Inner Tracker Upgrade and Jet Analysis

Physics REU Project

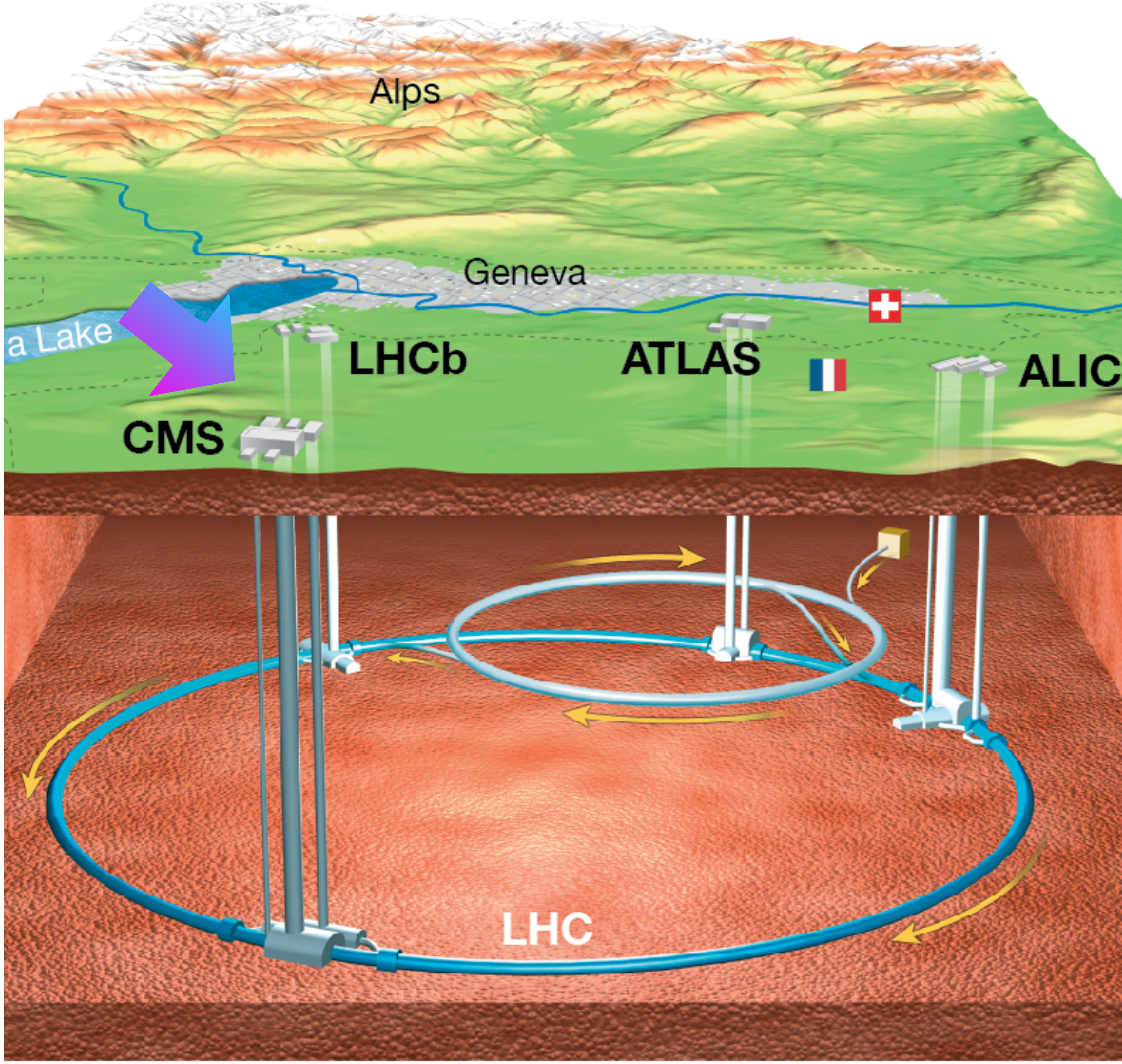
Carson McVay

Goals of this Talk

- To provide an overview of the shared projects between CERN and KSU
- Provide context to the work being done at KSU
- Share the work that I have done over the summer

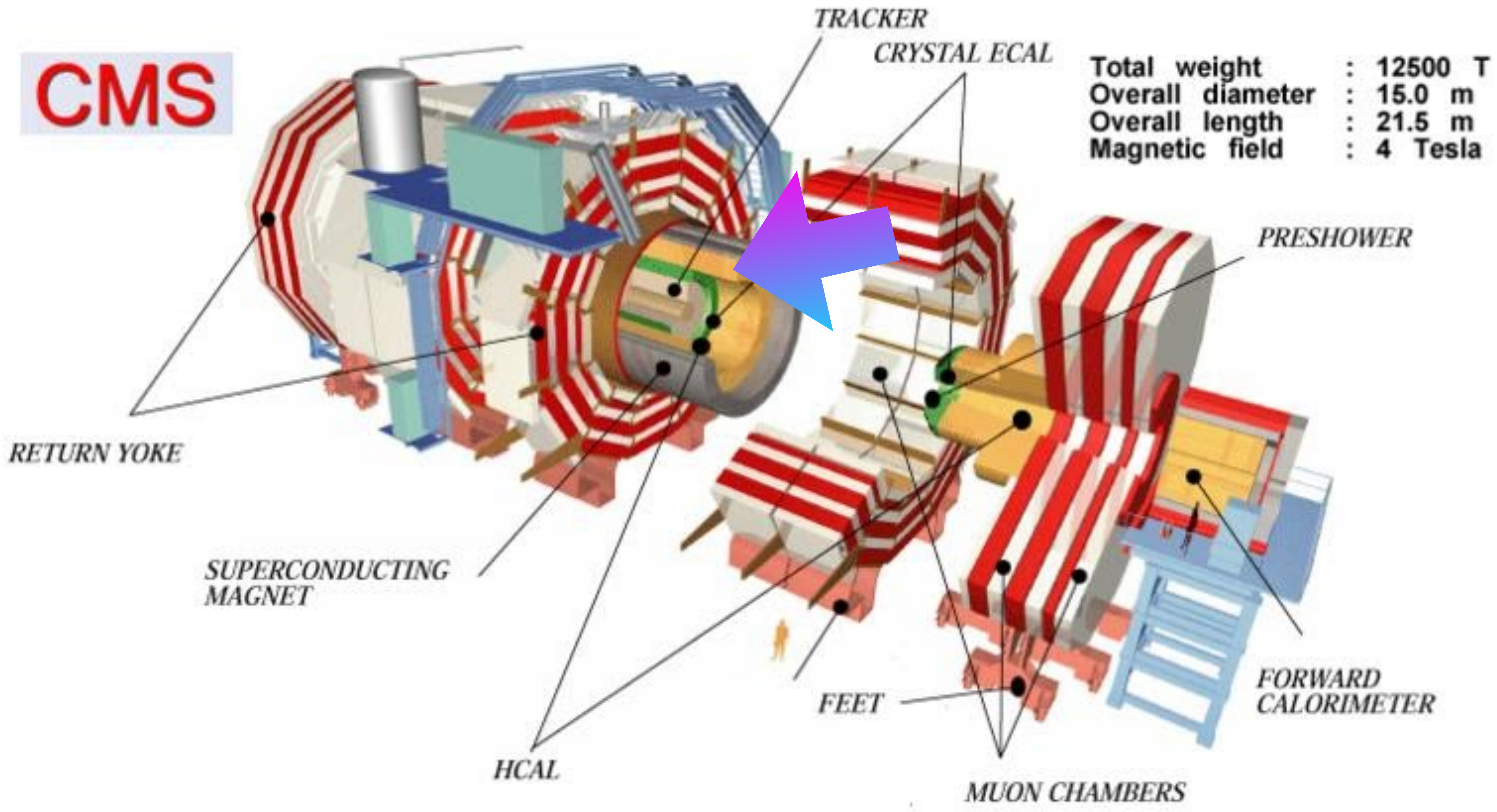
Projects at CERN

- Large Hadron Collider
  . Particle accelerator
  . Multiple experiments
- CMS



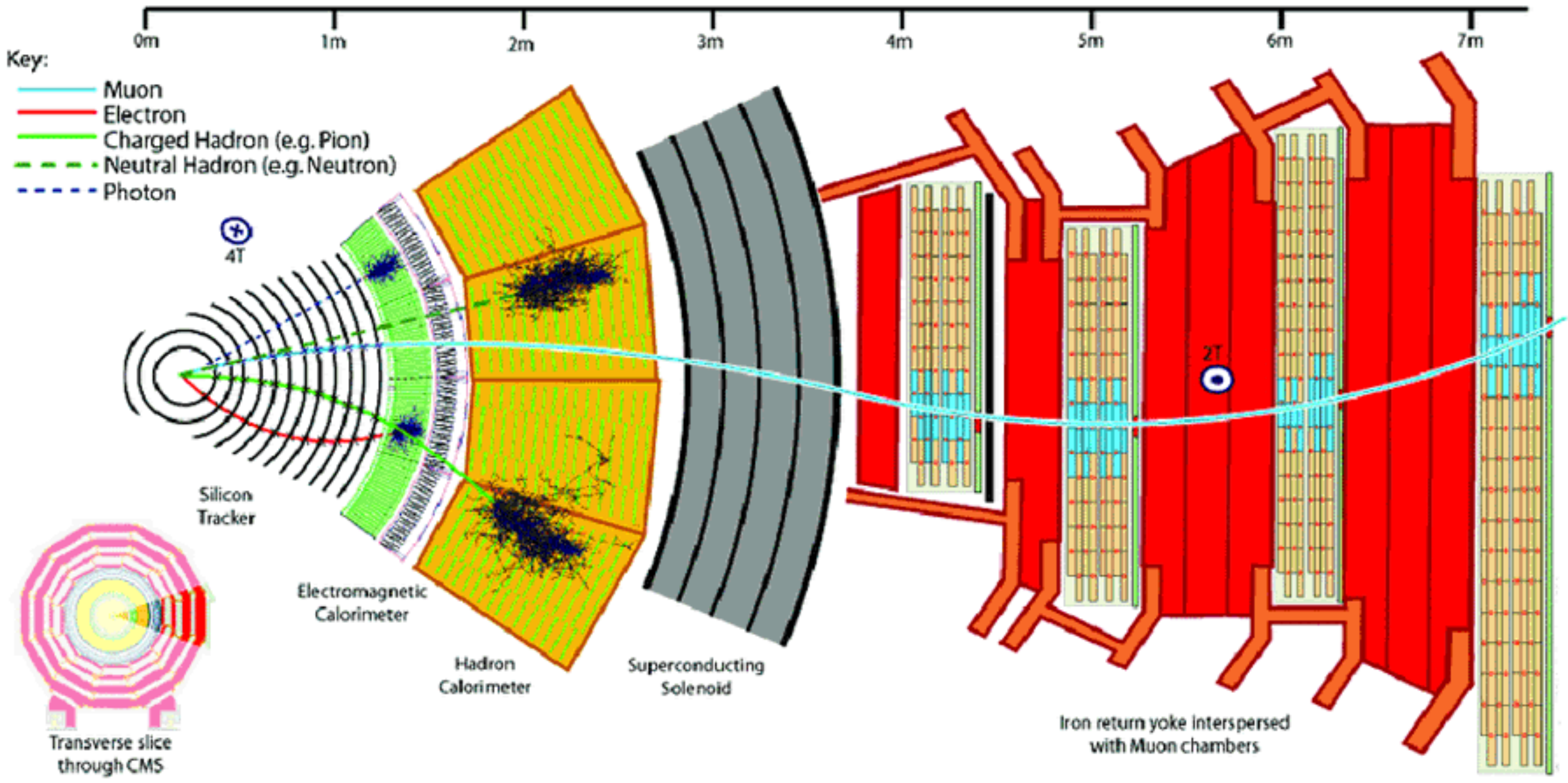
CMS

- Proton-Proton collisions .protons break up into quarks
- Uses conservation of energy and momentum of quarks to recreate collisions



Inner Tracker

- Used to detect charged particles
- Composed of silicon chips



How does the Tracker Detect Particles?

- Uses application specific integrated circuits (ASIC)
- Circuits are imprinted onto silicon chips
- The chips can detect particles because they have been “doped”

What is Doping?

- The process of generating a surplus or deficit of valence electrons
- Silicon has 4 valence electrons, so it can be P-doped with elements such as boron (3 valence electrons), or N-doped with elements such as phosphorus (5 valence electrons)
- Silicon strips are turned into reverse biased diodes-no current can pass through
- Particles passing through the strips create detectable ionization currents, which can be used to recreate the paths

Chips in the Inner Tracker

- 13,000 chips
- 150,000 pixels/chip
- = 2 billion pixels
- How do we make sure they work before they're installed?

How we test Chips:Probes

- Tests individual circuits for defects
- Does so by loading a wafer and physically probing it
- Probes deliver electrical information to conduct tests

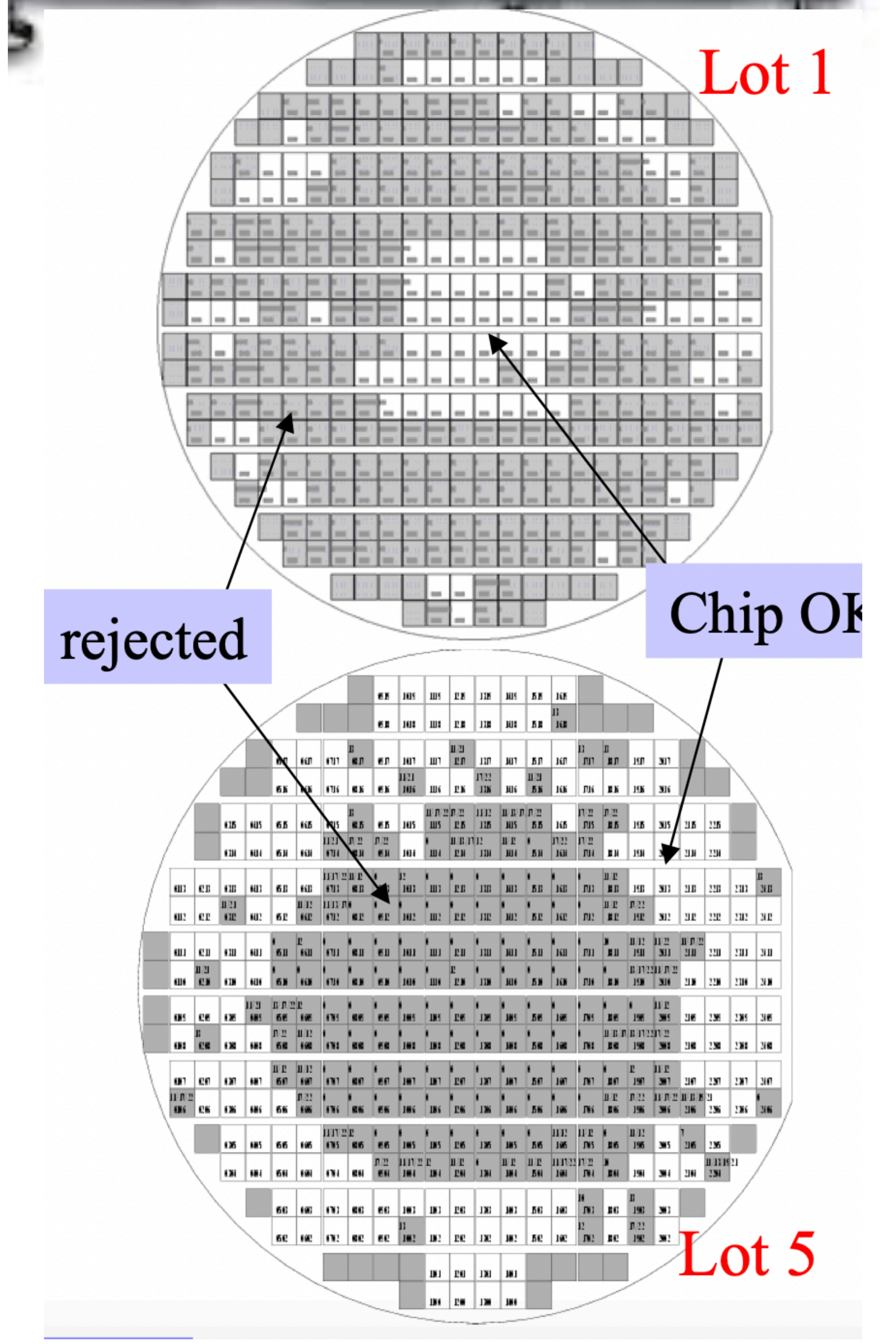
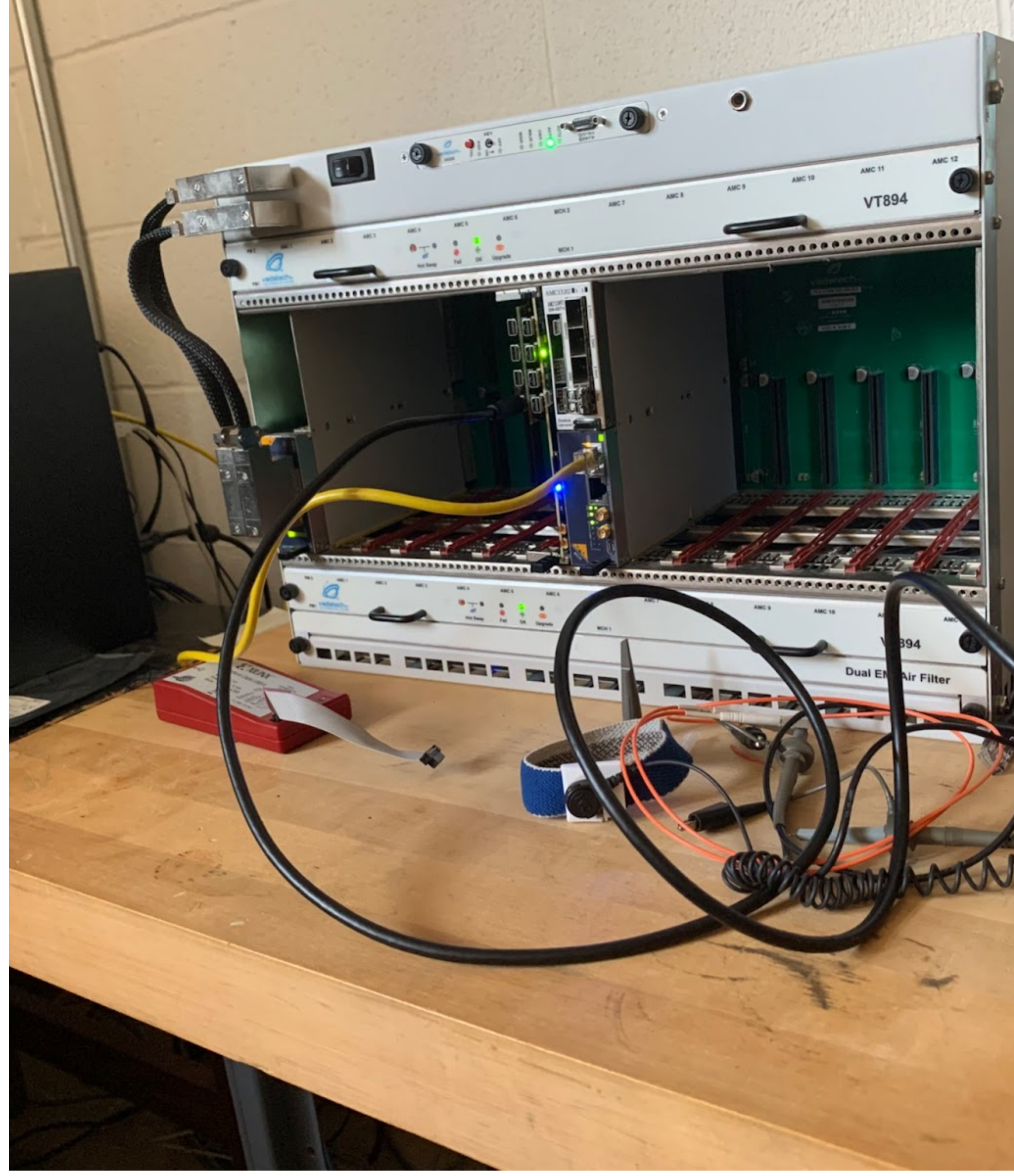
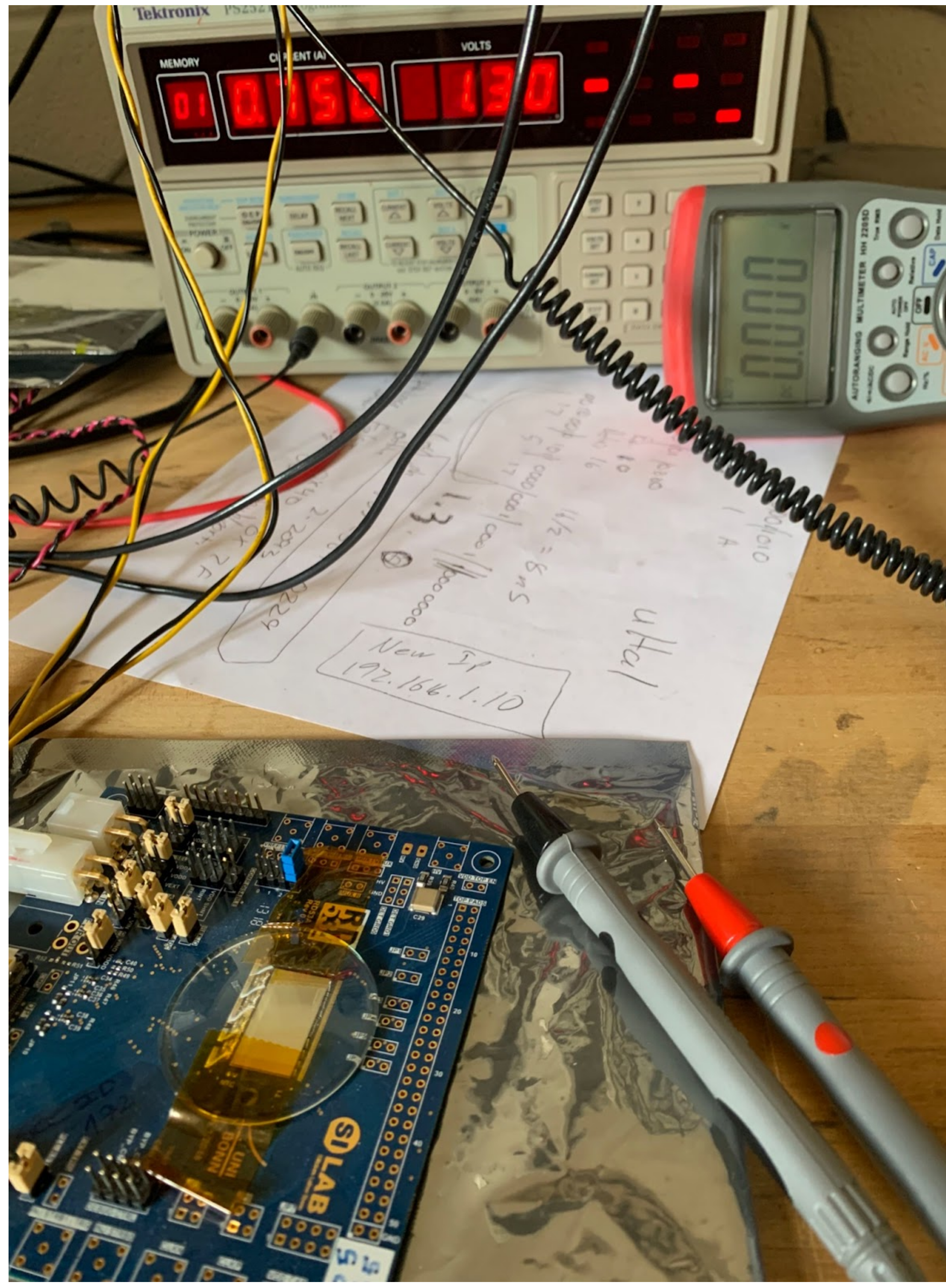


Image from P. Barillon et al.

Chip Configuration

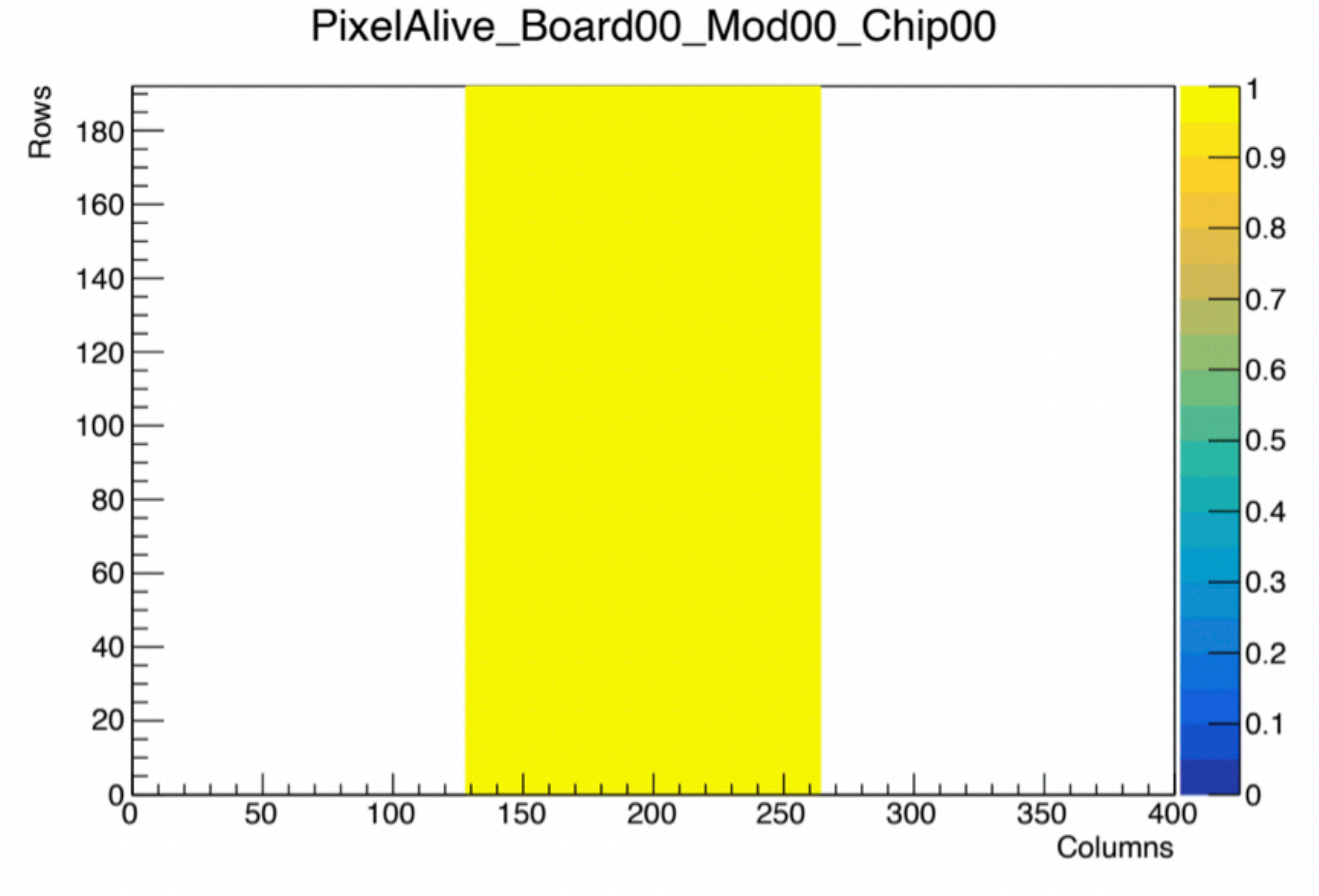
- Three tests
- Power Supply Voltage (1.2V)
  Reference Current (4 micro amps)
  Reference Voltage (.9V)





Chip Calibrations:Pixel Alive

- Tests to make sure pixels respond



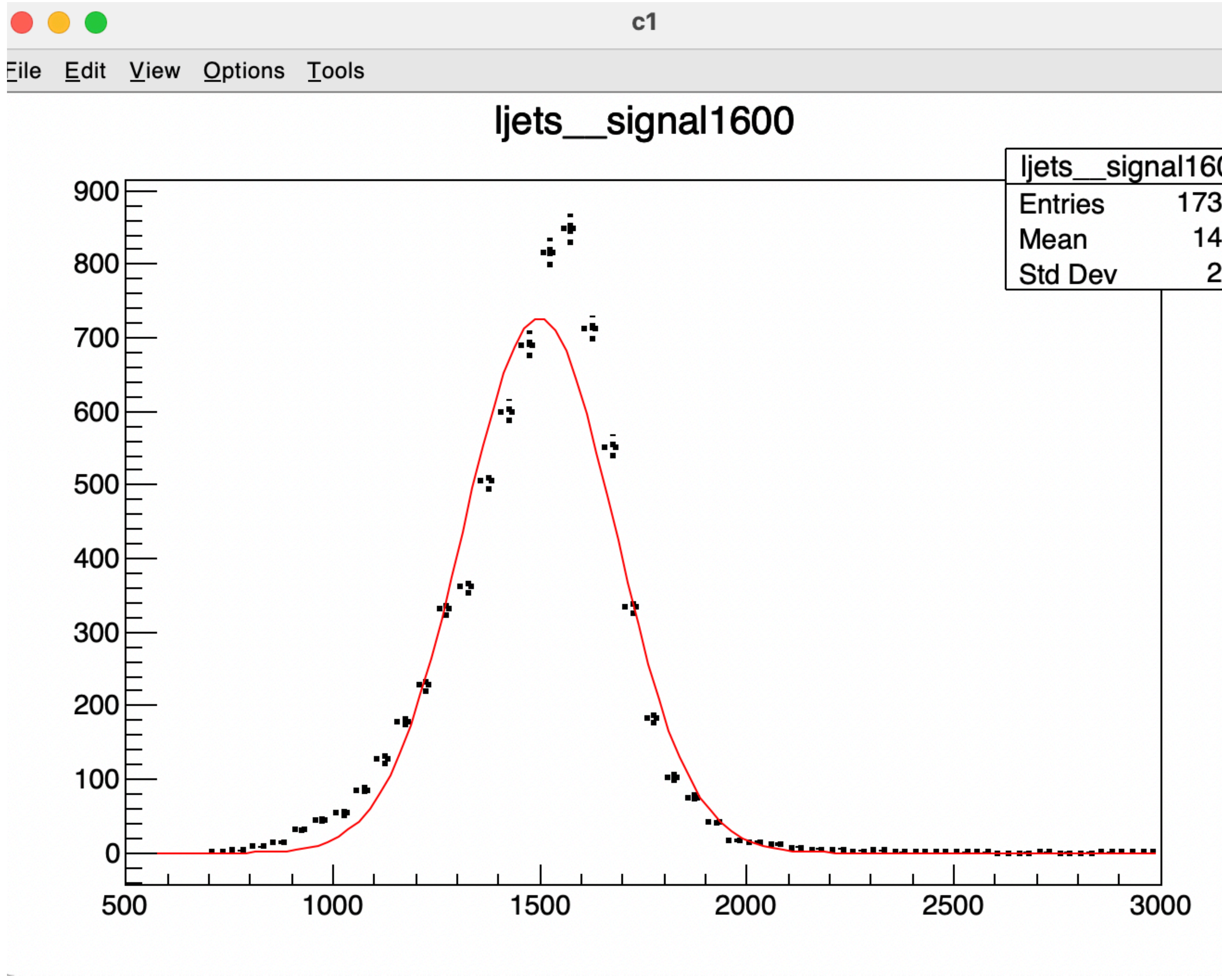
Data Analysis-Jets

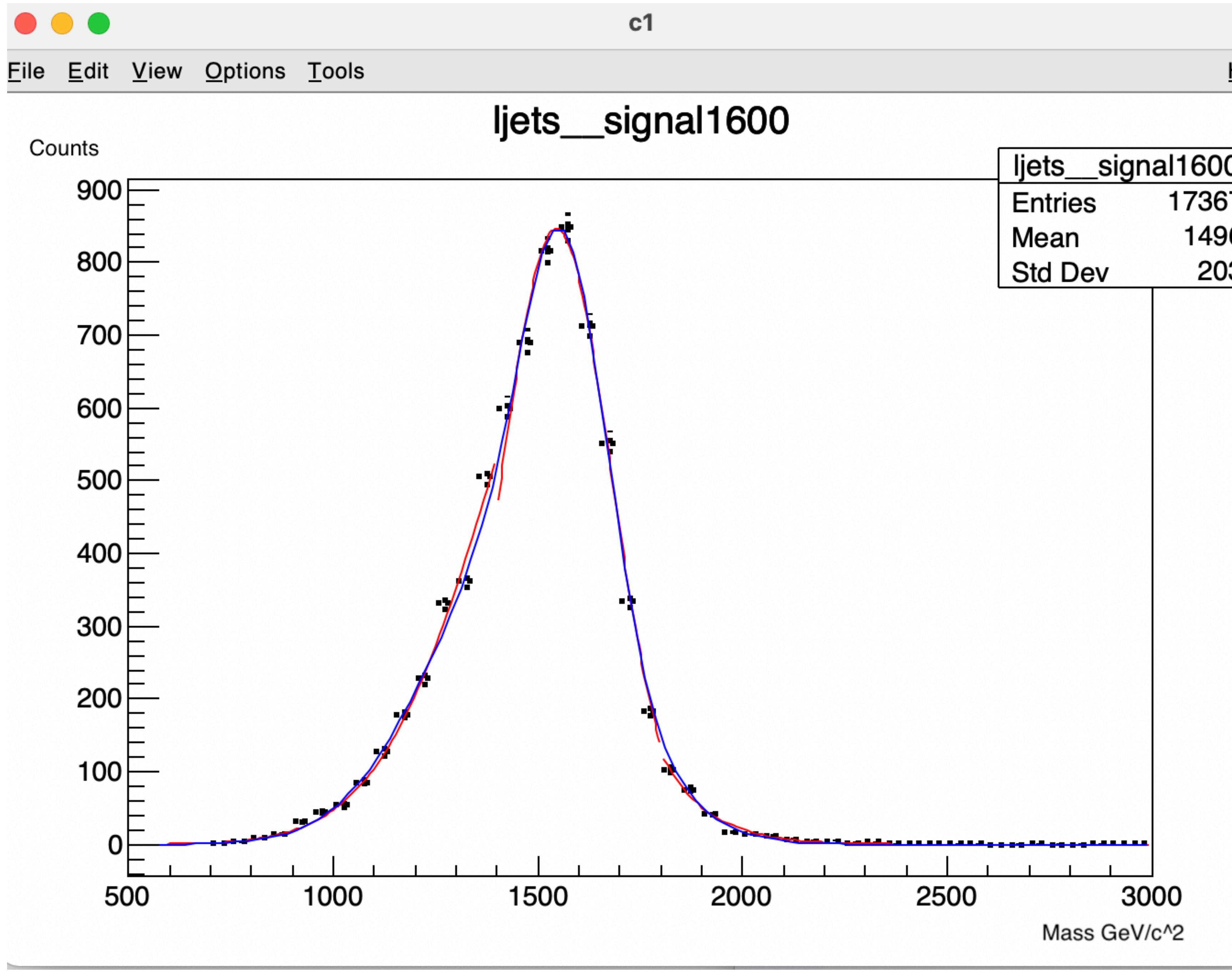
$$f(x;\alpha,n,\bar{x},\sigma) = N \cdot \begin{cases} \exp(-\frac{(x-\bar{x})^2}{2\sigma^2}), & \text{for } \frac{x-\bar{x}}{\sigma} > -\alpha \\ A \cdot (B - \frac{x-\bar{x}}{\sigma})^{-n}, & \text{for } \frac{x-\bar{x}}{\sigma} \leqslant -\alpha \end{cases}$$

- Jets-a collection of hadrons
- After collisions, resultant quarks experience attraction due to the strong force
- We want to determine which particles created the jet

$$f(x) = a \cdot \exp\left(-\frac{(x-b)^2}{2c^2}\right)$$

```
TF1 *g1 = new TF1("m1", "gaus", 500, q - (q/8)); // ranges ar
TF1 *g2 = new TF1("m2", "gaus", q - (q/8), q + (q/8));
TF1 *g3 = new TF1("m3", "gaus", q + (q/8), 3000);
// Total is the sum of the functions
TF1 *total = new TF1("mtotal", "gaus(0)+gaus(3)",500, 3000);
```

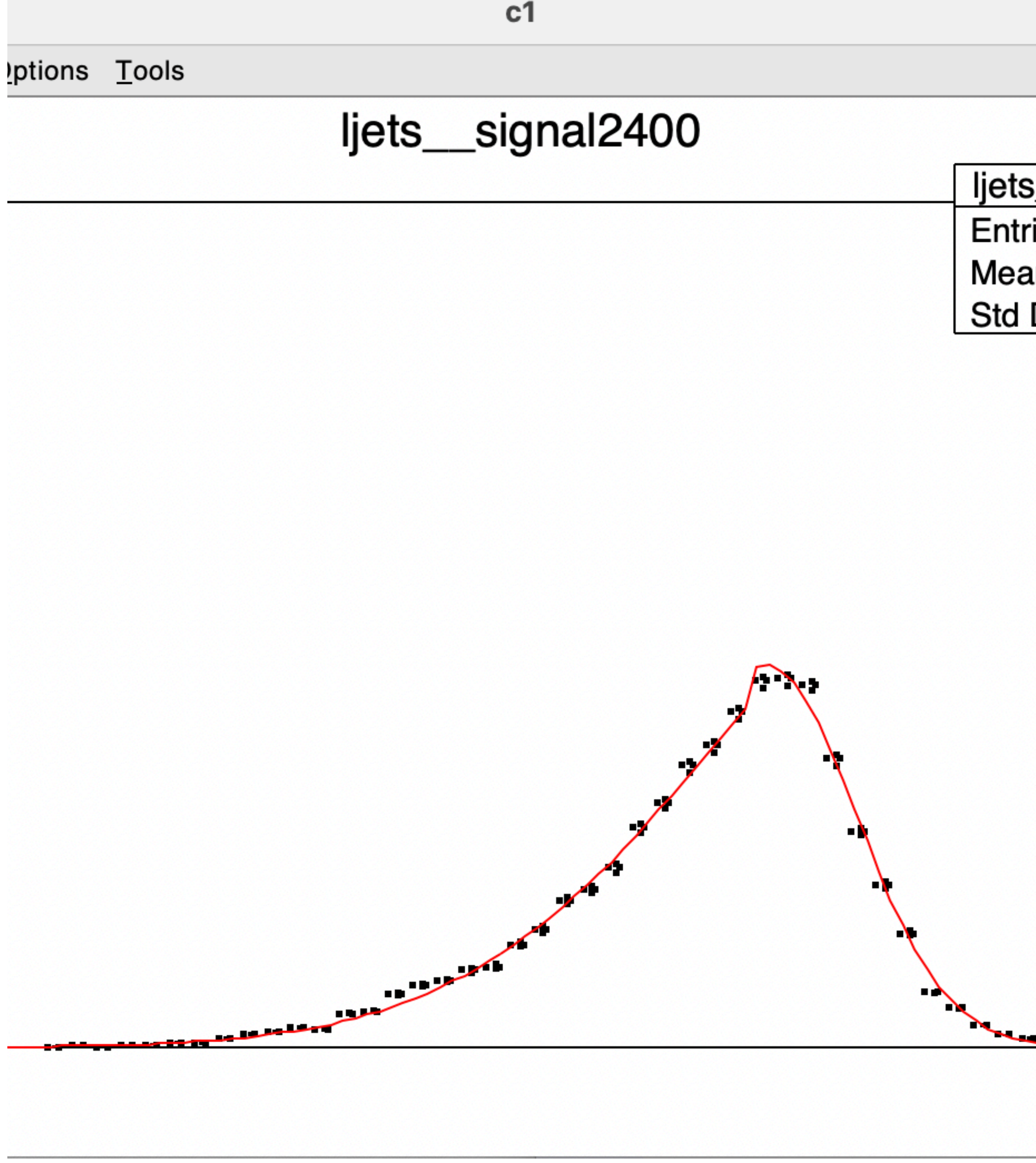


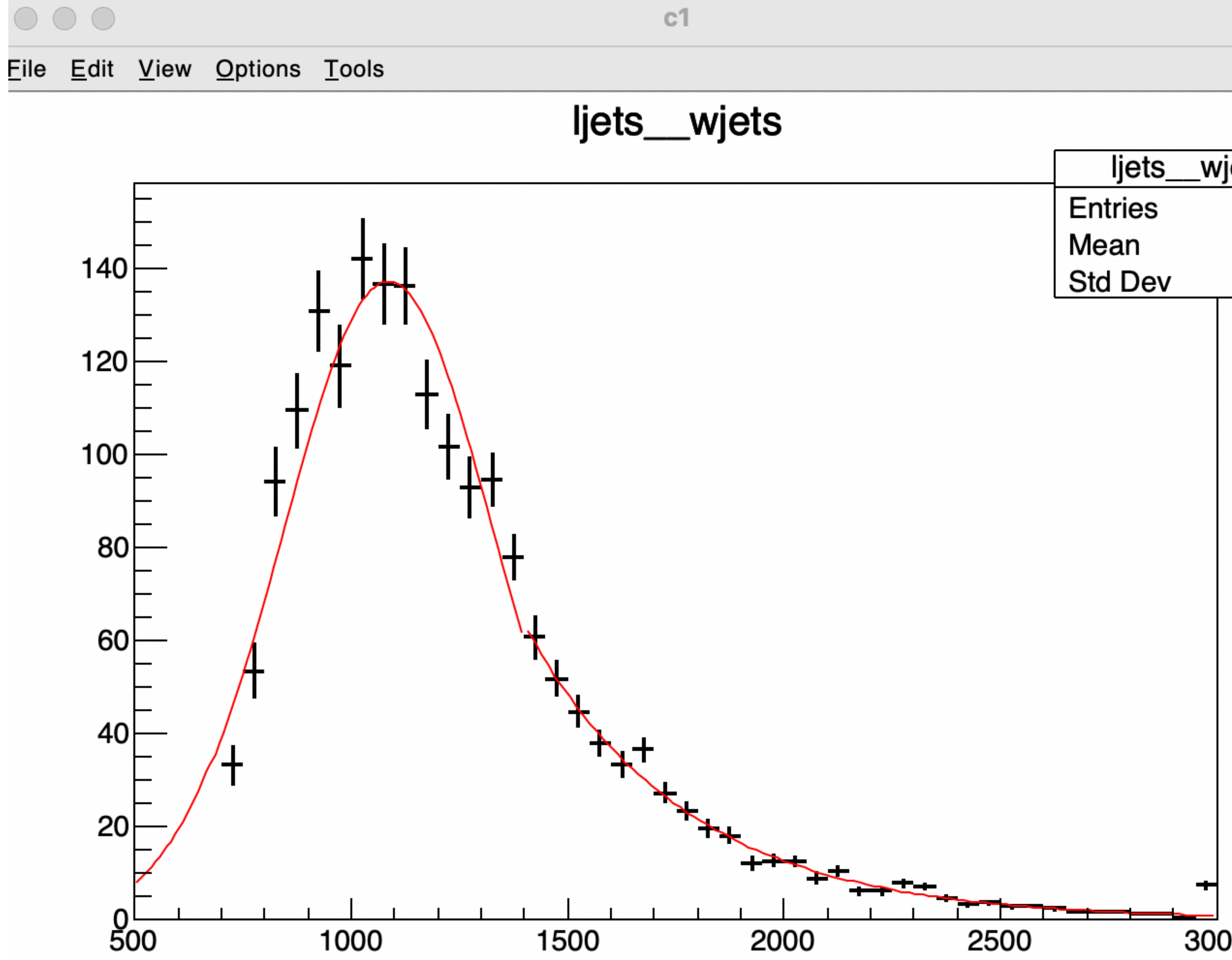


Data Analysis Continued

- Function Defined Parameters
- Gaussian and exponential

```
double signal_fit(double *x, double *par){
// Define parameters
double a = par[0]; // First Gaussian
double b = par[1]; // First Gaussian
double c = par[2]; // First Gaussian
double d = par[3]; // Second Gaussian
double f = par[4]; // Second Gaussian
double g = par[5]; // Second Gaussian
double h = par[6]; // Third Gaussian
double i = par[7]; // Third Gaussian
double j = par[8]; // Third Gaussian
double k = par[9]; // Determines Gaussian between one and two
double l = par[10]; // Determines Gaussian between two and thre
//create functions
if(x[0] <= k)
return a * std::exp(-.5 * std::pow(((x[0] - b)/c),2));
else if(x[0] >k && x[0] <= l)
return d * std::exp(-.5 * std::pow(((x[0] - f)/g),2));
else if(x[0] > l)
return h * std::exp(-.5 * std::pow(((x[0] - i)/j),2));
else
return 0;
}
```





Conclusions

- Chip testing will be ready to begin this Fall
- The triple Gaussian is a good fit for the signal series
- The Gaussian with an exponential tail is a good fit for the other set of data