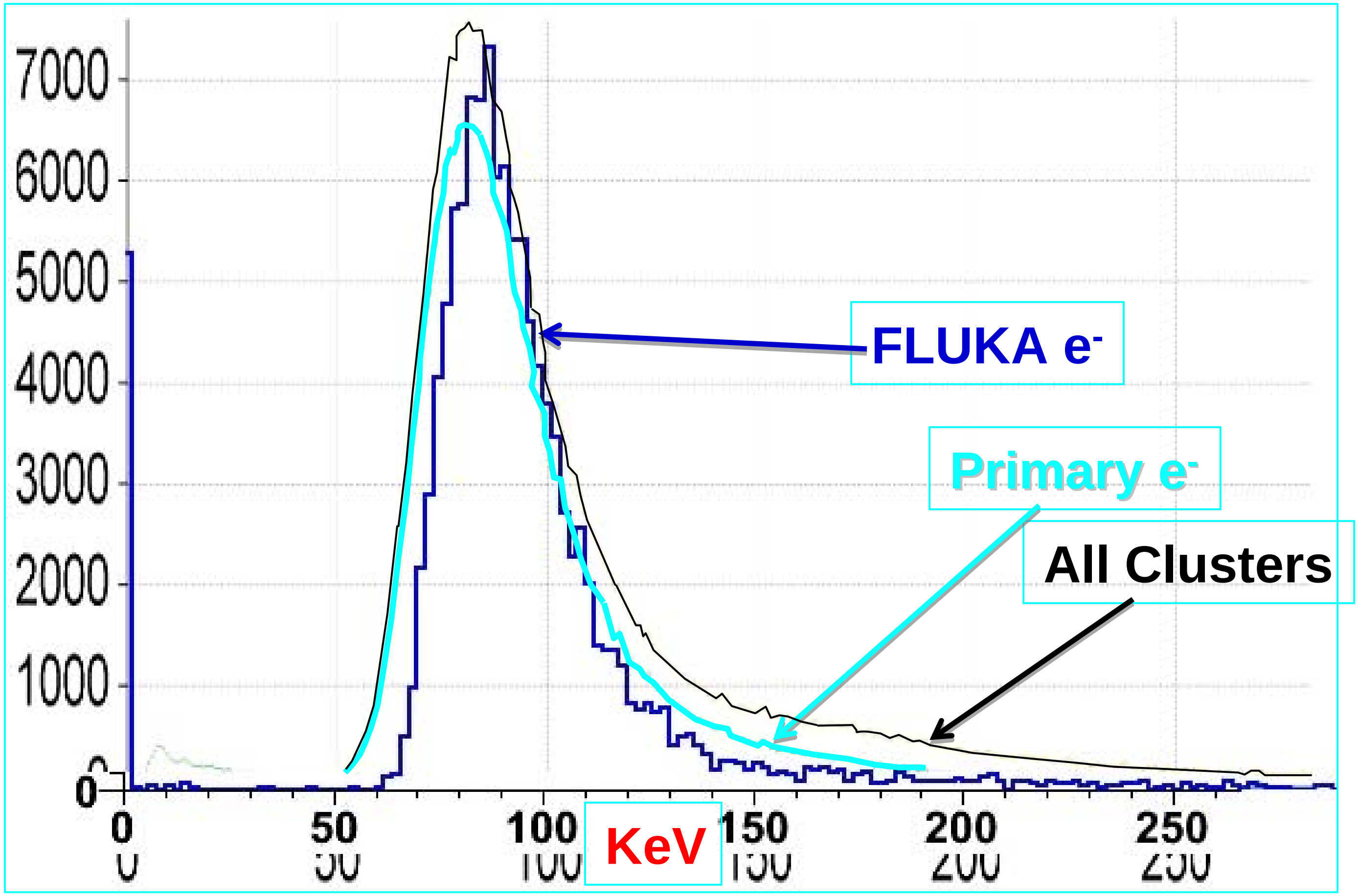


FLUKA Medipix (TimePix)Heavy Ion Simulations



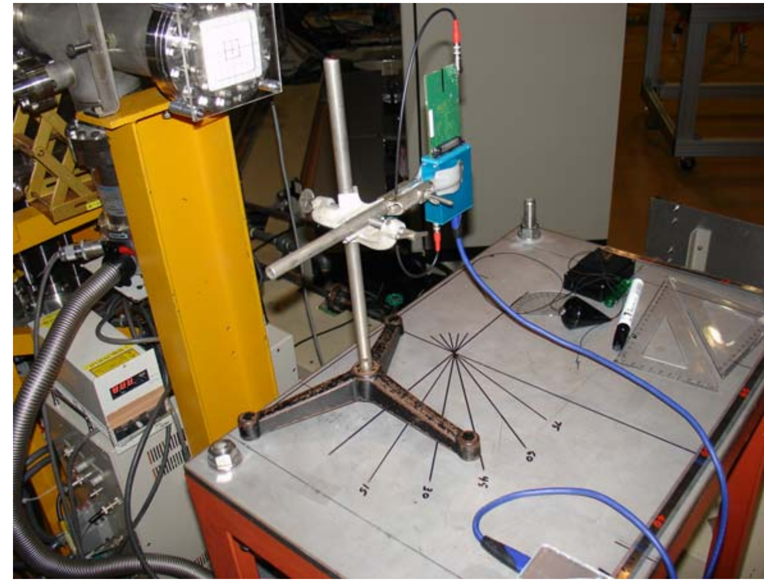
Note the ~10% differences in the peak location, with the measurements being 10% lower than the simulations due to peak saturation effects… However, the widths are the same ➔ The *Saturation* effects are common…

23 MeV e- Measurements @ IAC with the TimePix v. FLUKA



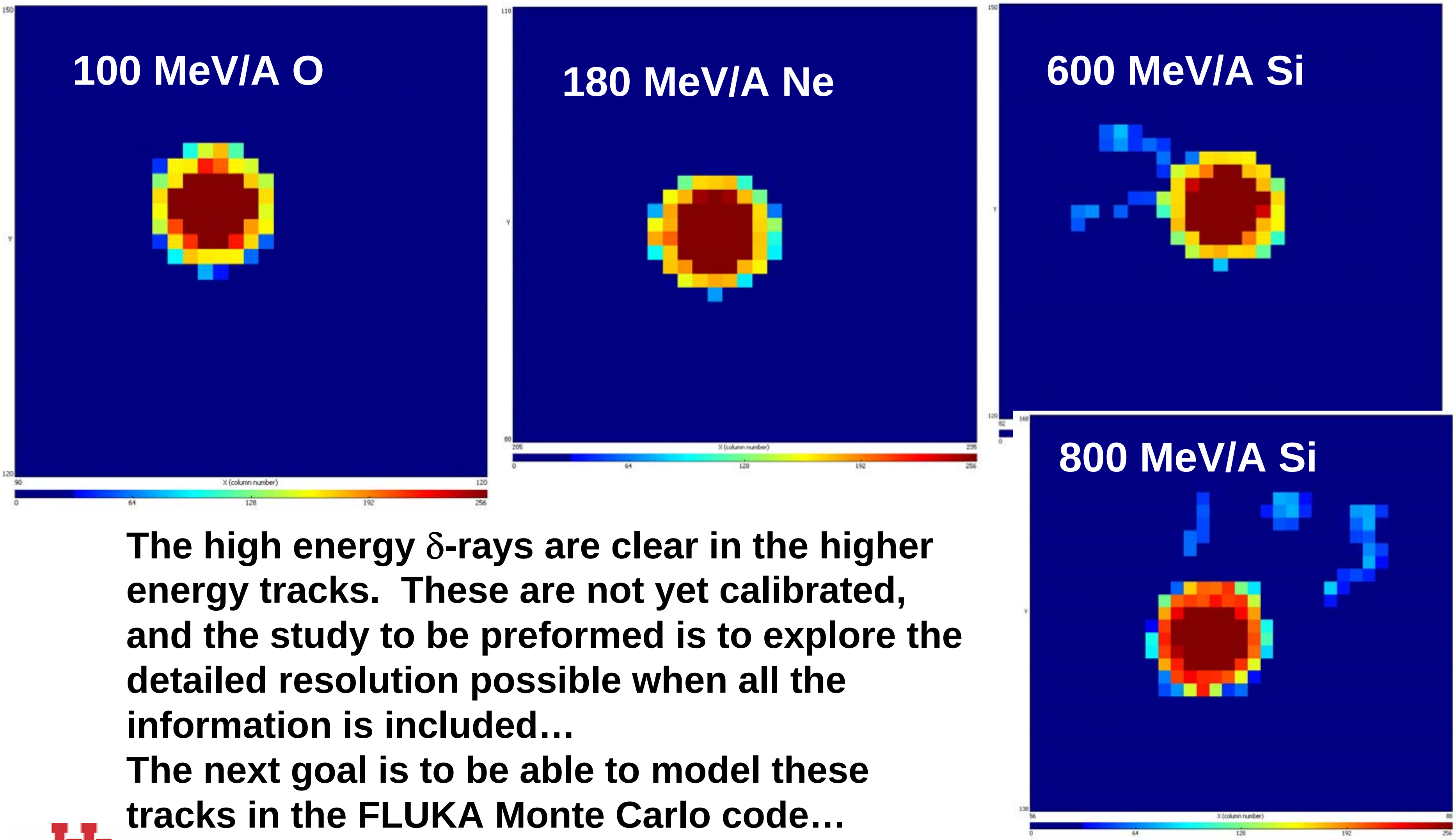
TimePix in the HIMAC Beams

- Data have been taken at HIMAC in some dedicated and many parasitic runs…
- Runs at a range of incident angles and with different detector settings are typically taken…
- The primary beams were (MeV/A):
  - ^{1}H (p) 160
  - ^{4}He 180 & 230
  - ^{12}C 230
  - ^{14}N 180 & 290
  - ^{16}O 100 & 230
  - ^{20}Ne 180, 430 & 600
  - ^{28}Si 400, 600 & 800
  - ^{56}Fe 500



KE (MeV/u)=>	100.00	180.00	230.00	290.00	350.00	400.00	430.00	500.00	600.00	650.00	800.00
He (KeV/μm)	5.42	3.60	3.09								
He (KeV)	231.14	433.00	566.81								
C (KeV/mm)	48.74	32.43	27.81	24.32	22.02	20.63	19.96				
C (KeV)	231.19	433.09	566.94	735.32	912.18	1066.04	1161.19				
N (KeV/mm)	66.34	44.14	37.85	33.10	29.97	28.09	27.17				
N (KeV)	231.19	433.10	566.95	735.33	912.20	1066.06	1161.21				
O (KeV/mm)	86.85	57.65	49.43	43.24	39.15	36.68	35.49				
O (KeV)	231.19	433.10	566.95	735.34	912.21	1066.08	1161.23				
Ne (KeV/mm)	135.38	90.08	77.24	67.56	61.17	57.32			48.55		
Ne (KeV)	231.20	433.11	566.96	735.36	39.65	1066.10			1740.46		
Si (KeV/mm)	265.35	176.55	151.39	132.41	119.89	112.35			95.15		87.18
Si (KeV)	231.20	433.12	566.97	735.37	912.25	1066.12			1740.51		2309.10
Ar (KeV/mm)		*291.85		218.88		185.71				153.11	
Ar (KeV)		433.13		735.38		1066.14				1923.86	
Fe (KeV/mm)		*608.92		*456.68		387.48		351.51			
Fe (KeV)		433.13		735.39		1066.15		1391.58			

Examples of Individual (Normal Incidence) "Tracks"

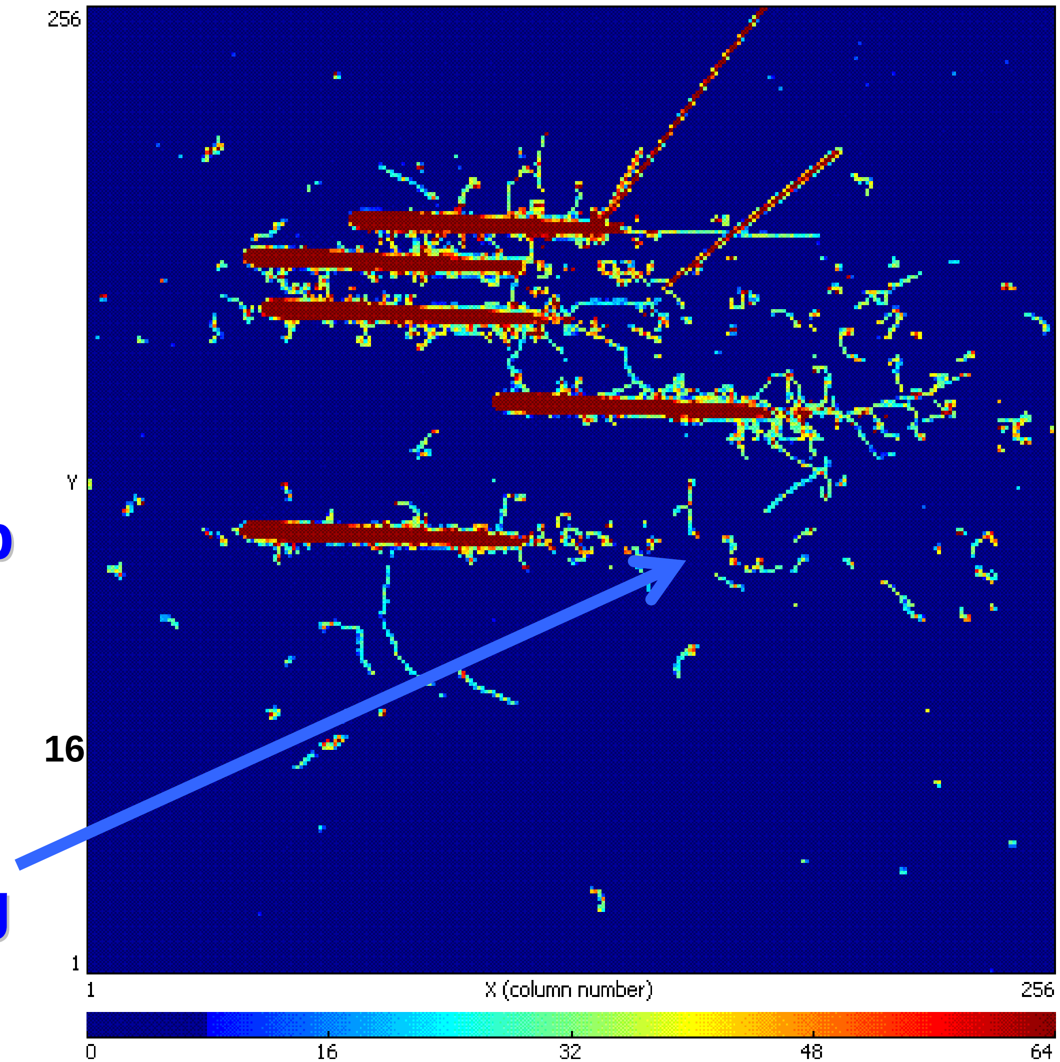


The high energy δ-rays are clear in the higher energy tracks. These are not yet calibrated, and the study to be preformed is to explore the detailed resolution possible when all the information is included…

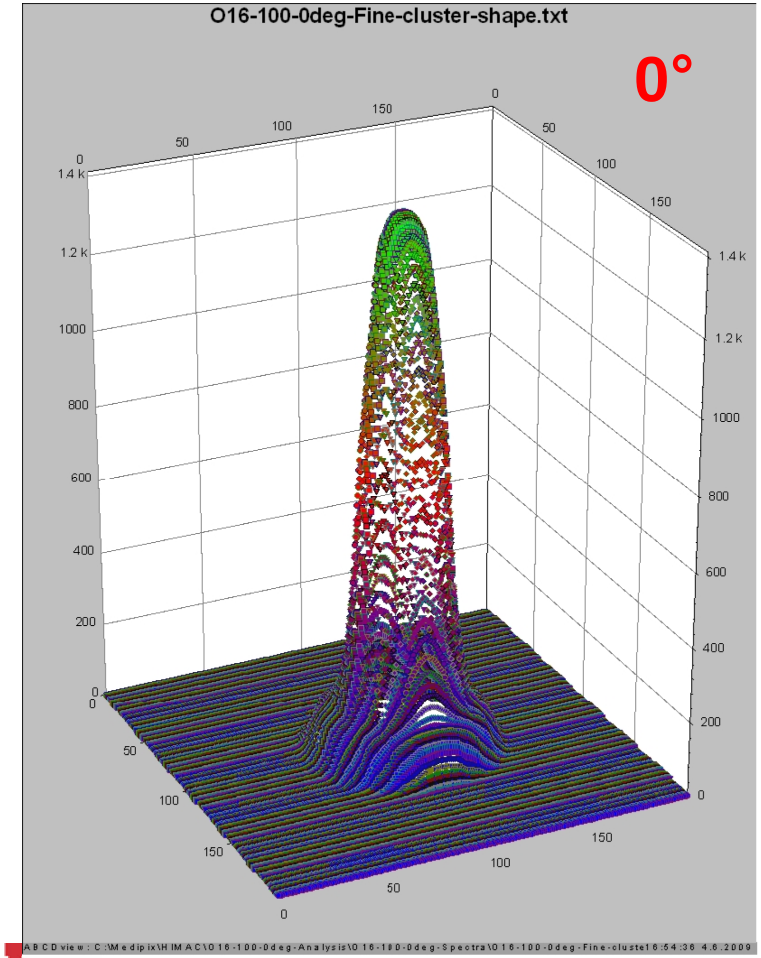
The next goal is to be able to model these tracks in the FLUKA Monte Carlo code…

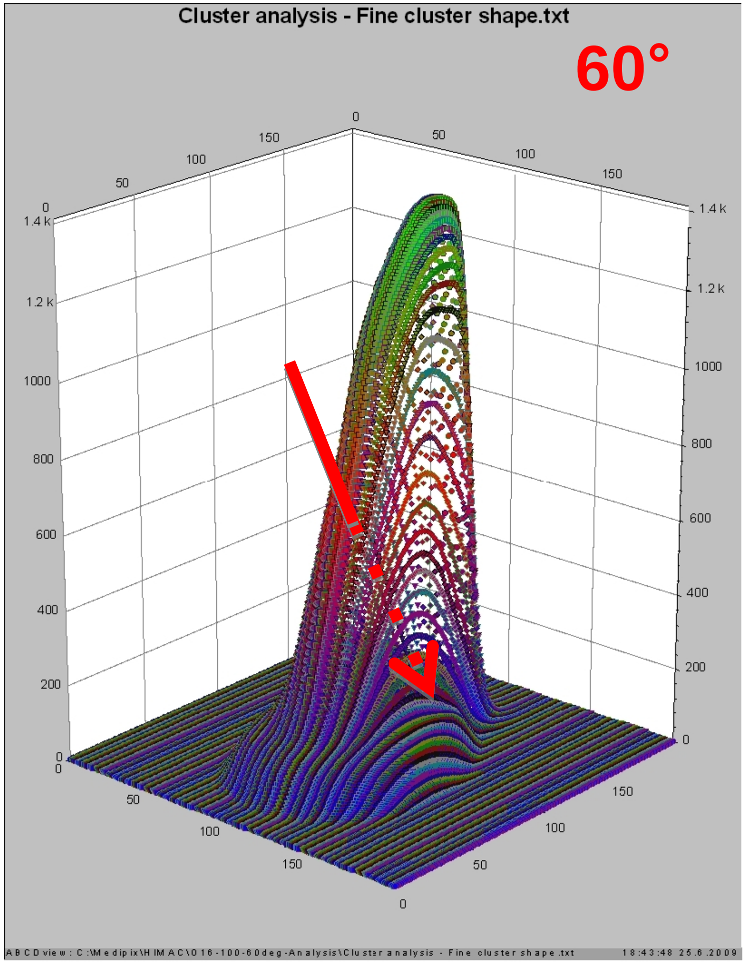
800 MeV/A Si 85 degree Tracks

- The tracks are from particles diving downward from left to right.
- As they pass though the solder-bumps and into the underlying chip after leaving the Si detector layer.
- Some of the high energy δ-rays from the chip enter the overlying detector layer…

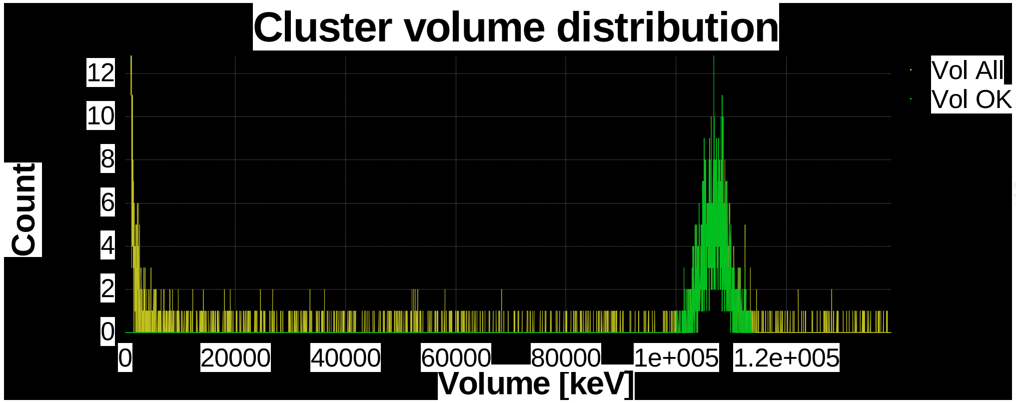


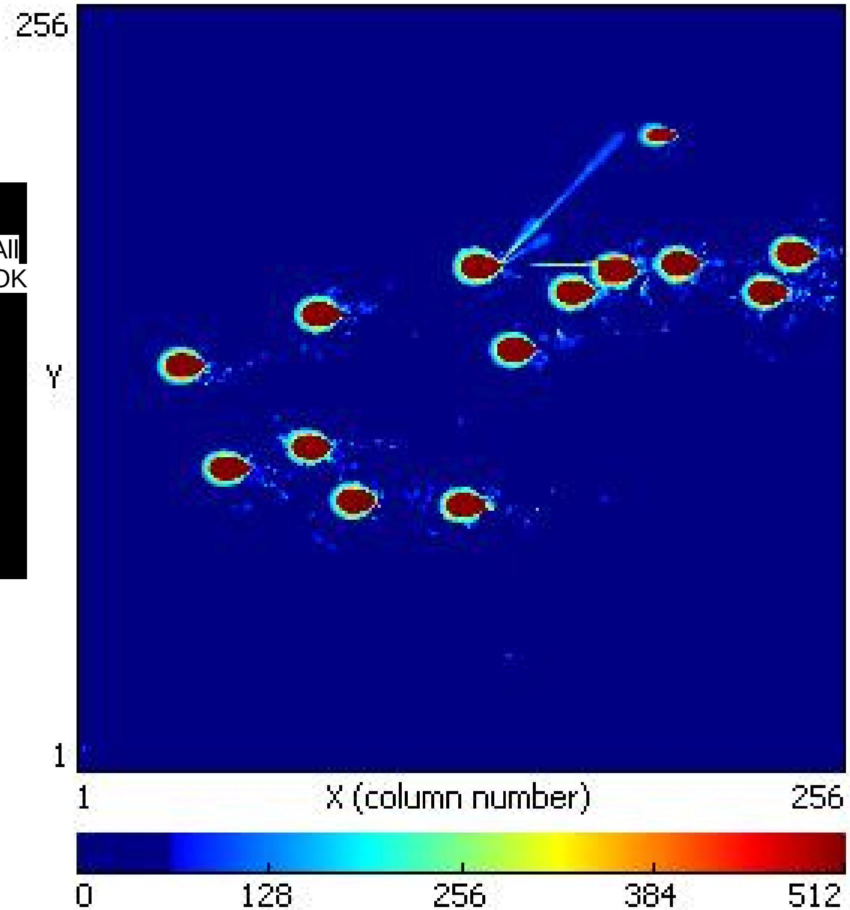
^{16}O @ 100 MeV/A—0° & 60° Averaged Cluster Shapes (Azimuthal & Polar Angle resolution ~ 1 Degree)



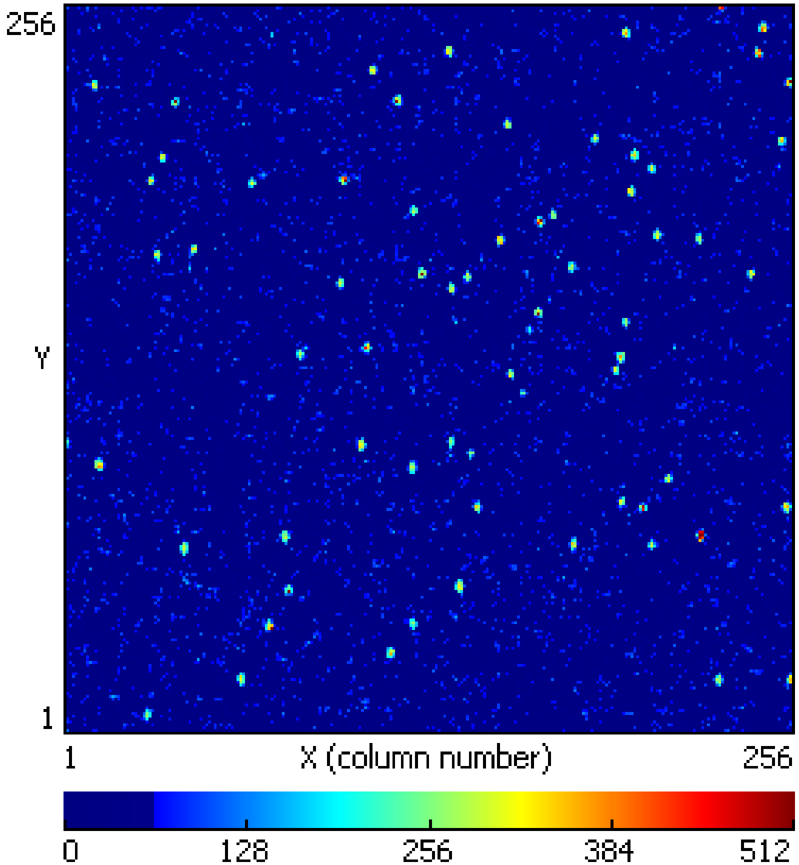


^{56}Fe 60 degree Runs…



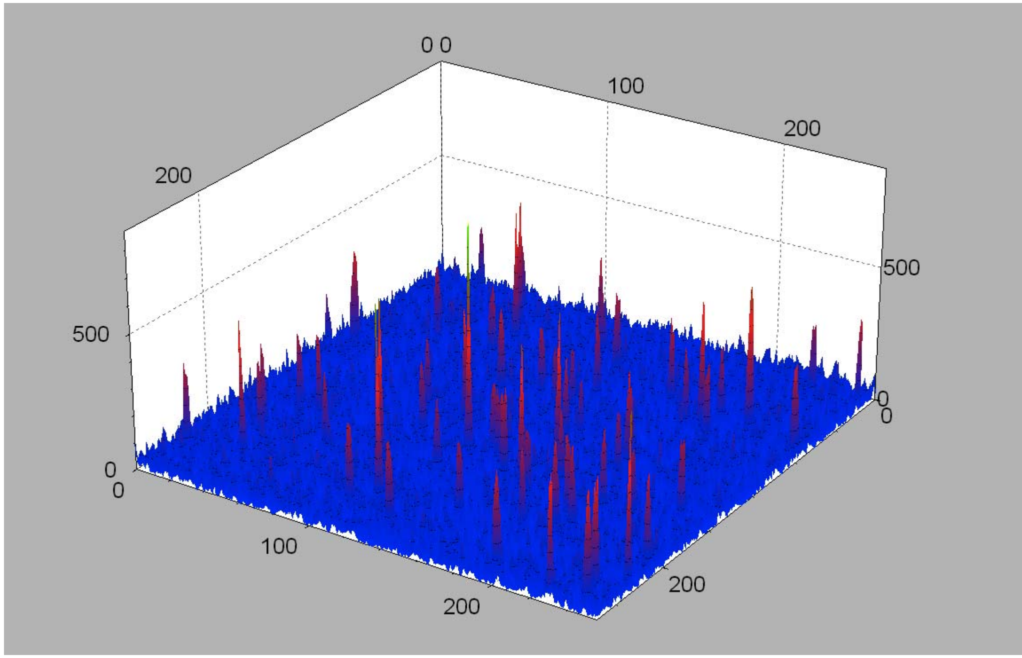


Background Radiation @ Daya Bay(An Underground Neutrino Oscillation Experiment Being Constructed Near Hong Kong



This is an Integral of the sum of all pixels for the May 20, 2010 Hall 5 run: (83280 sec = 23.13 hours)

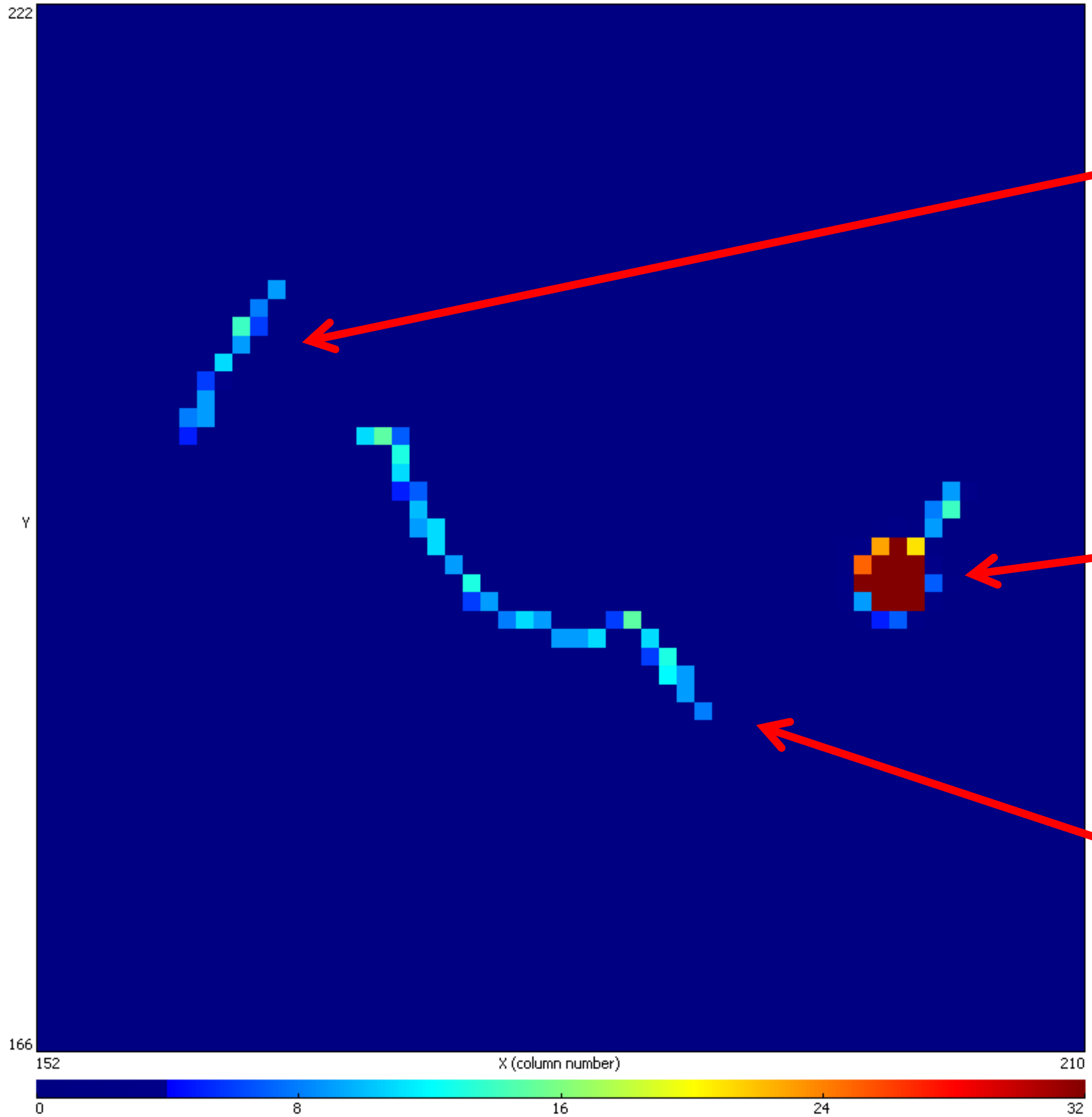
The heavily ionizing tracks are from Radon-Chain Alphas…



The plot has a high relative threshold to suppress the MIPs

The Pattern Recognition analysis takes into account the shape and energy per pixel as well as the integral energy in the total track cluster…

3 Prevalent Event Types in Daya Bay Hall 5



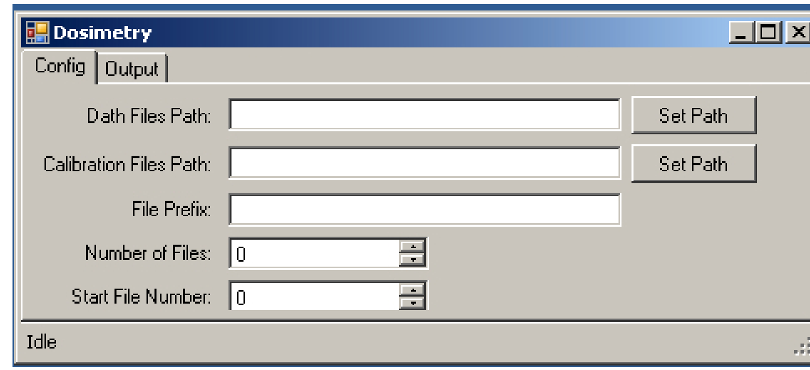
Penetrating Muon
Total Cluster Energy
< 120 Raw Counts
(angle dependent)

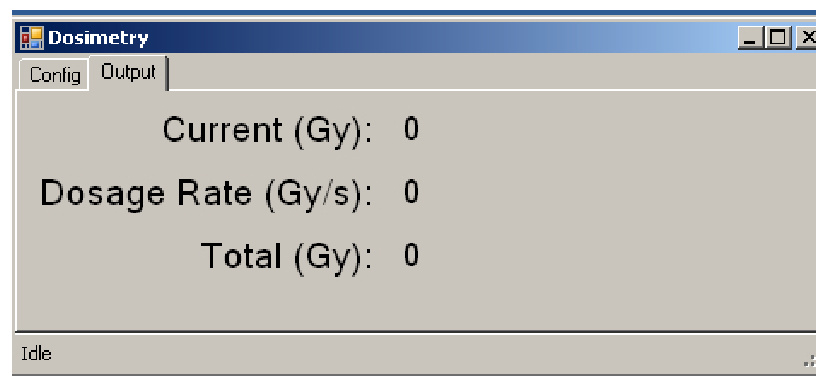
Alpha (Radon Chain)
Total Cluster Energy
> 1000 Raw Counts

Electron (γ Compton)

Dose and Dose Equivalent Calculating Plug-Ins

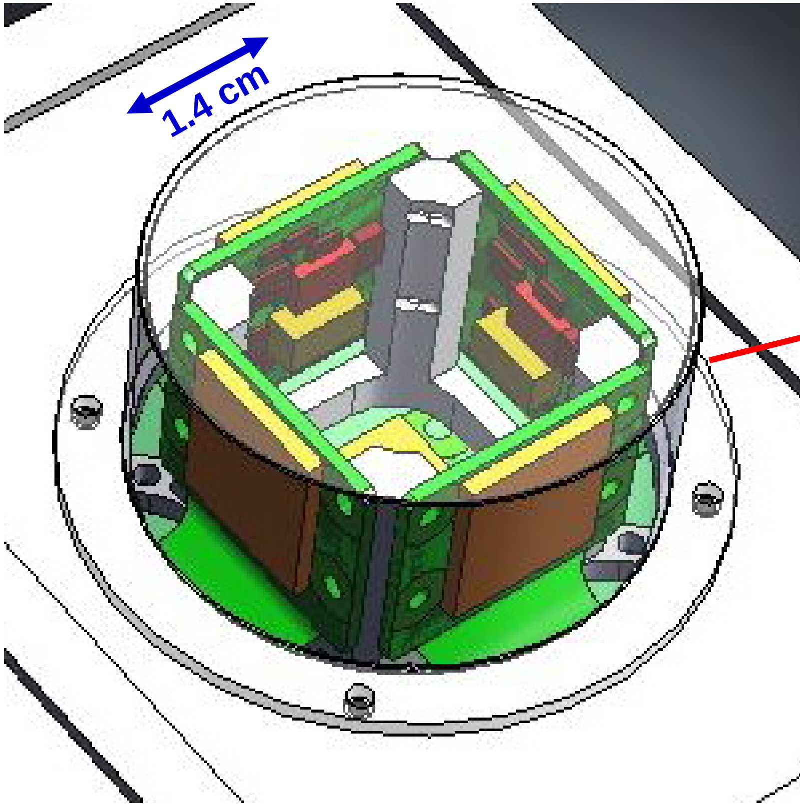
- **At the request of SRAG, we have developed a Dose-Calculating "Plug-In" that currently reads the raw output files each time a TimePix Frame is created.**
- **The Plug in has a basic cluster-finder algorithm and it will calculate and display the Dose and Dose Eq. (in tissue) for each frame.**
- **Since it has direct access to the Frame duration, it can also display the Dose rates, both total and decayed…**

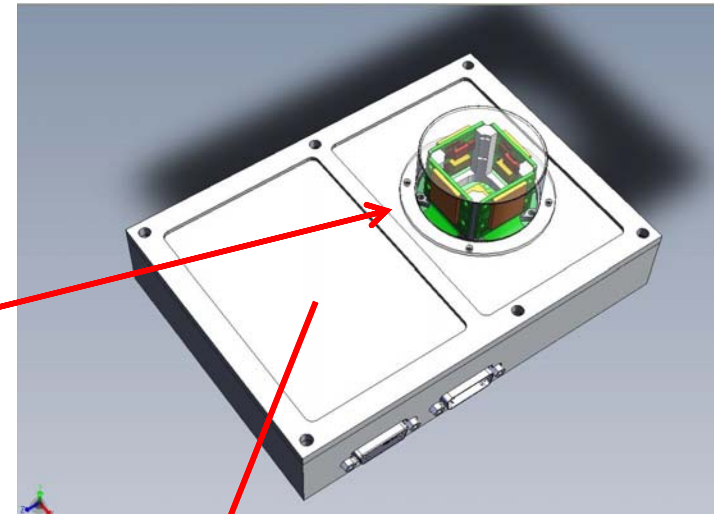


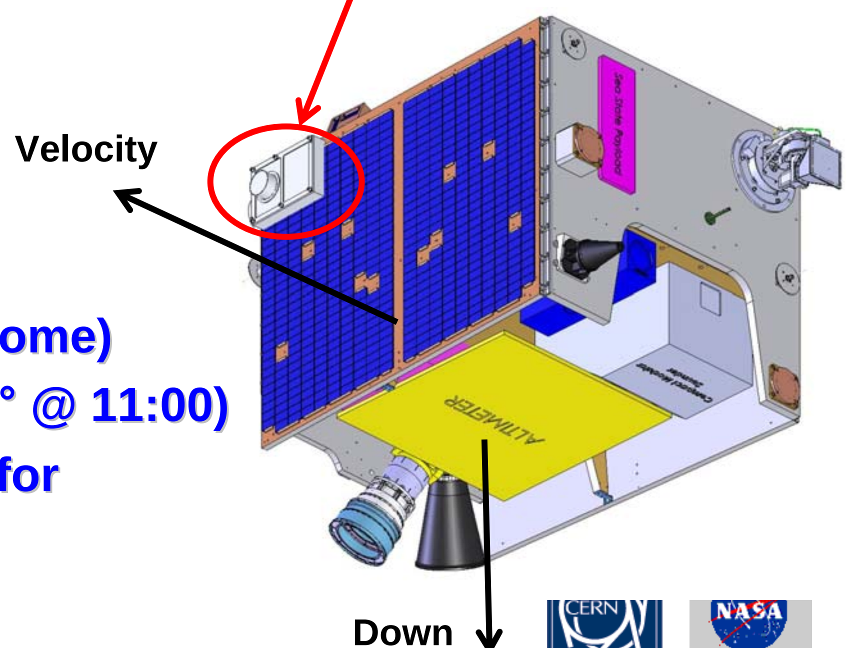


LUCID – *Langton* Ultimate Cosmic ray Intensity Detector

TimePix's First Space Mission—Educational Outreach
(UK Satellite to be Launched Q1—2012)



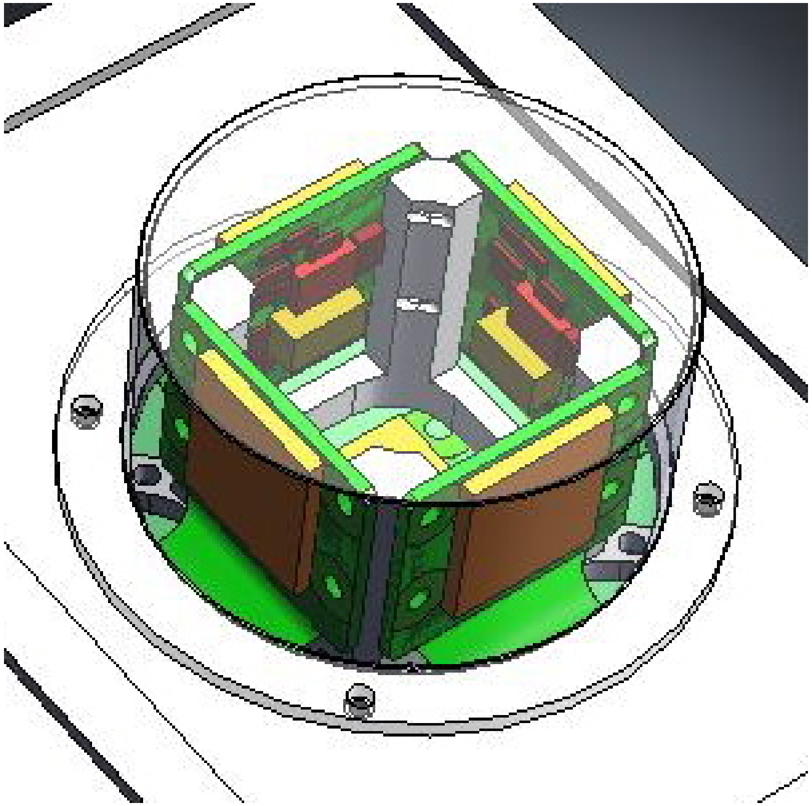




- 5 TimePix Detectors (0.7 mm Al dome)
- Sun-Synchronous Polar Orbit (98° @ 11:00)
- Programmable Signal Processor for
  on-orbit data analysis…

LUCID

- **Educational Outreach**
  - **PI is Becky Parker from the Langton School in Canterbury, UK.**
  - **Data will be available in Daily downloads to High School groups worldwide via the Web…**
  - **Online analysis tools will be provided…**
  - **Correlations with surface Cosmic Ray Detectors deployed in schools worldwide is possible…**



- **CERN@School**
  - **TimePix kits are being provided for laboratory use.**

Readout Hardware Improvements

- **USB-2 Interface is Available and in use.**
  - **80-100 Frames/s**
  - **Ready for Medipix3**

- **TimePix "Lite" is available as well…**
  - **< 10 g**
  - **Low Power**
  - **w/Signal Processor**
  - **Fully TimePix Compatible**
  - **Still USB 1.2 w/mini-USB connector…**

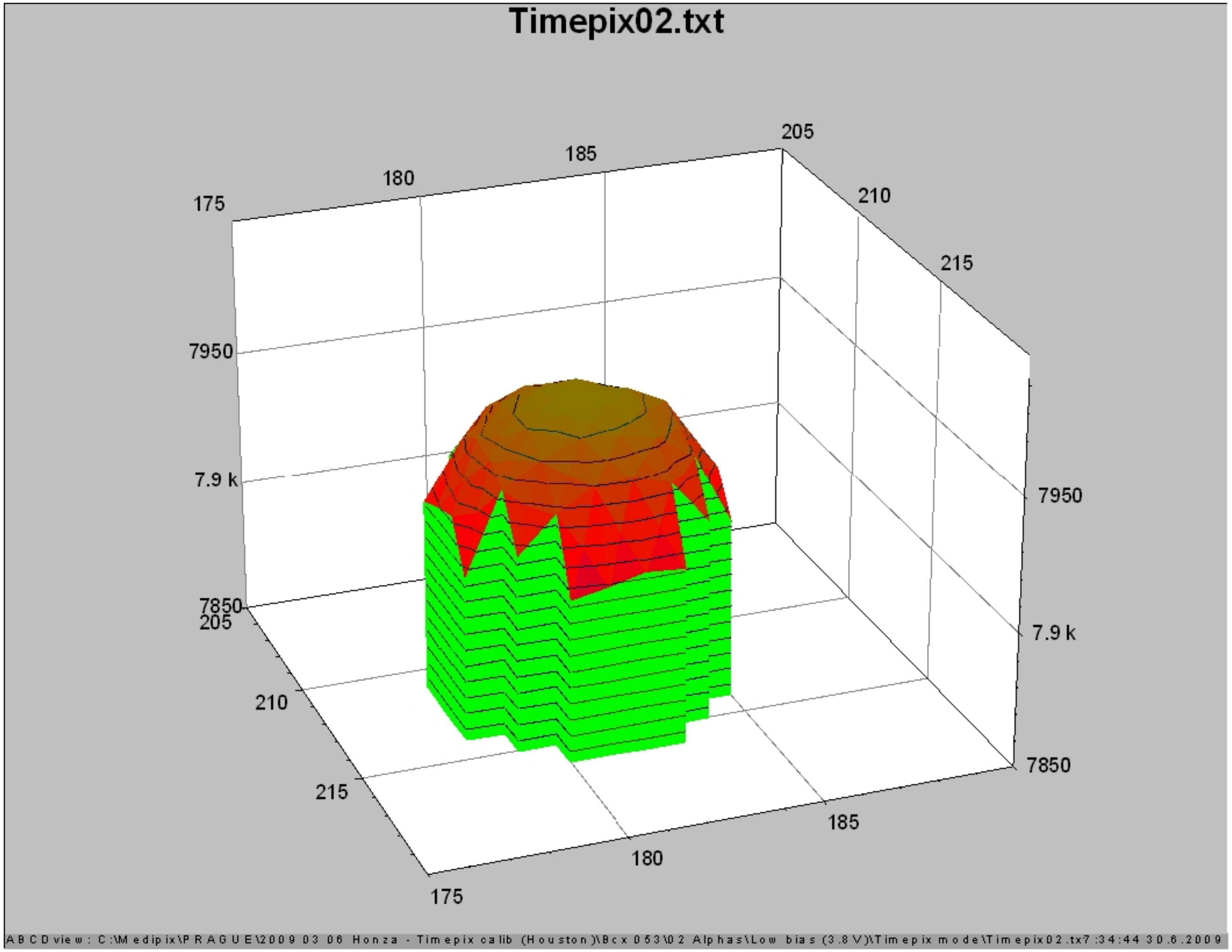
Medipix3 is Coming

- **Even more Rad-Hard!**
- **Dual Circuit Capability in EACH Pixel.**
  - **Either and ADC and a TDC simultaneously in each pixel…**
  - **Or, two ADCs with sequential use for 0 dead-time (< 100 ns)**
  - **Or, two ADCs with different Pre-Amp scales or responses…**
- **Linear and Log Pre-Amps Possible…**
  - **Eliminate Saturation Effects**
- **Smaller Pixel Sizes Possible**
  - **55μm → 25 μm**
- **Lower Noise**
- **On-Chip Output Clustering & Charge Centering**
  - **On Chip charge-sharing for sub-pixel position resolution**

Thank You for Your Attention

Charge Drift Cloud Image (^{241}Am 5.5 MeV α)

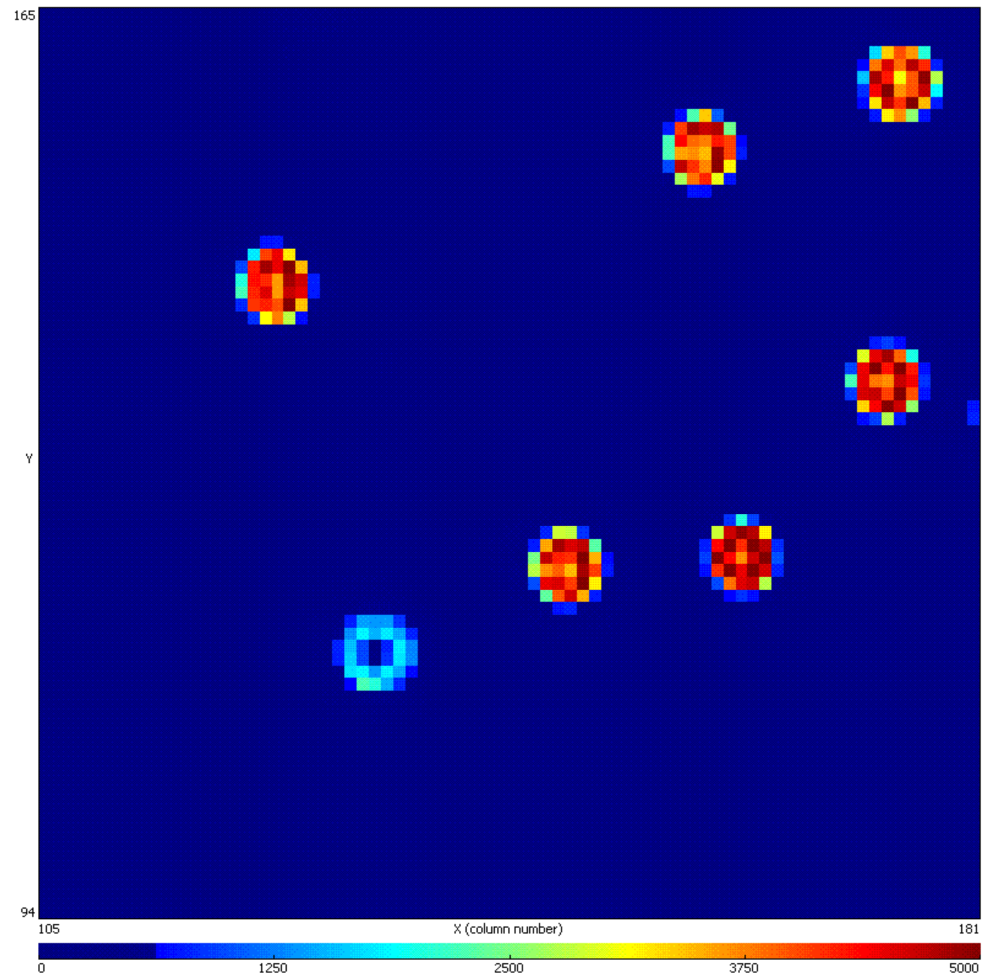
- ***Time of Arrival*** **image from a 5.5 MeV α from an ^{241}Am decay.**
- **Common global threshold can be adjusted to get time (i.e. charge) contours through the drift cloud…**
- **(Single Event)**



UNIVERSITY OF HOUSTON
Learning. Leading.

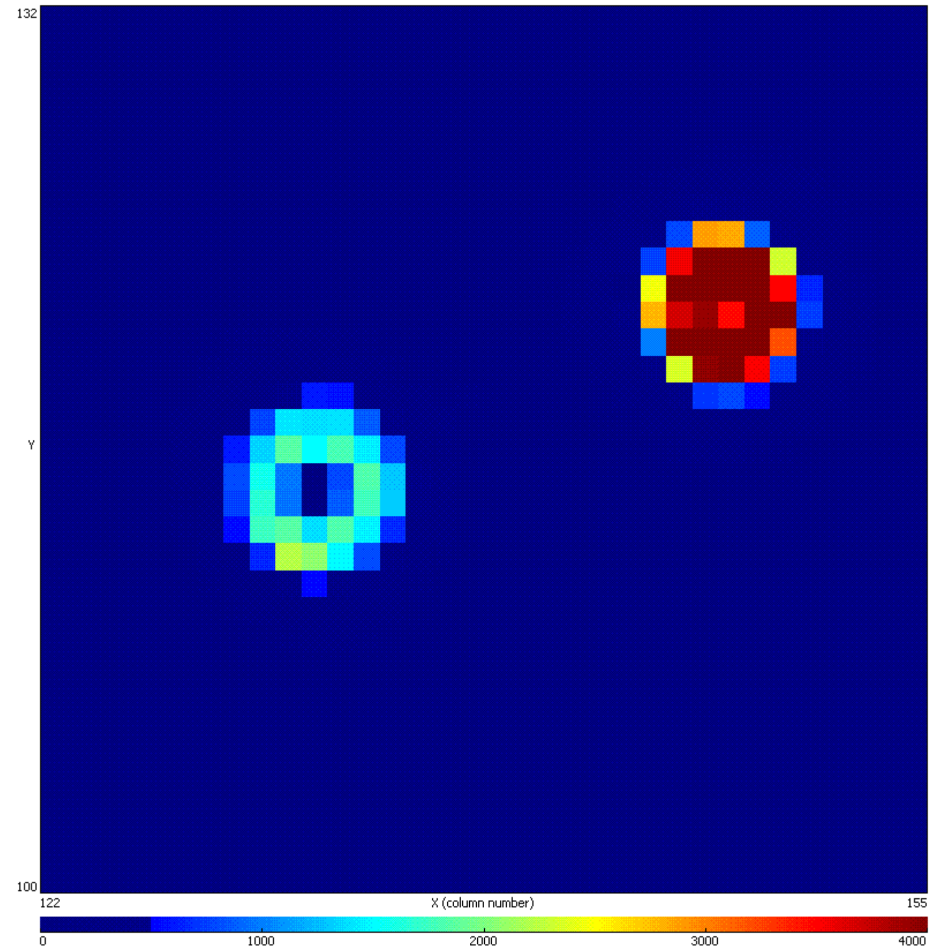
The "Volcano" Effect

- We see a dip in response for the highest charge deposition rates…
- This may be due to detector saturation effects…
- …Or to a plasma effect that causes high recombination rates…
- So far we see this only in the Fe tracks…

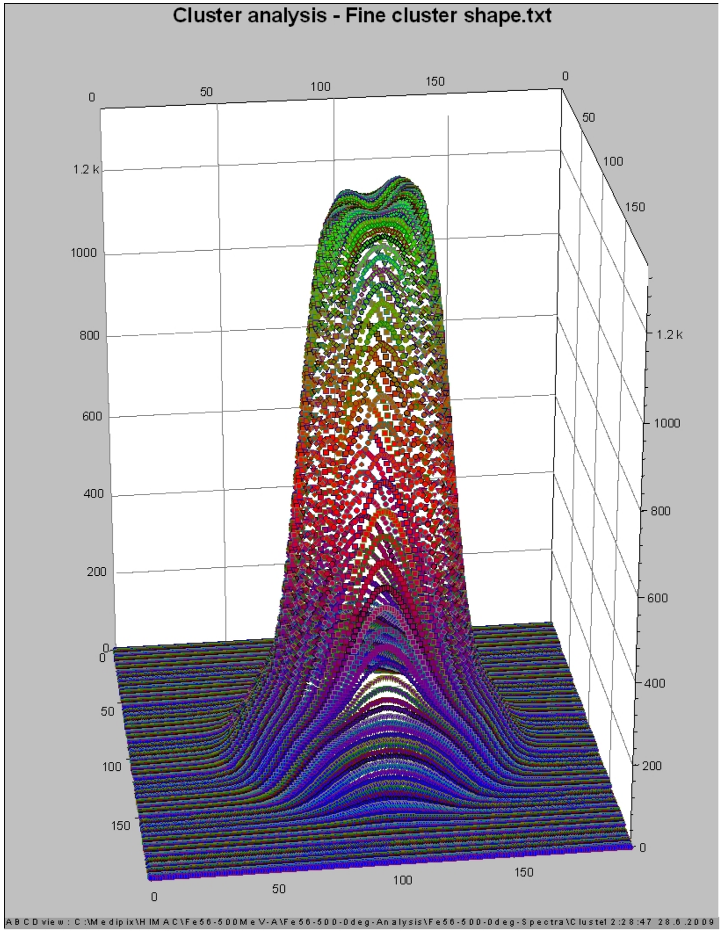


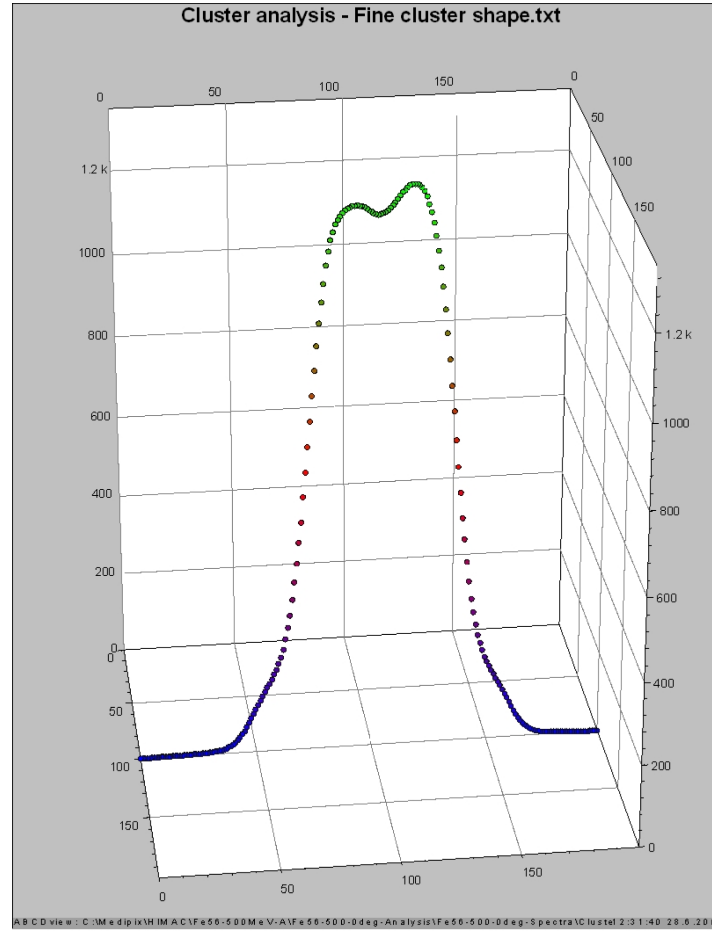
Close Up of the “Partial” Event

- The right-hand event is a “normal” iron event, which does show a clear “Volcano” Effect. The scale is so high that the δ-rays are not visible.
- The left-hand event is a “Partial-Event.” One that was partially cutoff by the “Shutter.”
- Because the central hole essentially goes to zero, it would appear that this event occurred at the end of the Shutter window and was only the early part of the drift image…

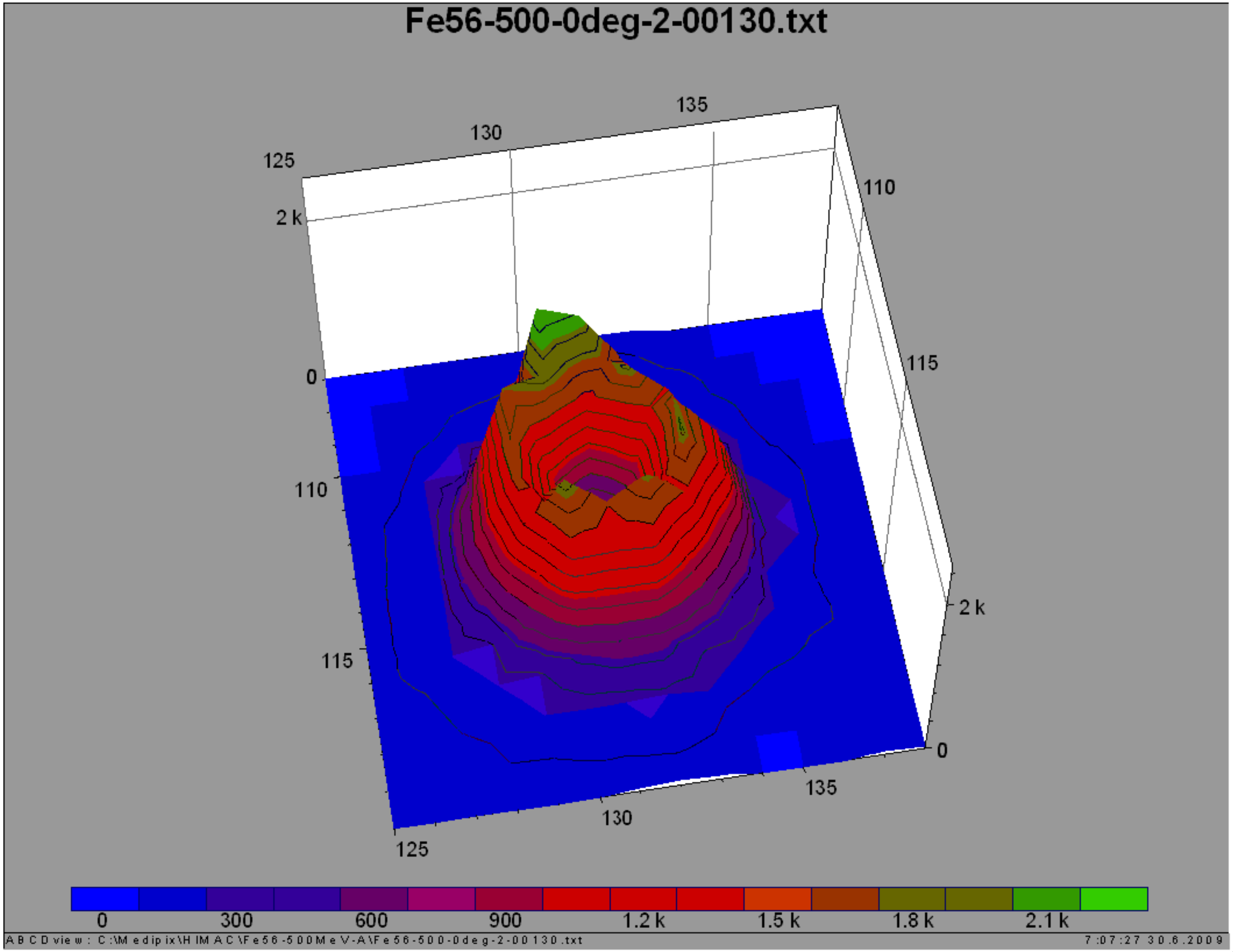


^{56}Fe @ 500 MeV/A

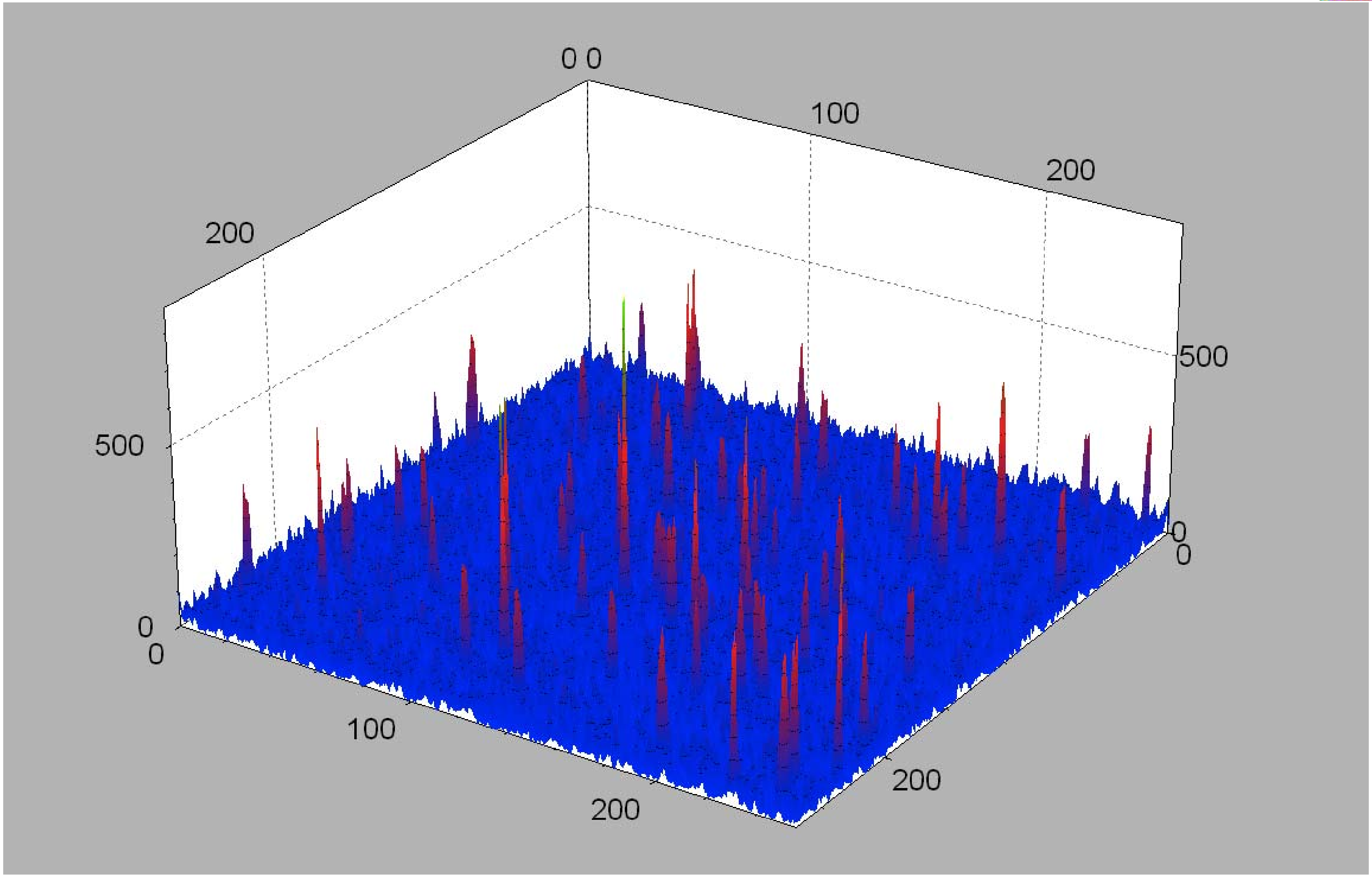




Fe “Volcano” Event



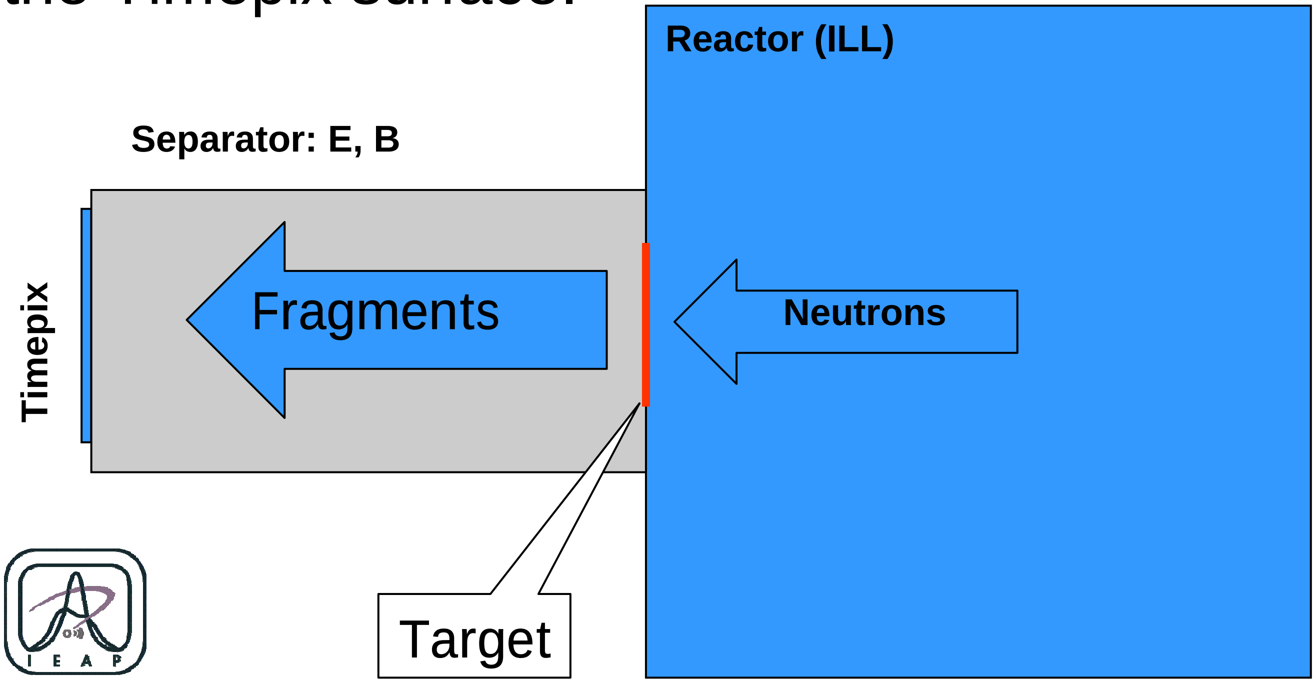
Hall 5 – May 20 – 23 hour Pixel Sum



UNIVERSITY OF HOUSTON
Learning. Leading.

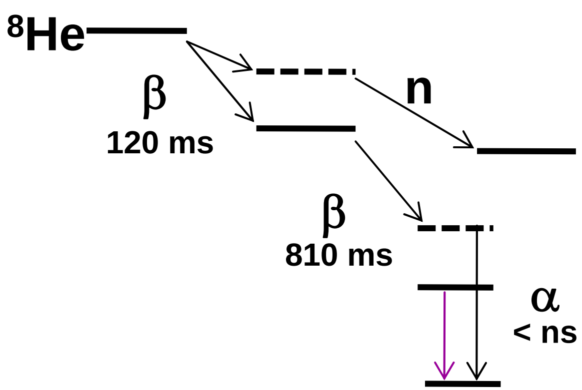
Nuclear Fission Measurements Using TimePix (TDC) Mode

- Radioactive fragments from ^{239}Pu selected by mass separator LOHENGRIN (Grenoble) and deposited onto the Timepix surface.

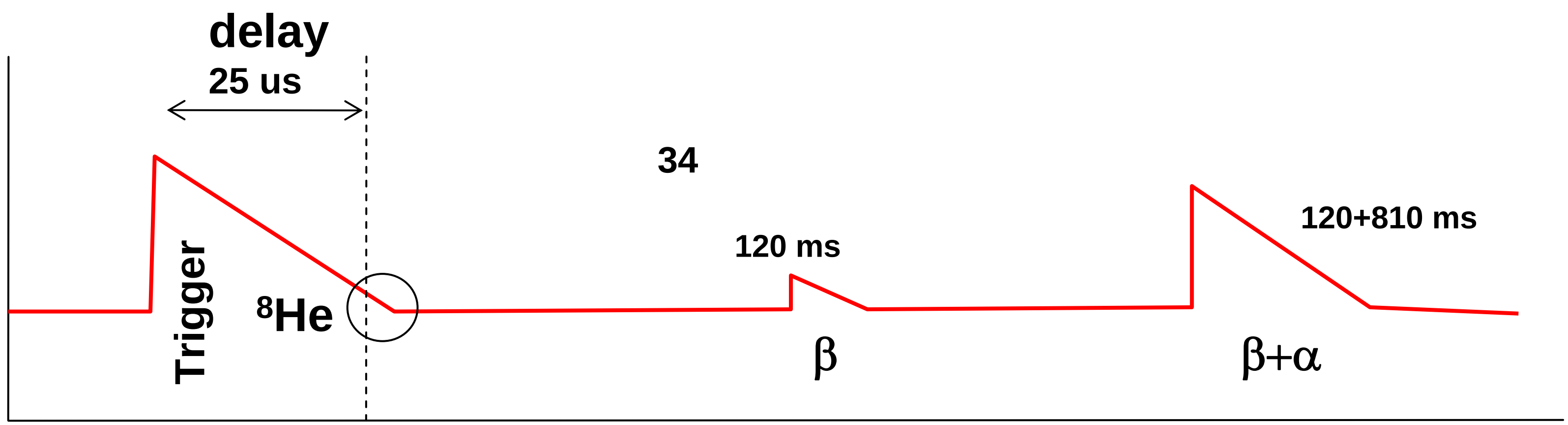


Courtesy of Jan Jakubek

Test with ^{8}He



1. Decay is slow => Timepix clock set to 2.5 kHz
2. To suppress the initial cluster from ion the delay of 25 us inserted

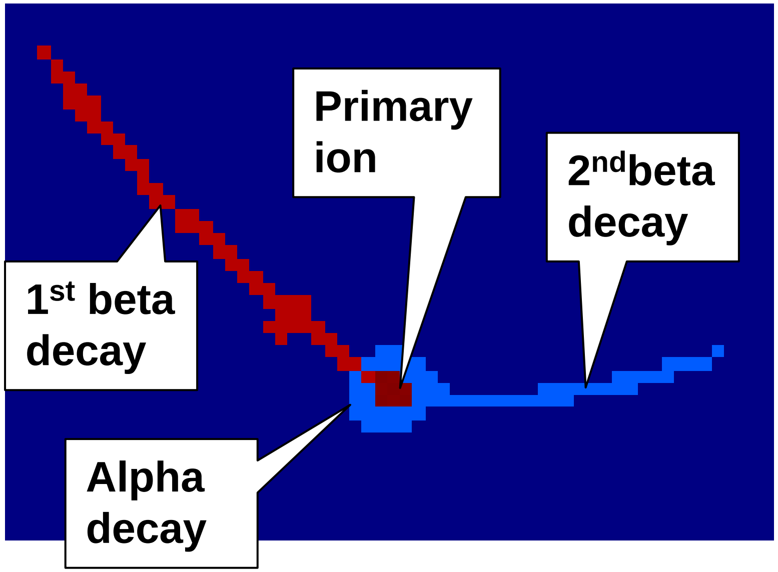


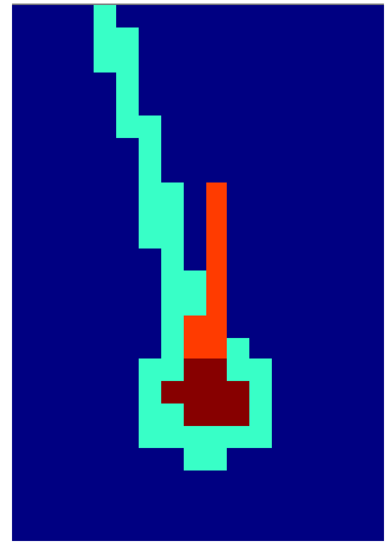
WRMISS-15, Frascati, Italy
Pinsky – September 7, 2010

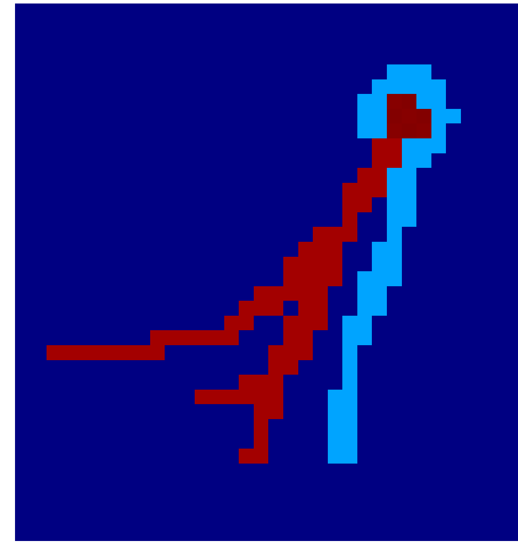
Courtesy of
Jan Jakubek

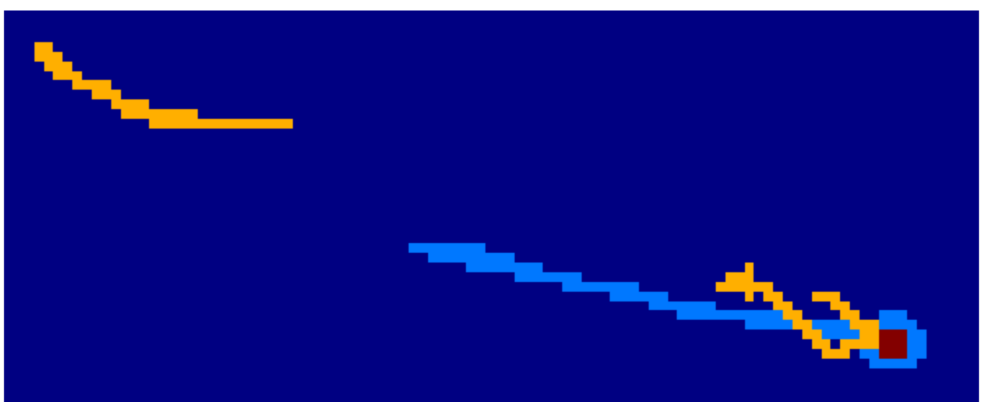
UNIVERSITY OF HOUSTON
Learning. Leading.

Measured events: ^{8}He decays (TDC Mode)

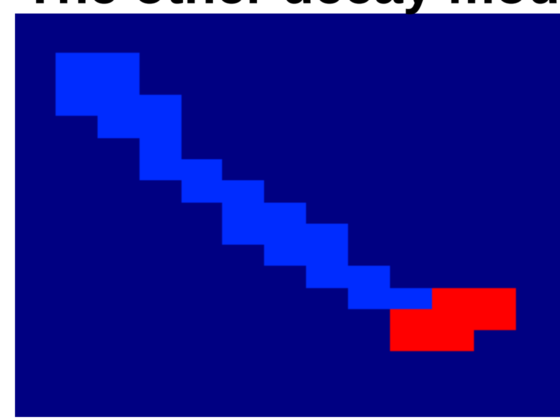








The other decay mode



Courtesy of Jan Jakubek