Fluid Dynamics Data Acquisition and Tcl

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What’s this all about?

- Describing the problem.
- Describing the software I already had.
- Describing the modifications to make it all work.
- Some screen shots
- Some acknowledgements

What do we want to do?

- Track the flow of ‘fluid particles’ through a complex multi-phase system.
  - Multiphase means a mixture of solids, liquids and gasses depending on the type of system.
- …and the system is optically opaque.
- Large volumes

Why do we want to do it?

“Multiphase reactors are widely used in petroleum, chemical, petrochemical, pharmaceutical and metallurgical industries as well as in materials processing and pollution abatement….the physical phenomena that affect the fluid dynamics of such systems are not yet entirely understood. This make a priori predictions of important process parameters… very difficult.”

Opaque Multiphase Reactors: Experimentation, Modeling and Troubleshooting.

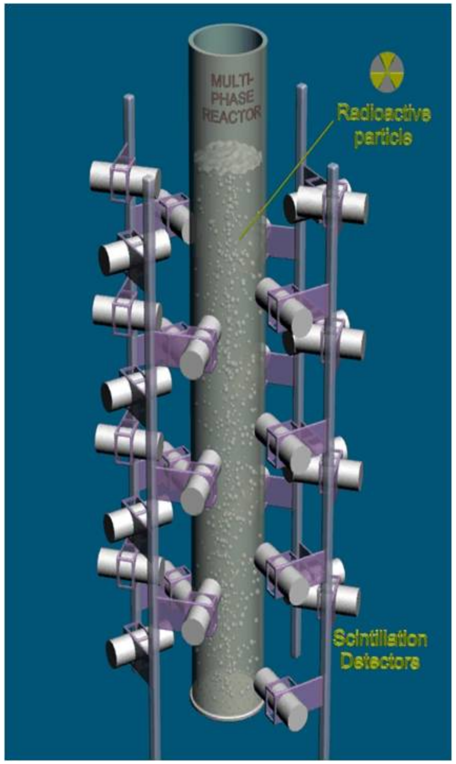
- M.P. Dudukovich

Oil & gas Science and Technology Rev. IFP V 55 (2000) #2 pp135-158

“Because its fun and you get to play with cool toys”
- Ron Fox 2011

How do we do it?

- Computer Automated Radioactive Particle Tracking (CARPT)
- Make ~2mm source of ^{46}Sc (gamma emitter) so that it has neutral boyancy.
  - The source will move around in the reactor.
  - Track the movement as a function of time.
- A typical example is shown at the right:



How do we do it?

- Turns out with some ‘relatively straightforward’ math (left as an exercise for the reader) you can show you just need count rates (intensities)…

$$\frac{\partial \psi(\bar{x},t)}{\partial t} = -\bar{V}(\bar{x},t) \bullet \bar{\nabla}\psi(\bar{x},t) - \left|V(\bar{x},t)\right| \cdot \sigma(\bar{x},t) \cdot \psi(\bar{x},t) + q(\bar{x},t) \qquad (3\text{-}1)$$

$$0 = -|V|\hat{e} \bullet \bar{\nabla}\psi(\bar{x}) - |V|\sigma(\bar{x},t)\psi(\bar{x}) + q(\bar{x}) \qquad (3\text{-}2)$$

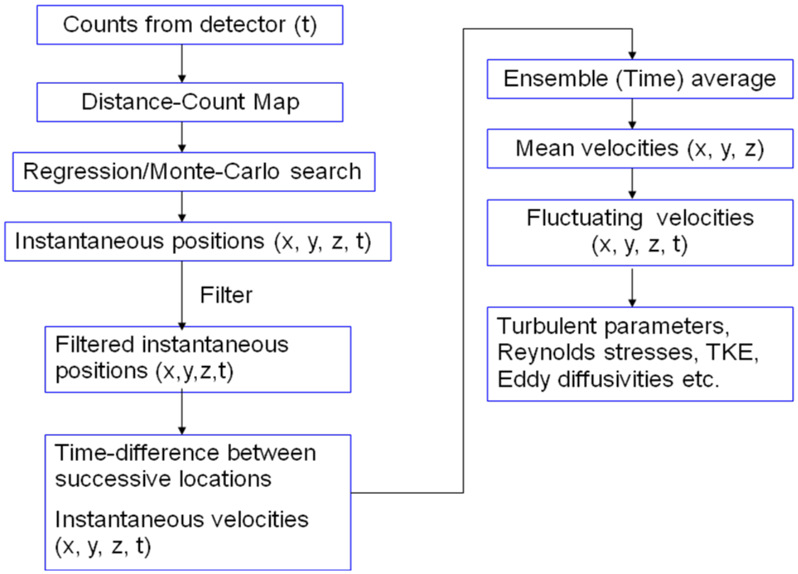
$$I_{\overline{x_d}} = \int_0^{\overline{x_d}} q(\bar{x}) \cdot e^{-\int_{x}^{\overline{x_d}} \sigma(\bar{x}',t) . d\bar{x}'} . d\bar{x} \qquad (3\text{-}3)$$

…

$$I_{\overline{x_d}} = q(\bar{x}) e^{-\oiiint_{R^3} \sigma(x,y,z,t) \cdot \delta(l - x\cos\theta\sin\phi - y\sin\theta\sin\phi - z\cos\phi) \cdot dx \cdot dy \cdot dz} \qquad (3\text{-}5)$$

To find the source position/velocity at any time.

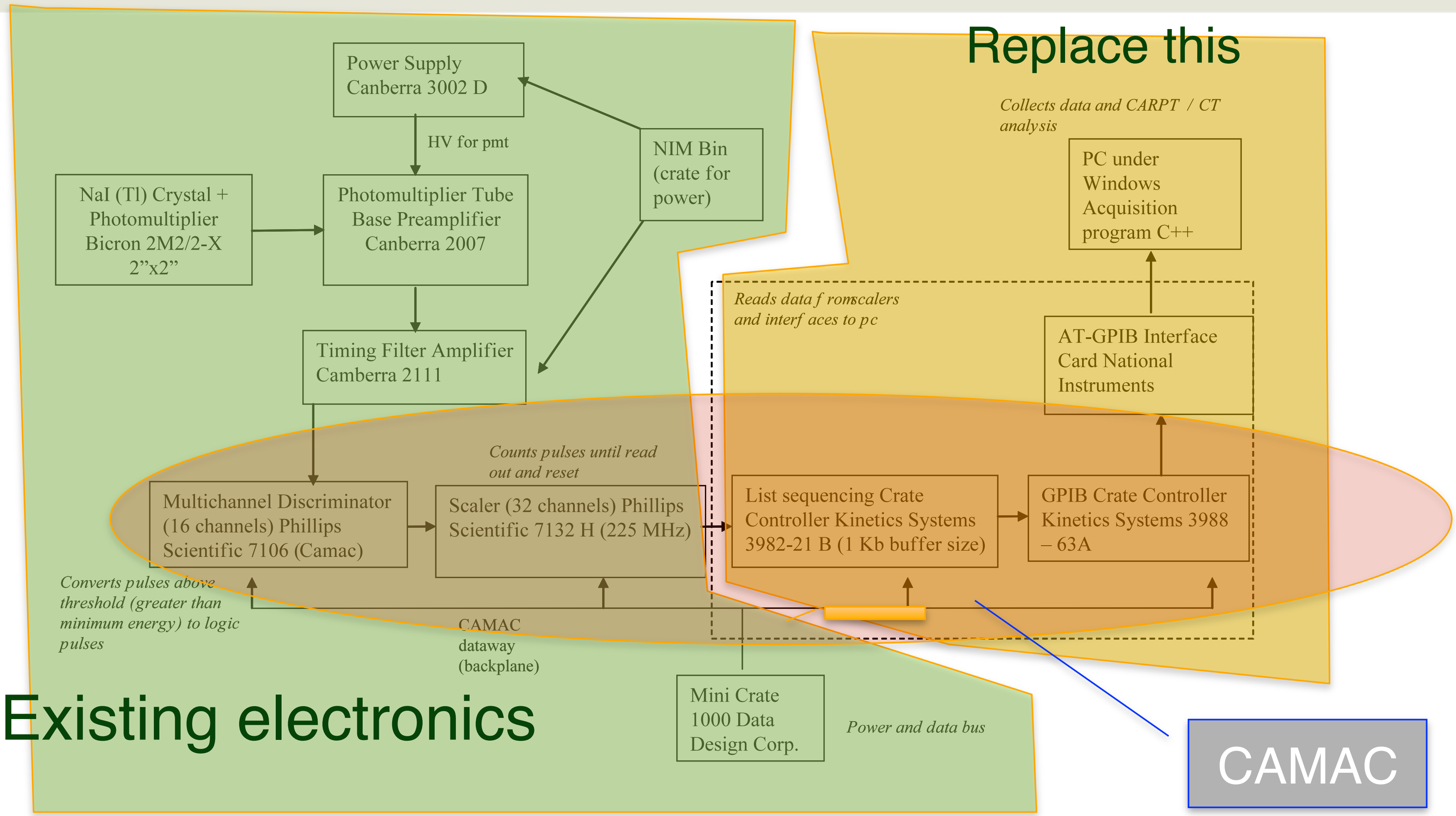
More algorithmically you want:



There are quite a few difficulties outside the scope of this paper:

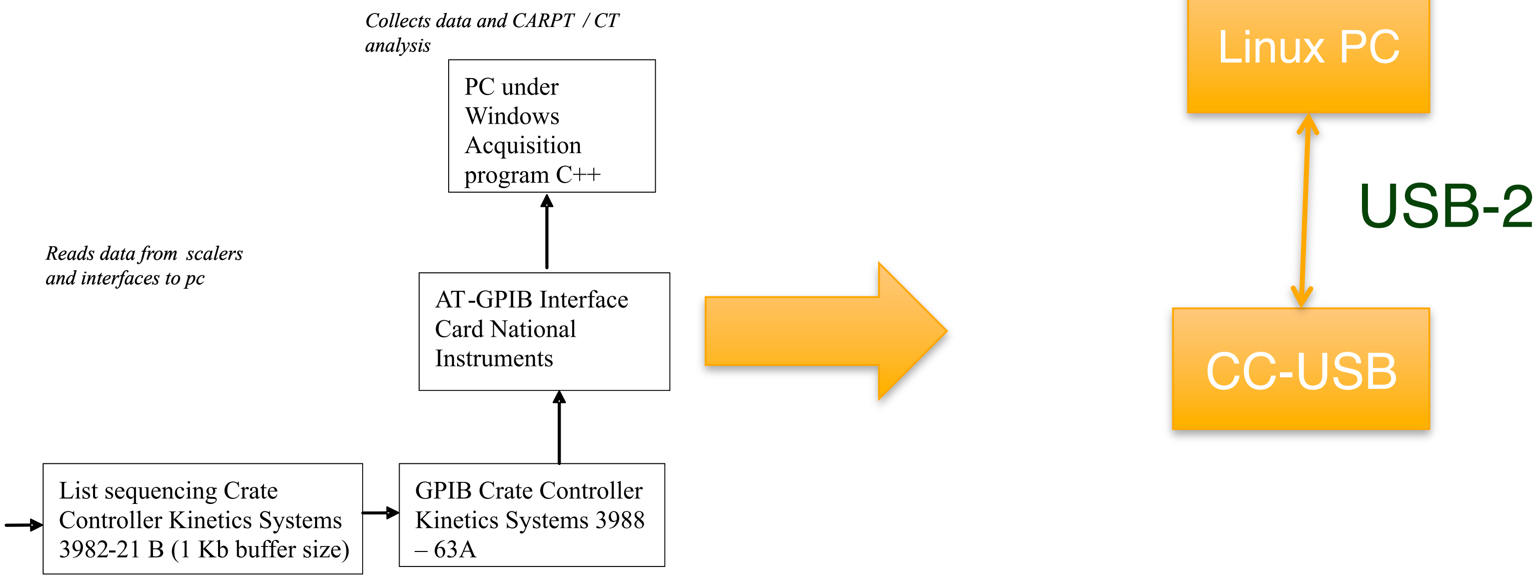
- You need good knowledge of detector efficiencies
- The detector acceptance is not perfect
- If you use a hot source there will be dead time associated with fall time of the signal in the NaI detectors (1uSec).
- The contents of the reactor can absorb emitted gamma rays. Attenuation can be difficult to determine/measure (and may be a function of position).

My Job

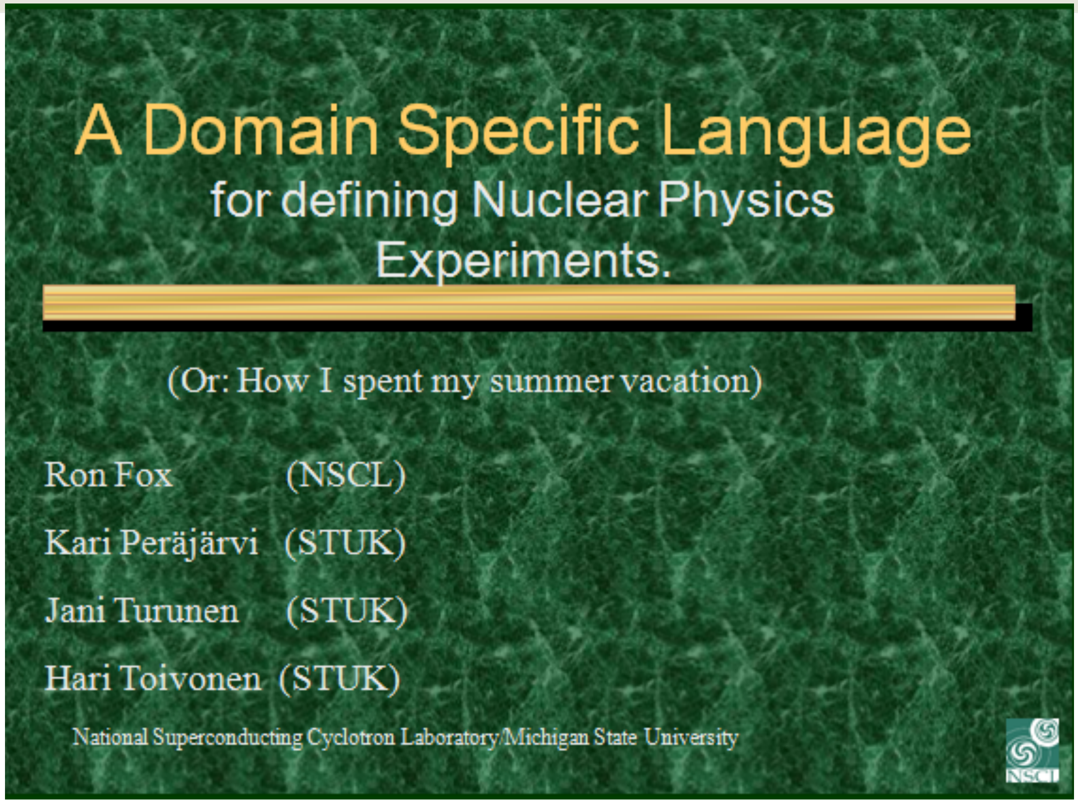


Development effort must be cheap

Replace with This.

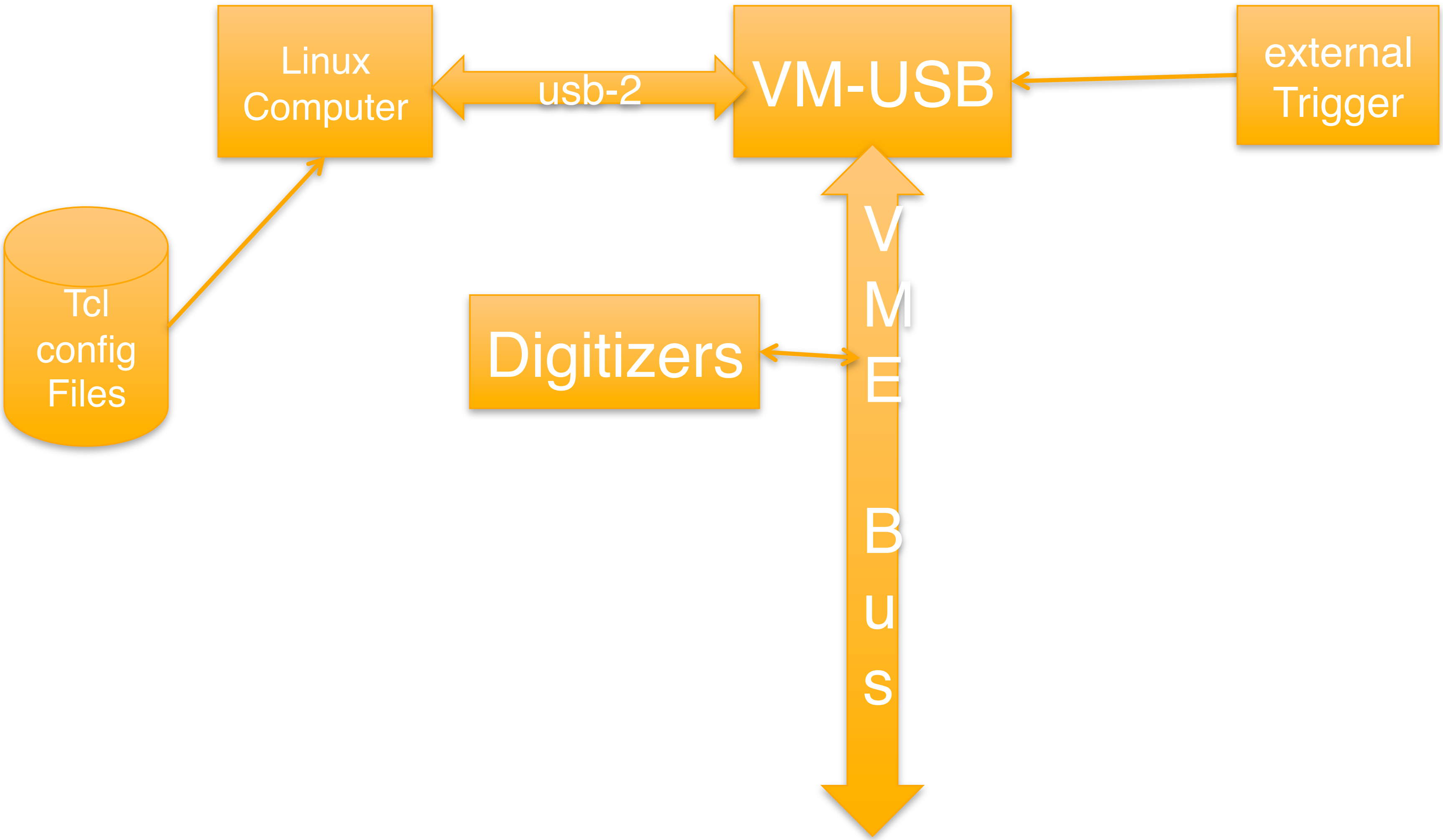


Remember me from last time we were here?

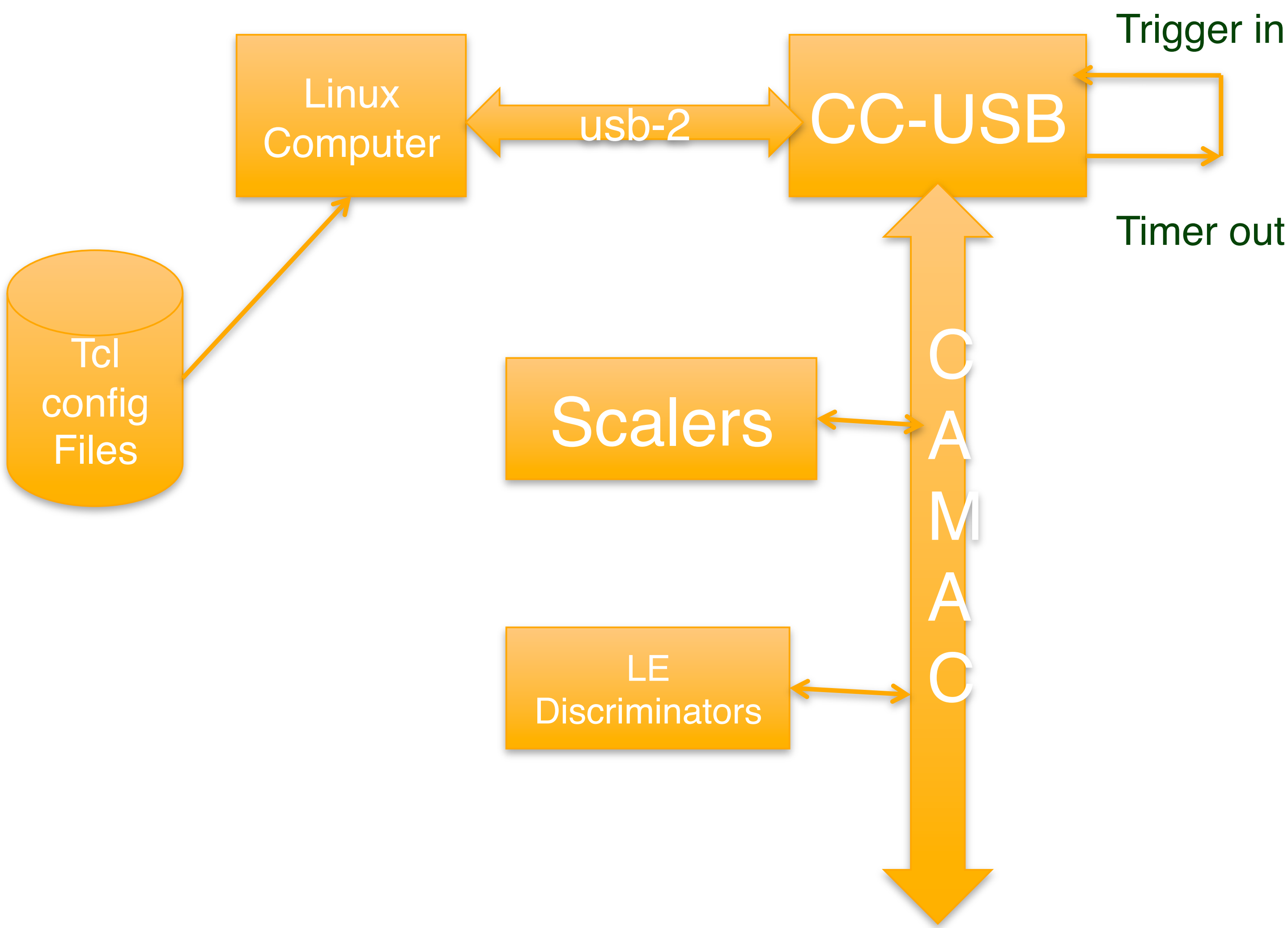


This project used a USB ↔ VME interface

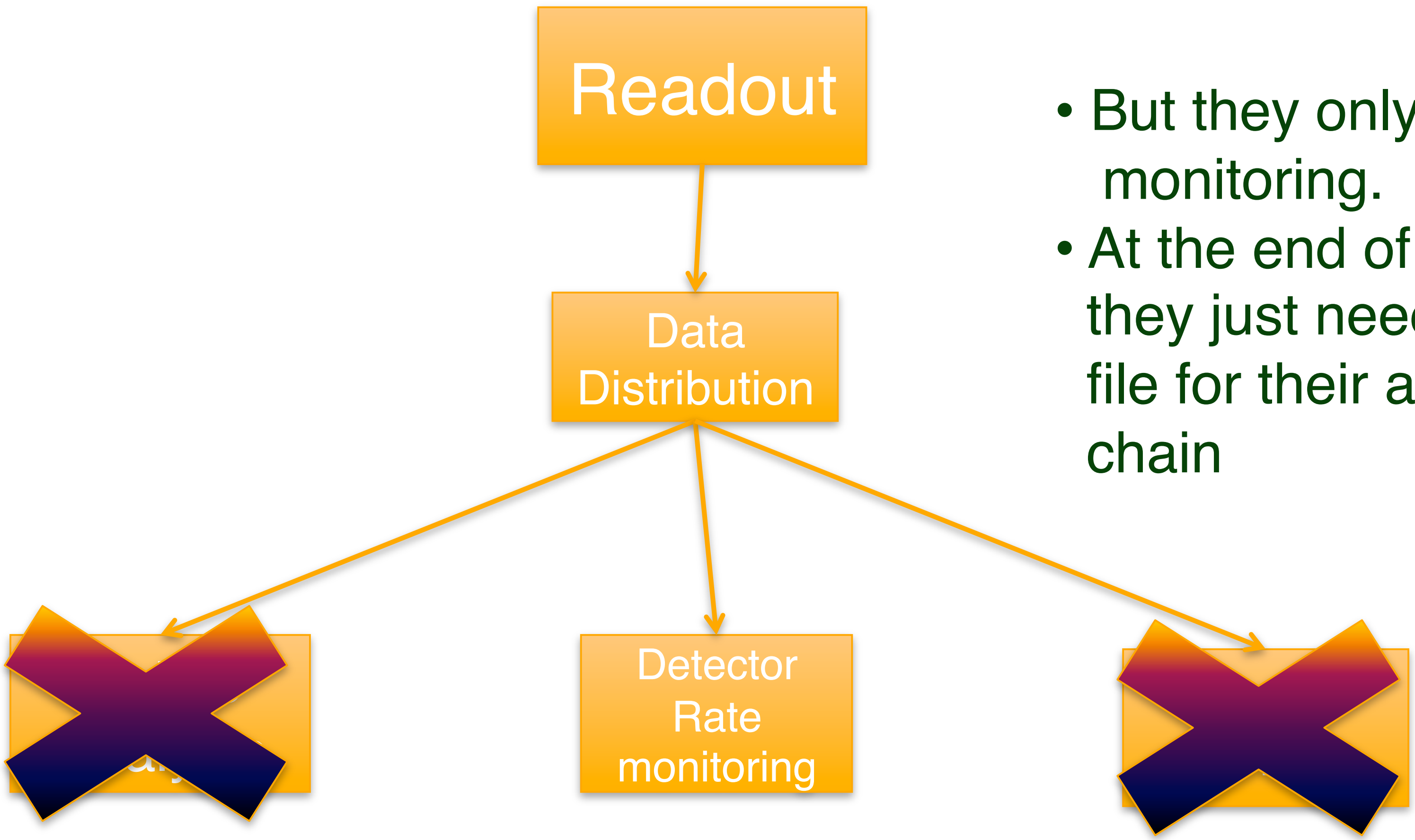
Hardware Changes



Hardware Changes

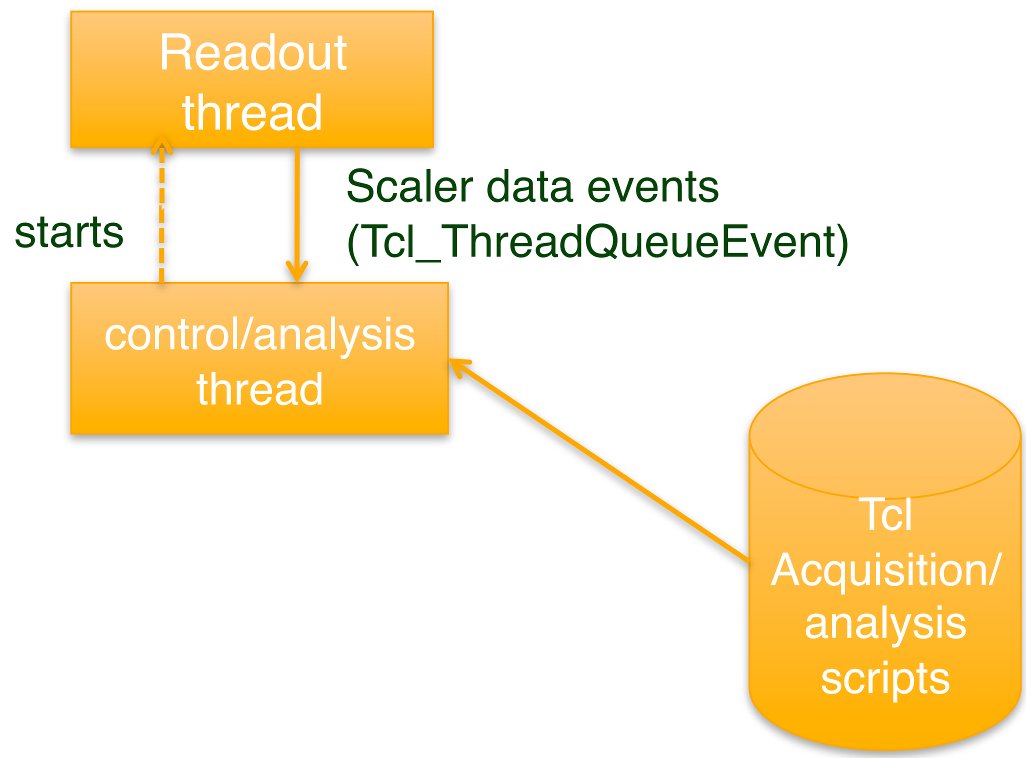


Software Old:



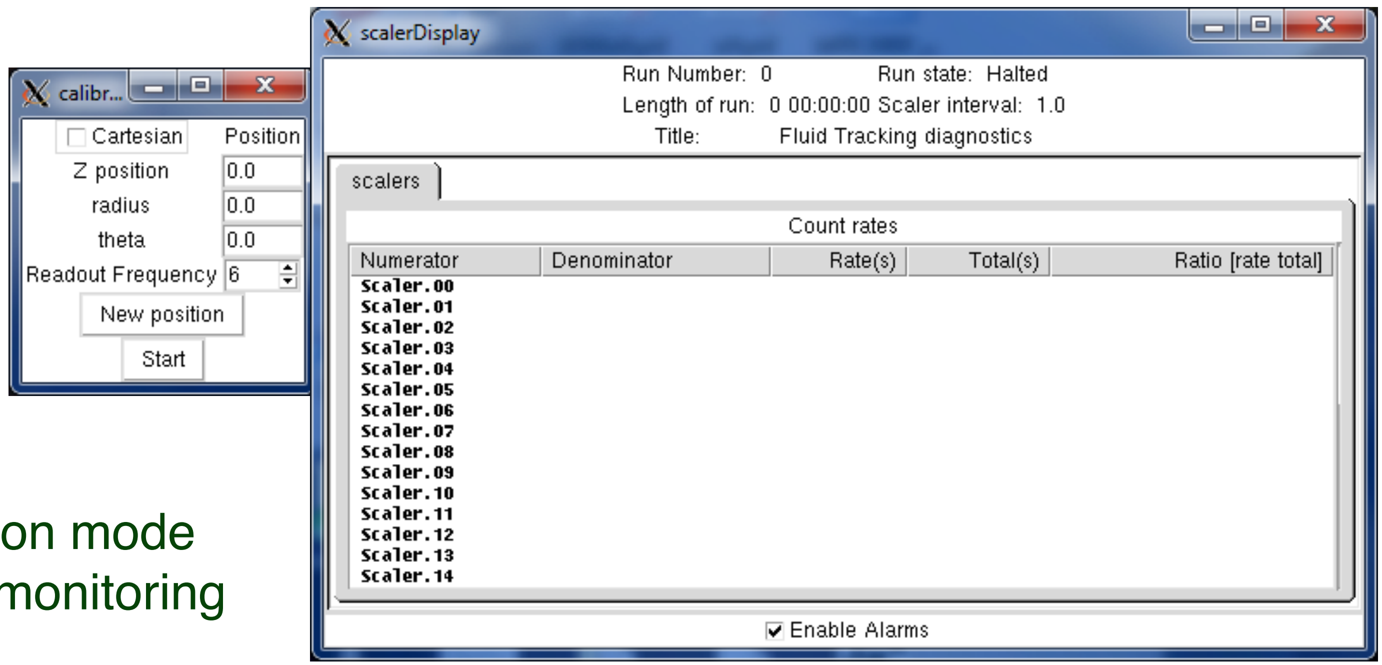
- But they only need rate monitoring.
- At the end of each run they just need a CSV file for their analysis chain

Software New



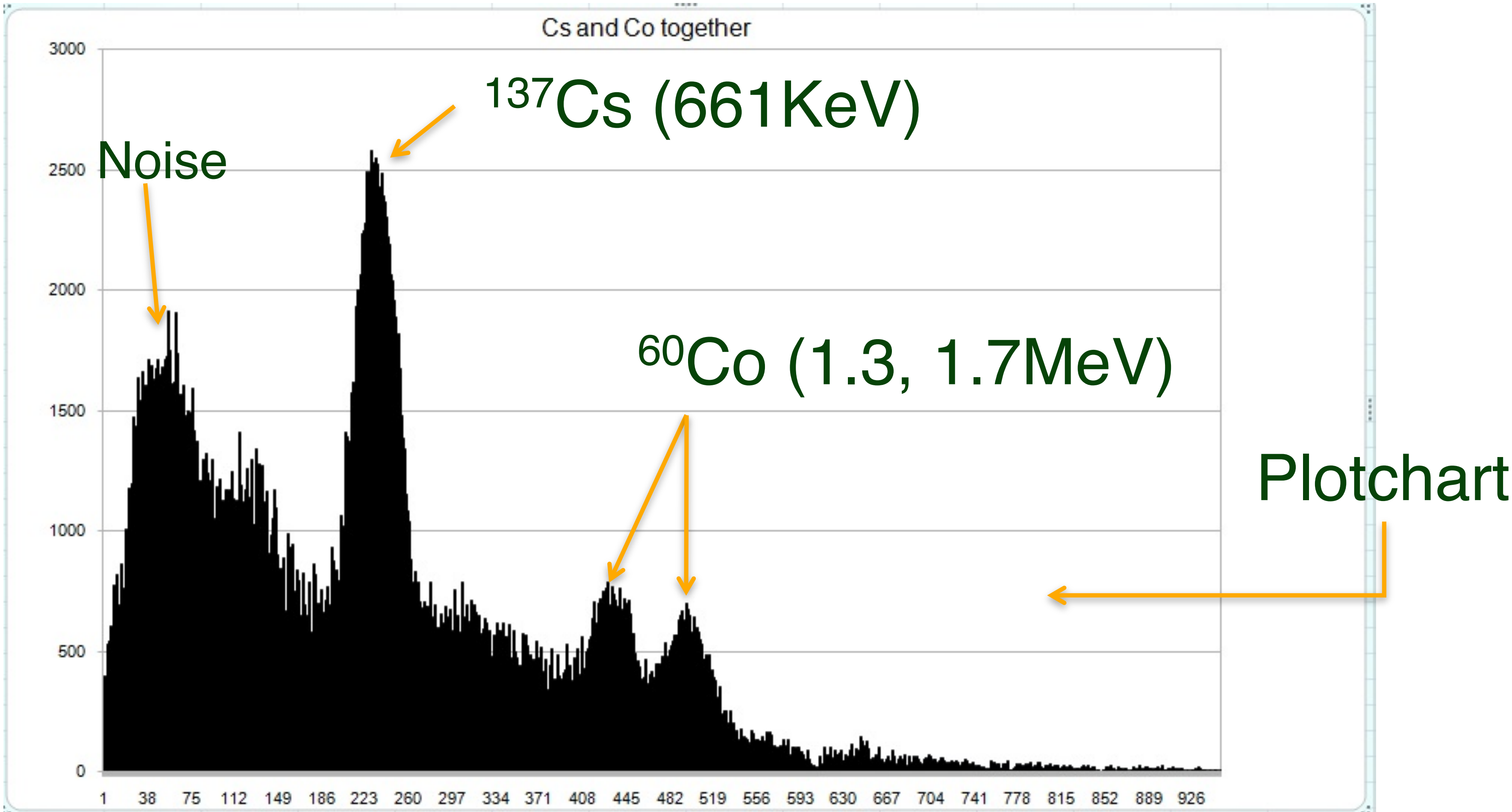
Acquisition/Analysis modes

- Calibration – Run with a source in a known location move the source run some more.
- Discriminator setting – Scan the discriminator settings (poor-man’s ADC) to know how to set the threshold.
- Production running – Take data for as long as they want to.



Calibration mode
Control/monitoring

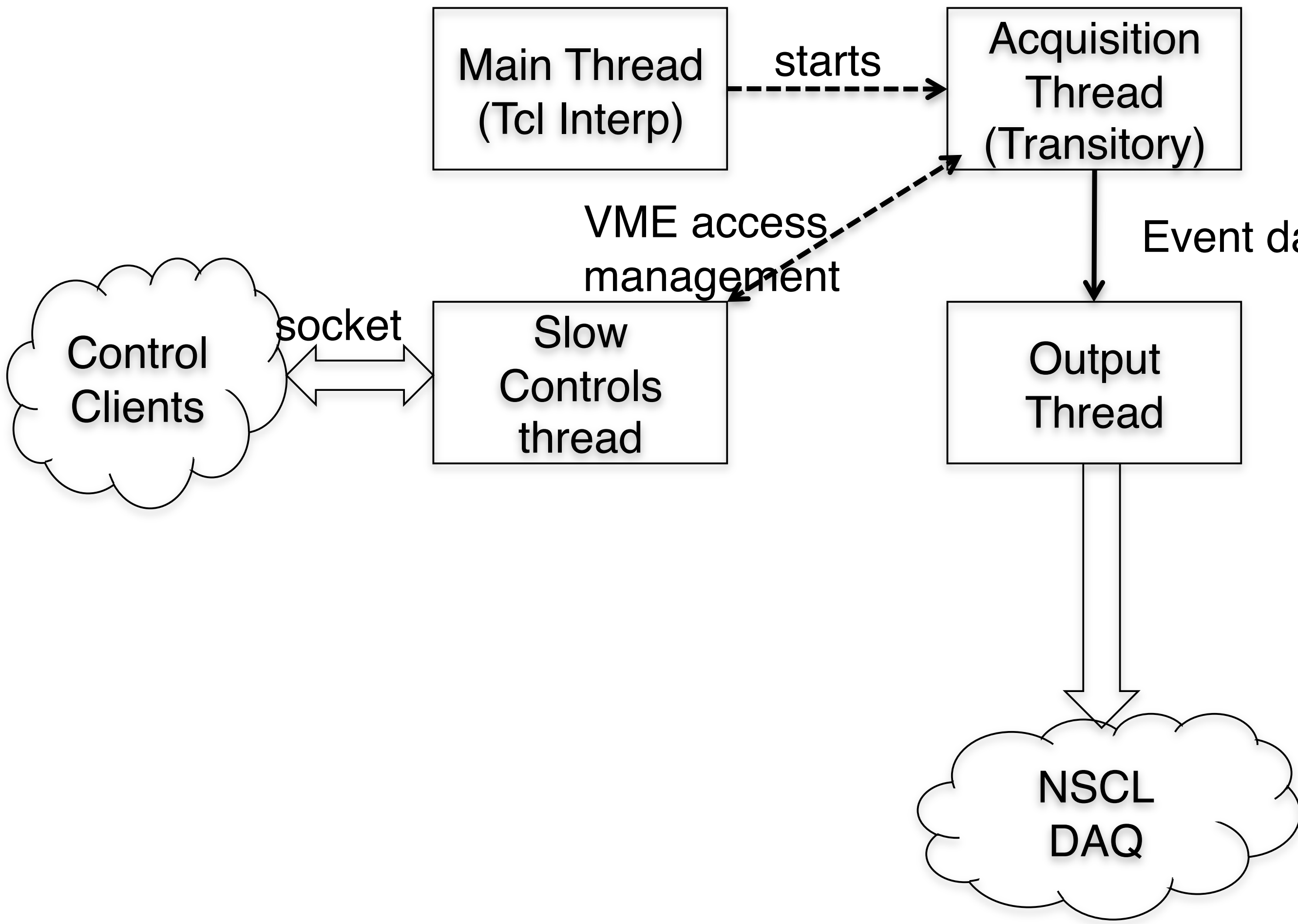
Sample Spectrum from discriminator setting mode.



Conclusions

- Modifying the “STUK” readout to be an all-in-one data acquisition system was easy.
- Doing the analysis in Tcl provided a lot of flexibility and leveraged:
  - The speed of Tcl development
  - Ease with which Tk can be used to build user interfaces.
  - Plotchart to allow the display of LED threshold data.
- At present, position calibration is manual. In the future adding motor control to the application would allow that to be automated.
- Having the STUK framework as a starting point allowed this project to be deliverd on the cheap…thanks to the Tcl assist for the analysis control/analysis sections of code..

Readout Software Structure



Readout software modified for CARPT data taking