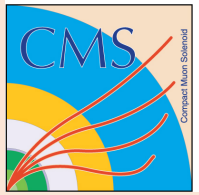
Cornell Laboratory for
Accelerator-based Sciences
and Education (CLASSE)

Thermal Runaway Studies for the CMS TFPX Phase-II Upgrade

8/16/2021

Kevin Souhrada

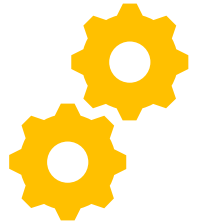


FERMILAB-SLIDES-21-081-V

Outline:

What is CMS/TFPX?

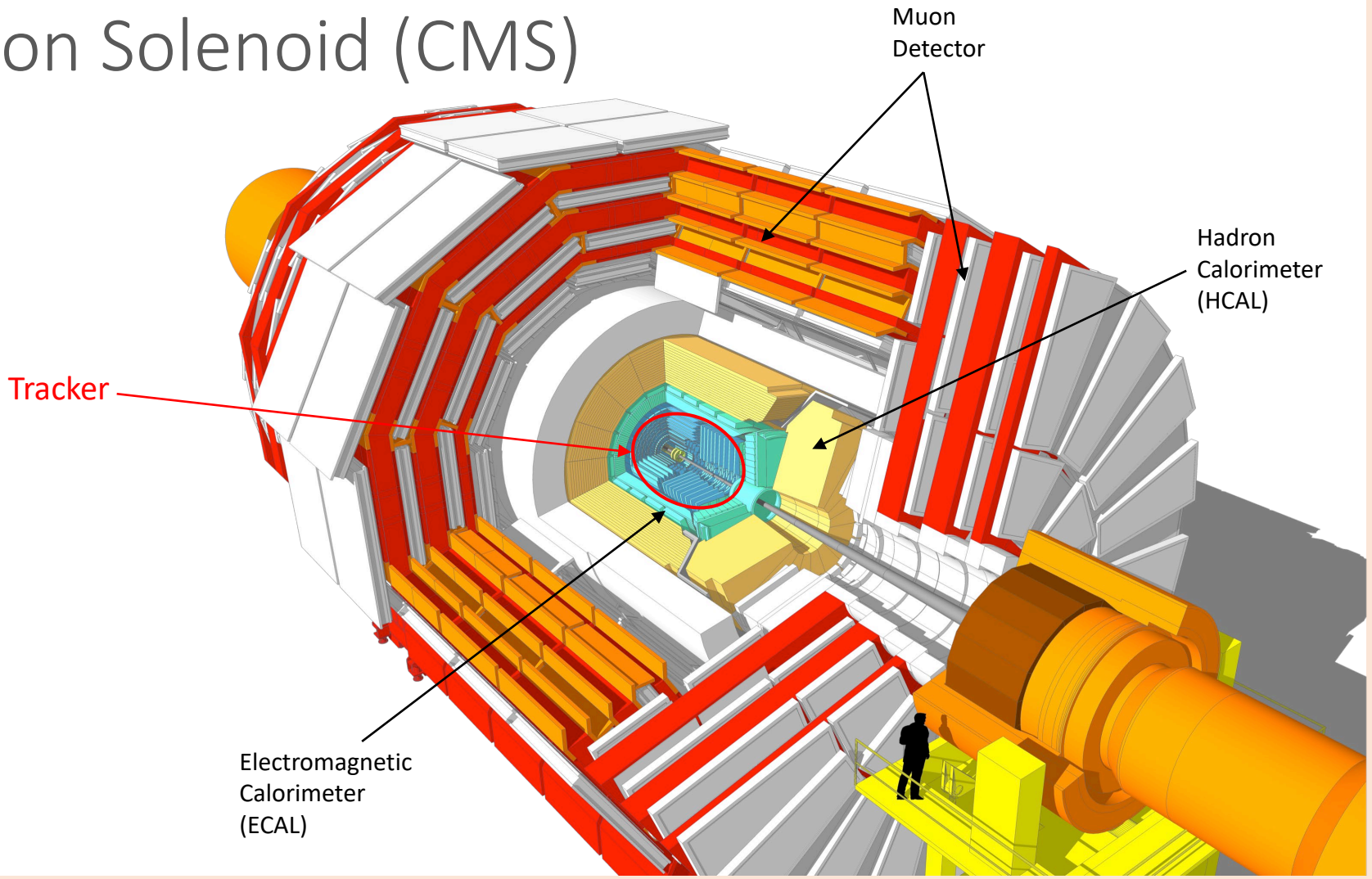
What is Thermal Runaway and how do we prevent it?



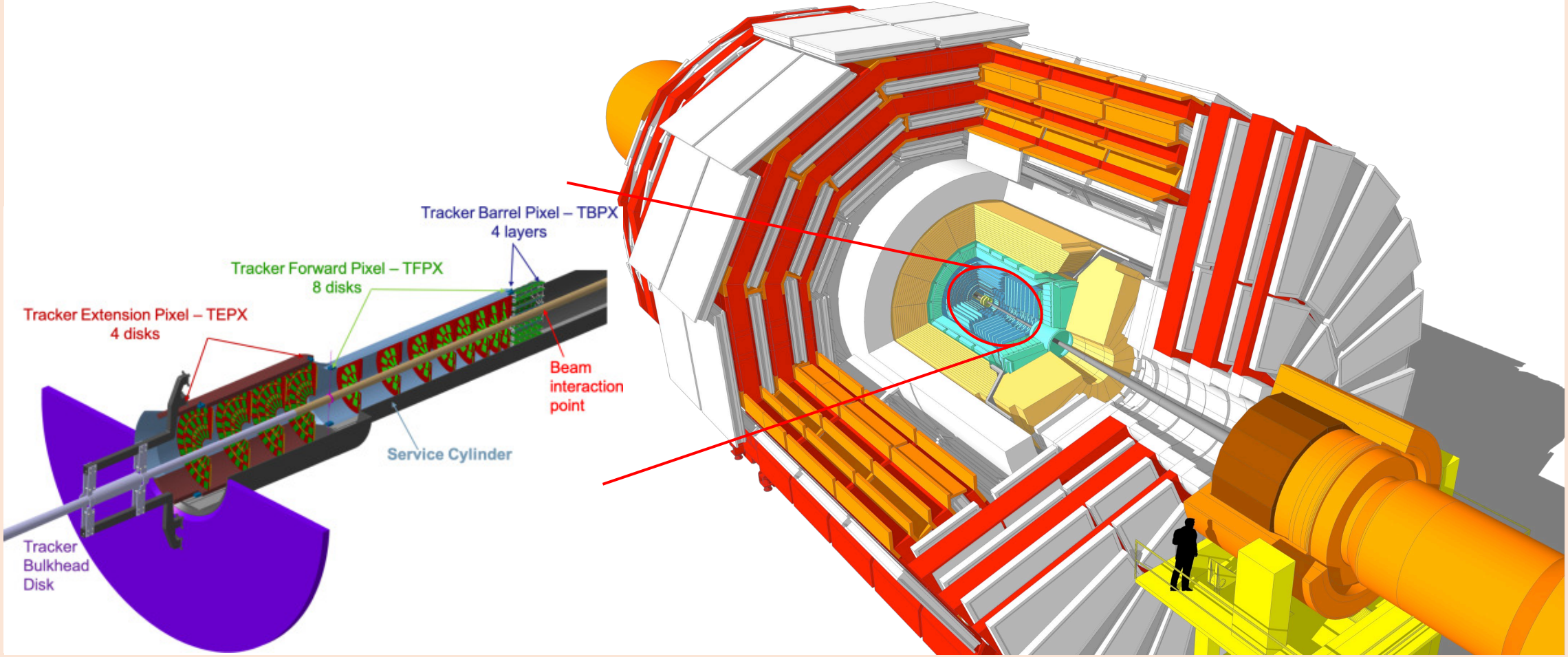
How do we simulate runaway in the lab?

What is CMS/TFPX?

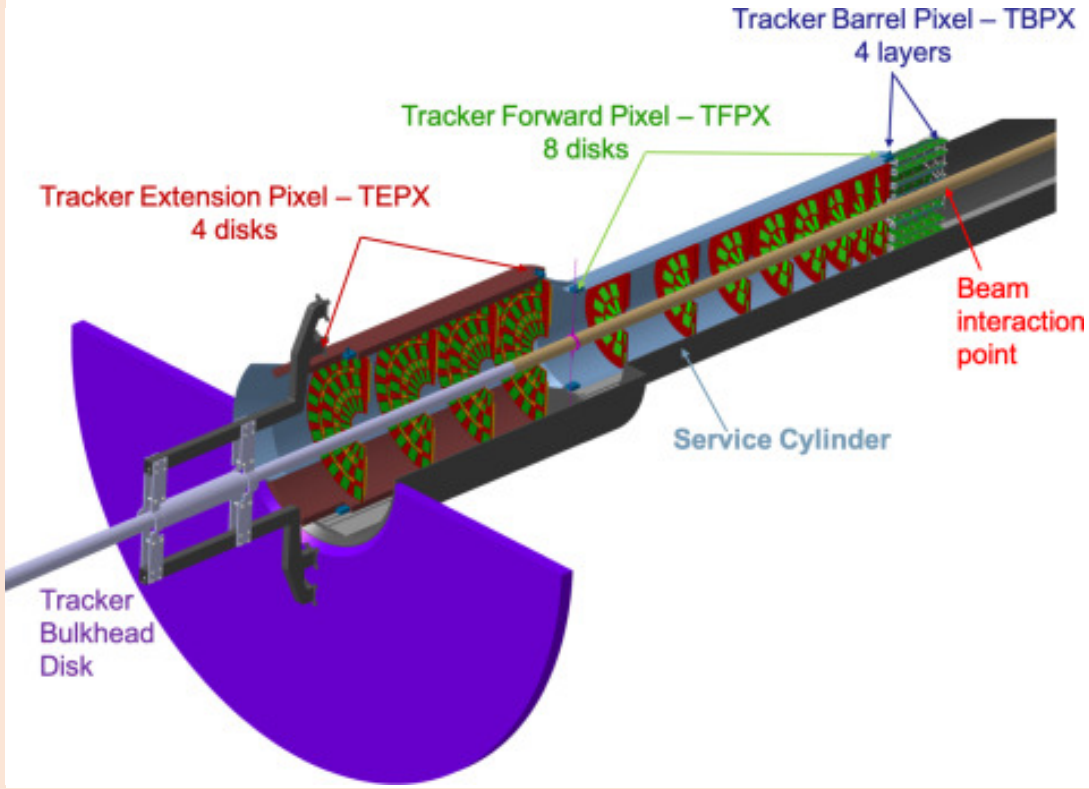
Compact Muon Solenoid (CMS)



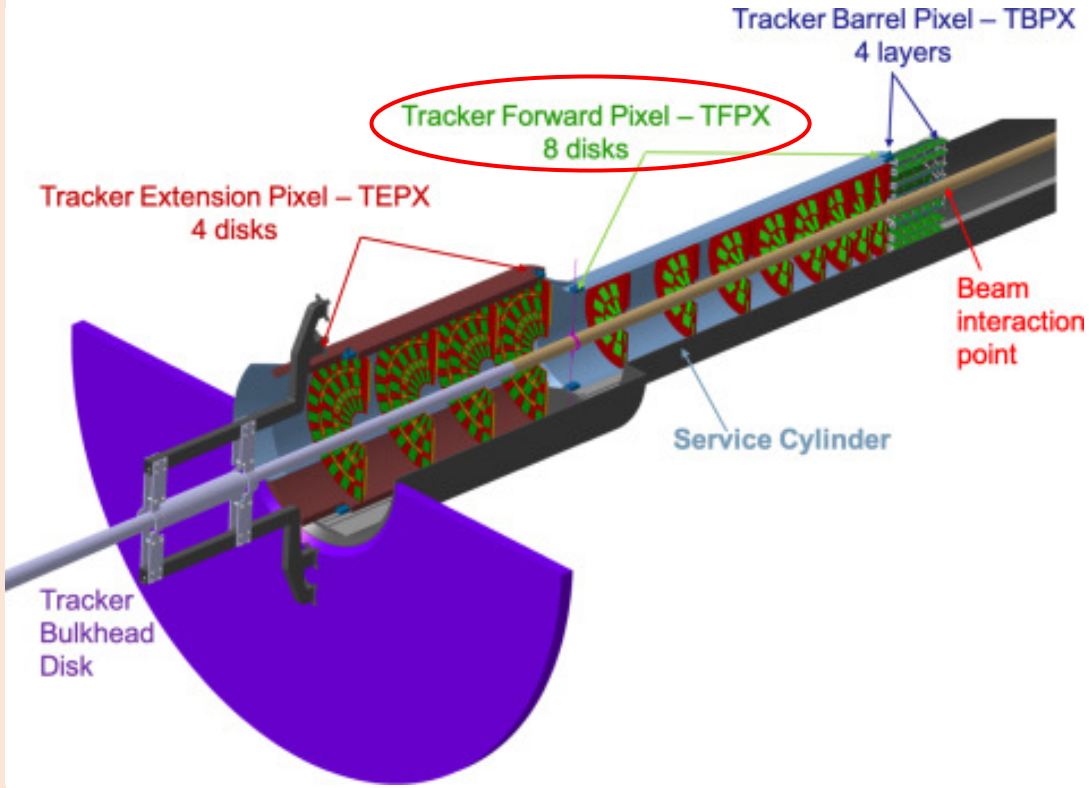
CMS / Tracker


Tracker Barrel Pixel – TBPX
4 layers
Tracker Forward Pixel – TFPX
8 disks
Tracker Extension Pixel – TEPX
4 disks
Beam
interaction
point
Service Cylinder
Tracker
Bulkhead
Disk

Tracker / TFPX



Tracker / TFPX



Innermost subdetector

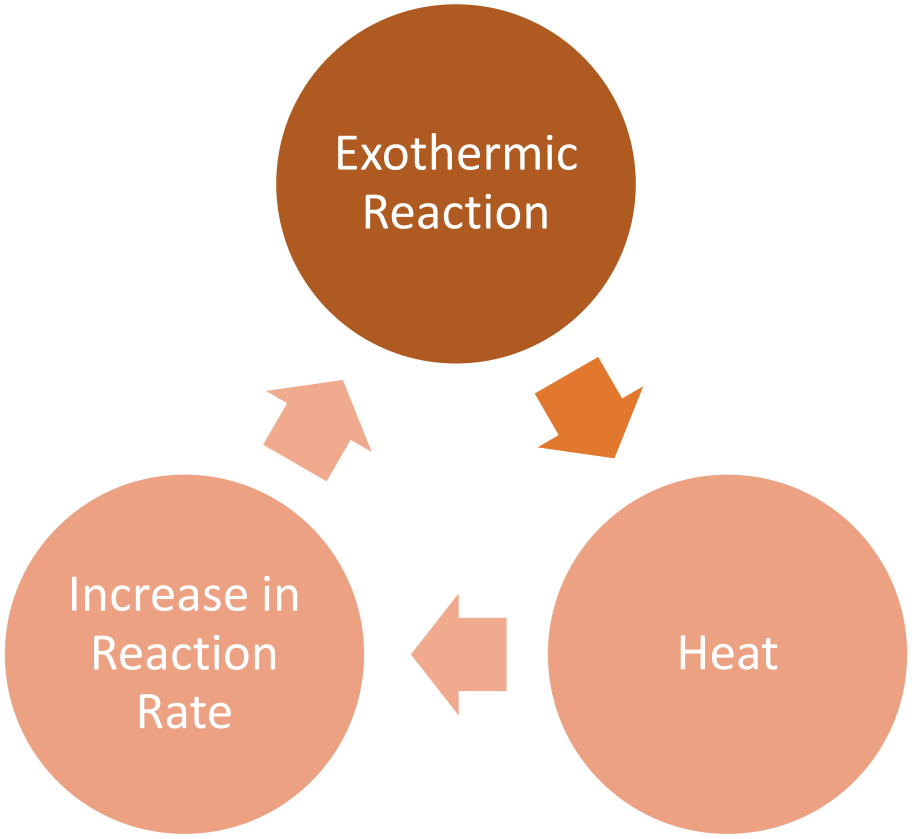
Closest to collision point

Highest radiation dose

*Structure needs to be radiation hardy!

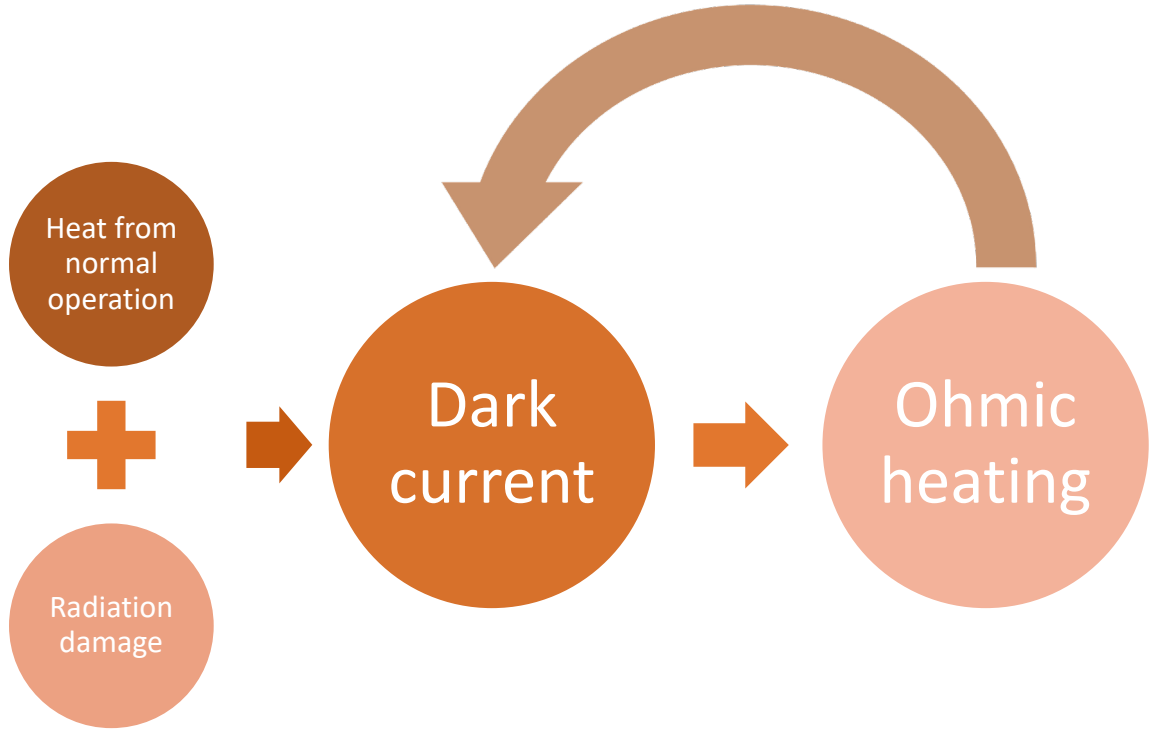
What is Thermal Runaway?

What is Thermal Runaway? (Chemistry)



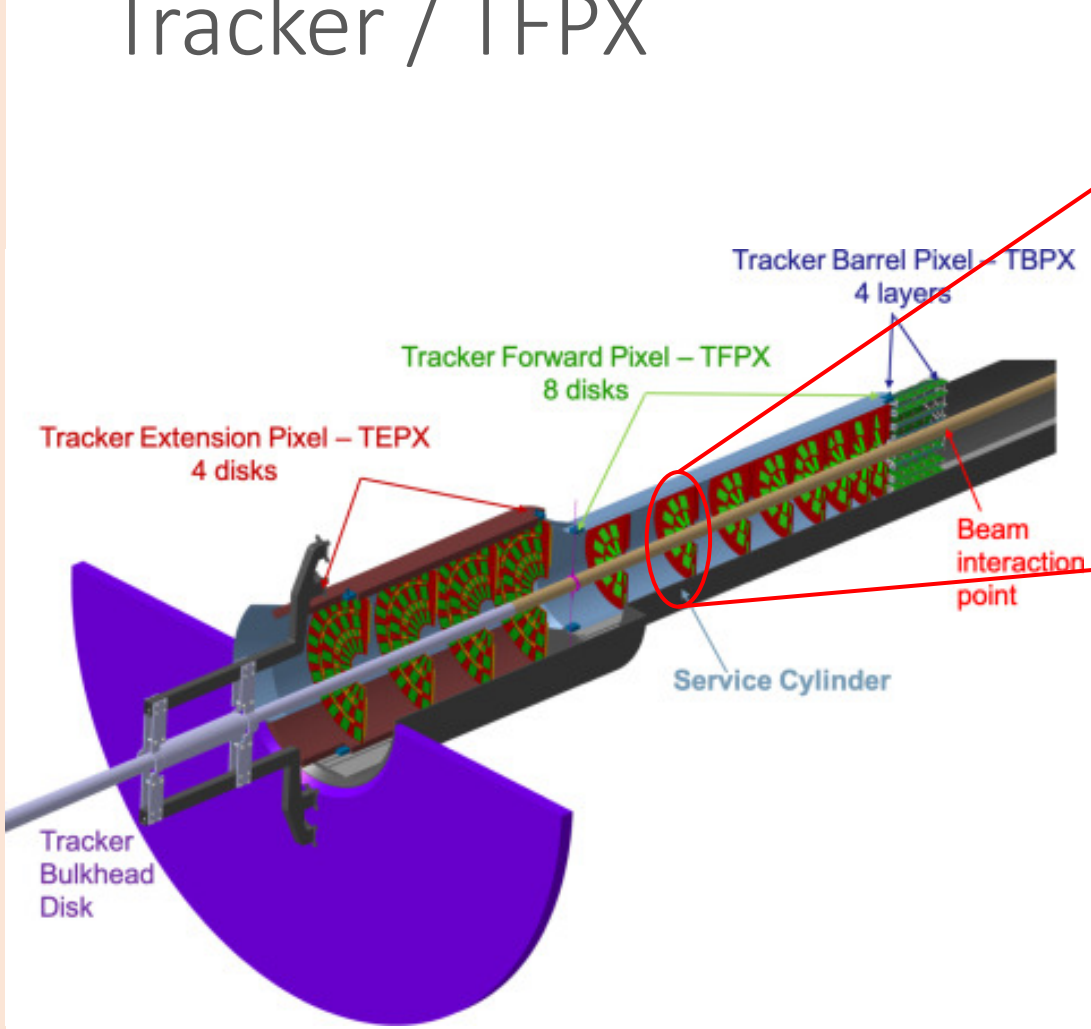
What is Thermal Runaway? (TFPX)

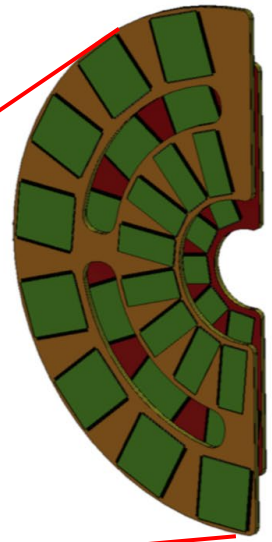
- Collisions happen *very* fast (every ~25ns)
  - Huge amounts of data must be transferred at high speeds
  - Electronics generate heat
- Dark current across the semiconductor of the silicon sensor
  - With increased radiation damage, the silicon crystal is damaged allowing greater dark current to bridge the bandgap of the semiconductor
  - Dark current generates ohmic heating, which in turn increases dark current, etc.

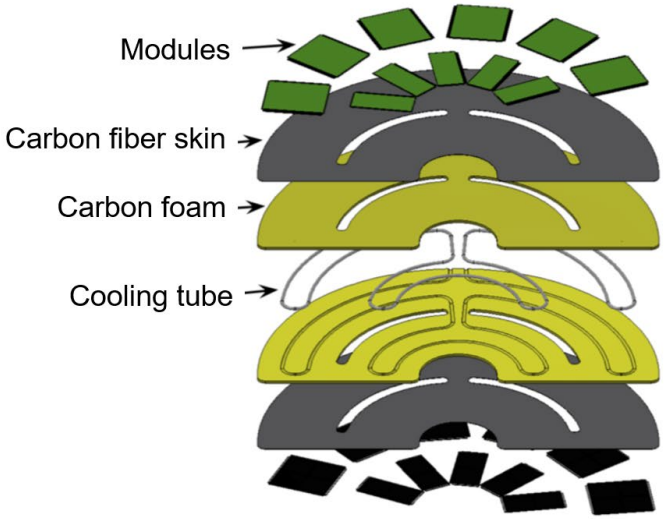


How do we prevent runaway?

Tracker / TFPX

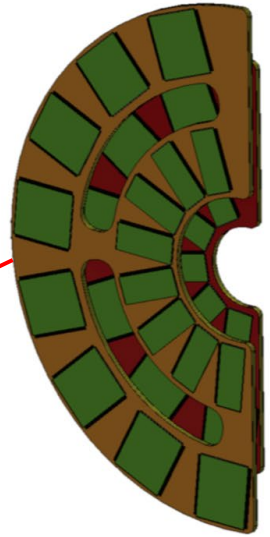


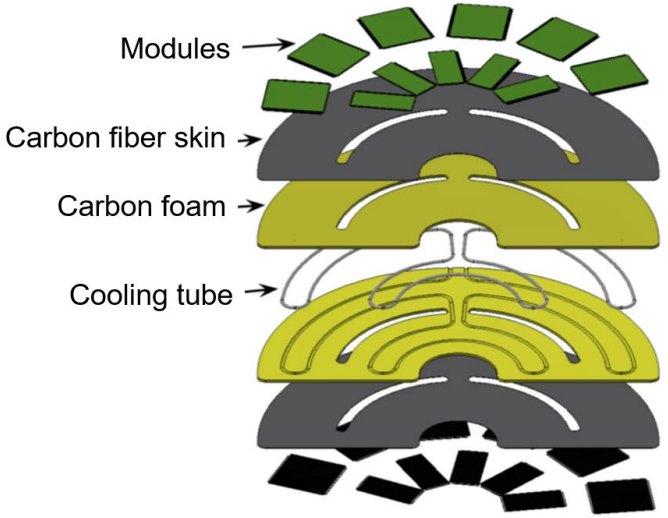




Dee cross section view

TFPX “Dee”



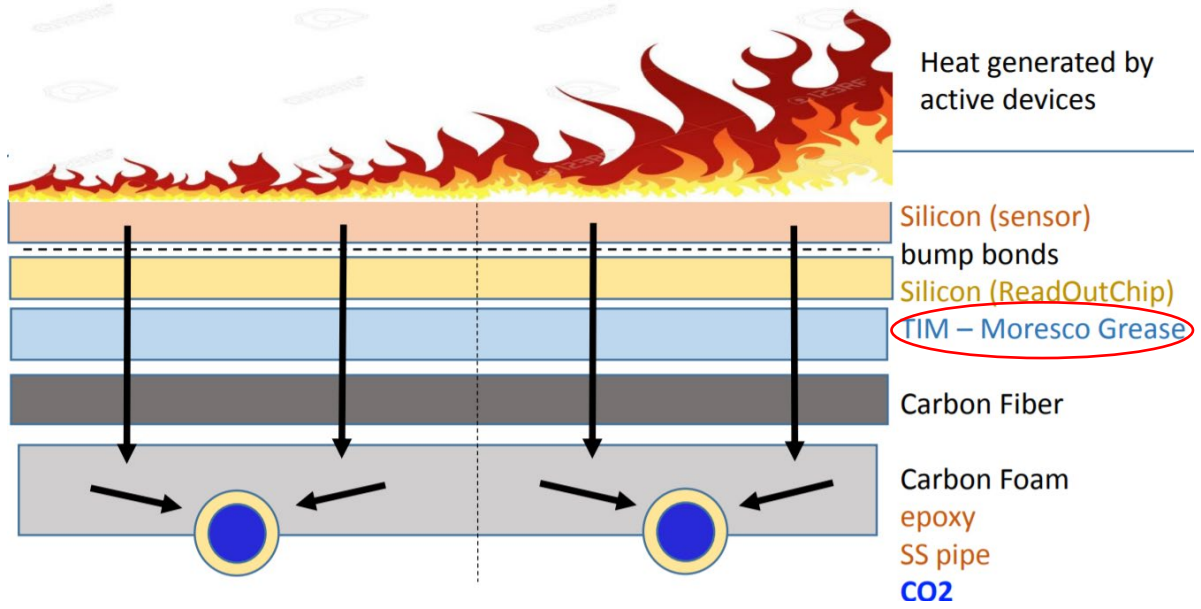


Dee cross section view

How do we prevent Thermal Runaway?

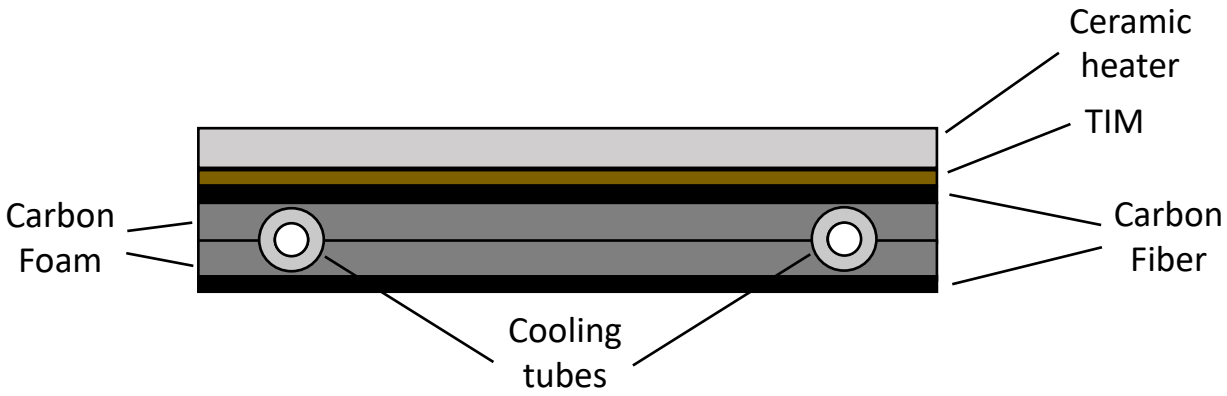
- Need to remove generated heat through the CO_2 cooling
- The thermal impedance of the structure must be managed alongside several other design requirements (minimizing total mass, module interchangeability, radiation hardiness, etc.)
- One component of the structure that we can change:

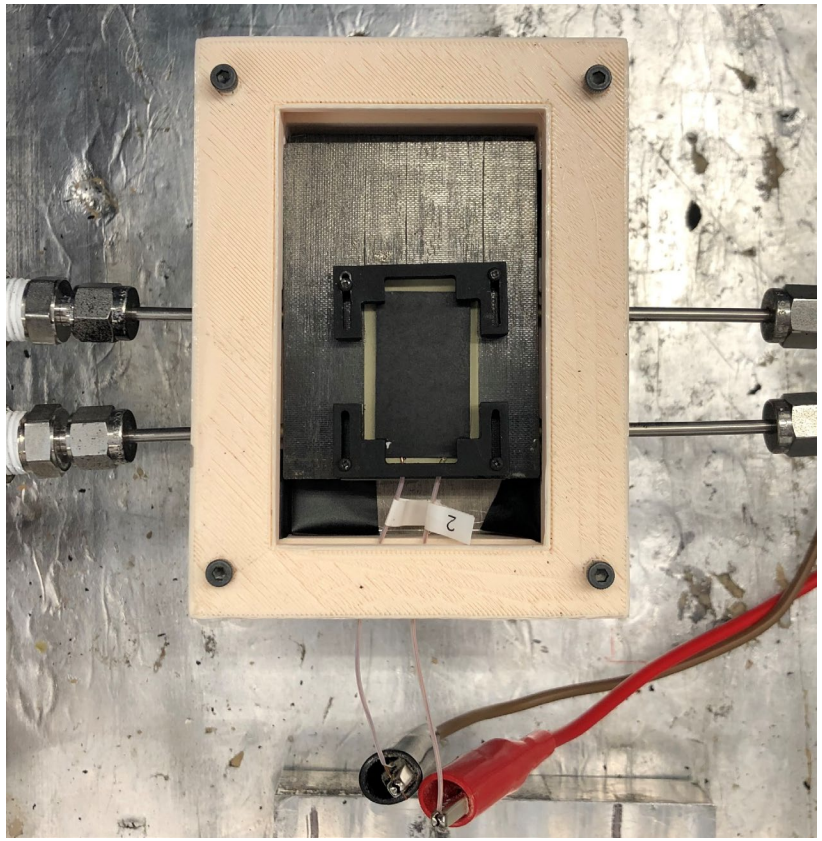
Thermal Interface Material (TIM)



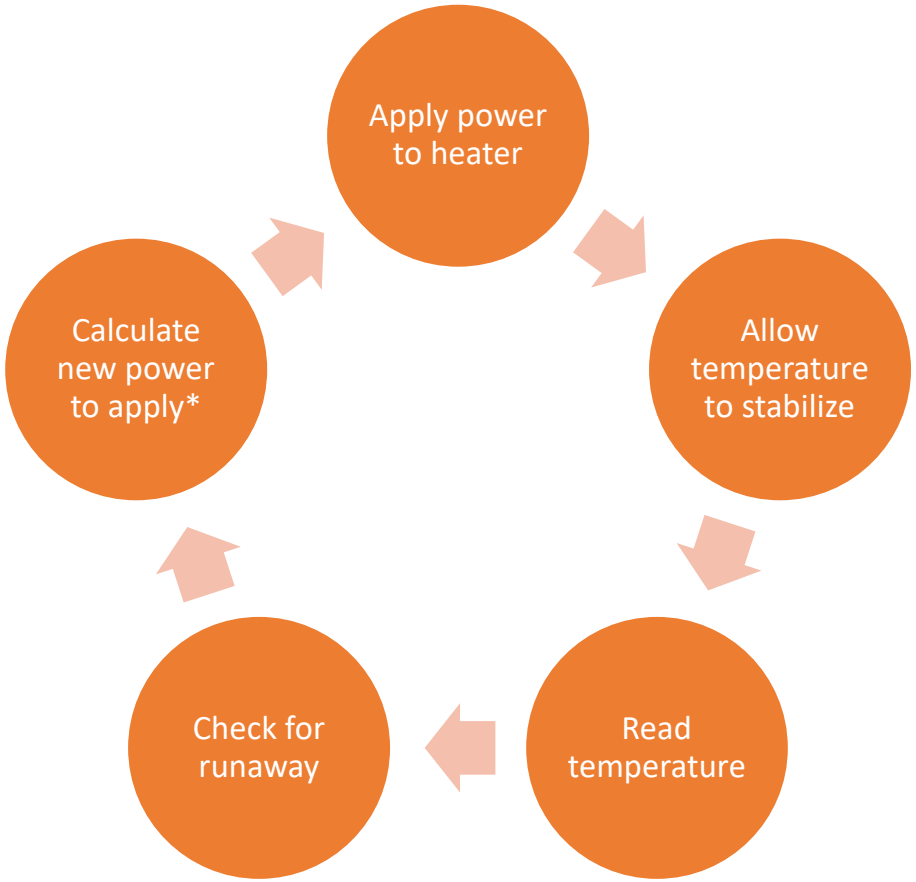
How do we simulate runaway?

How do we simulate Thermal Runaway?



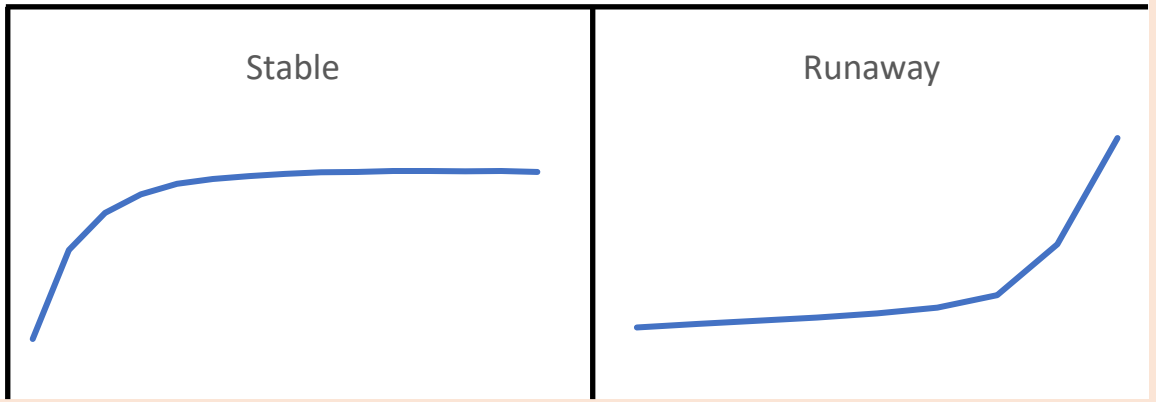


How do we simulate Thermal Runaway?



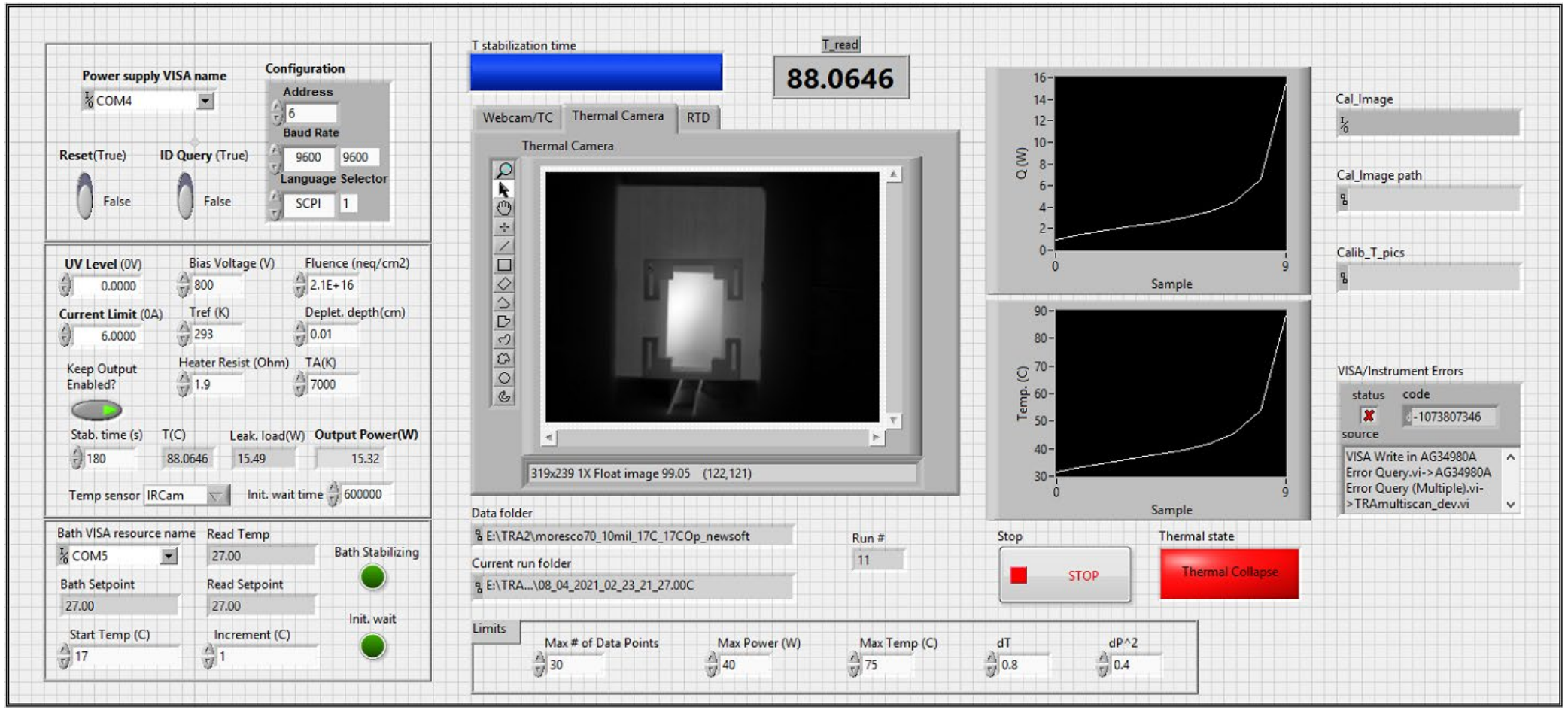
Power calculated by the equation*:

$$Q(T) = \text{const.} \times \left(\frac{T}{T_{ref}}\right)^2 e^{-T_A\left(\frac{1}{T}-\frac{1}{T_{ref}}\right)}$$



*Equation from "Analytic model of thermal runaway in silicon detectors," Beck & Viehhauser, 2010

Current runaway LabVIEW program



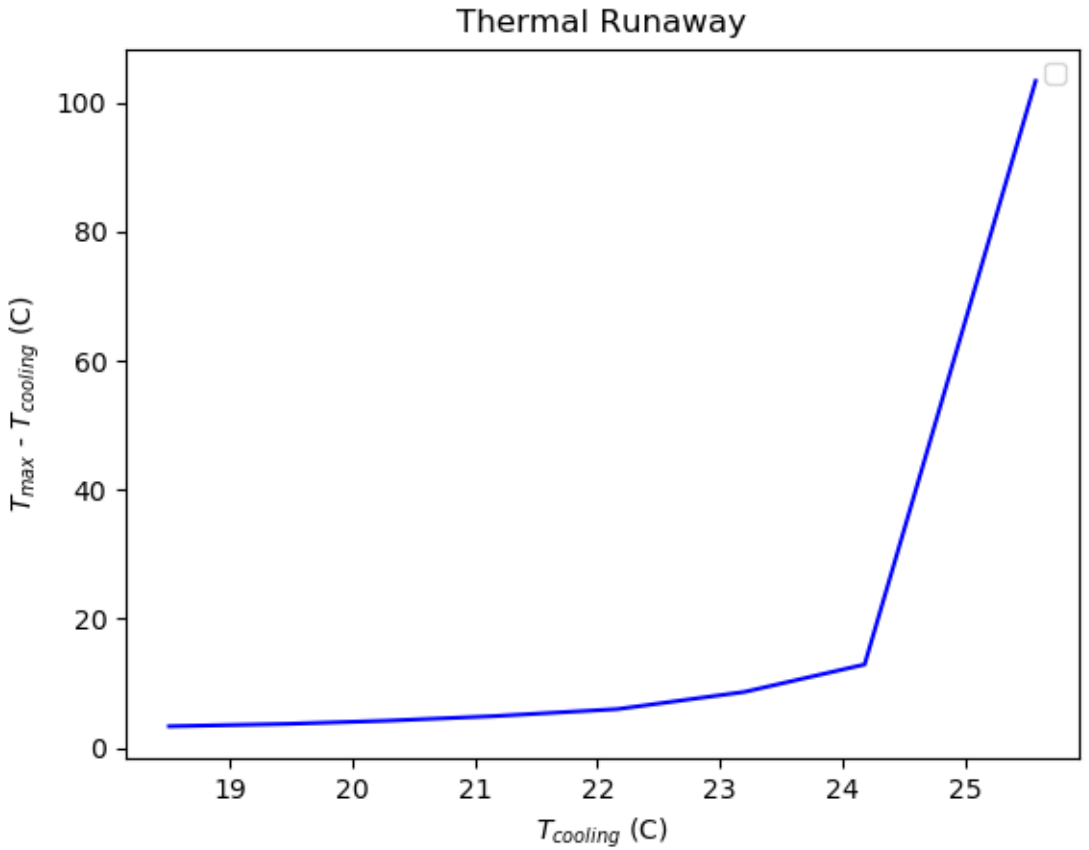
Conclusions

- Achieved a reproducible and systematic method for generating thermal runaway
- Simulating runaway allows us to determine the stable operating range for our final detector
  - Our decisions on the final parameters of the mechanical structure of TFPX will be based on their thermal performance as determined through runaway testing
- Long term goals:
  - Runaway testing on full-sized Dees with asymmetrically heated replica modules to fully model the detector environment

Thank you!

Comments / questions?

Data


Thermal Runaway
100
80
60
40
20
0
T_{max} - $T_{cooling}$ (C)
19
20
21
22
23
24
25
$T_{cooling}$ (C)