SiD Hadron Calorimeter and Higgs to Invisible

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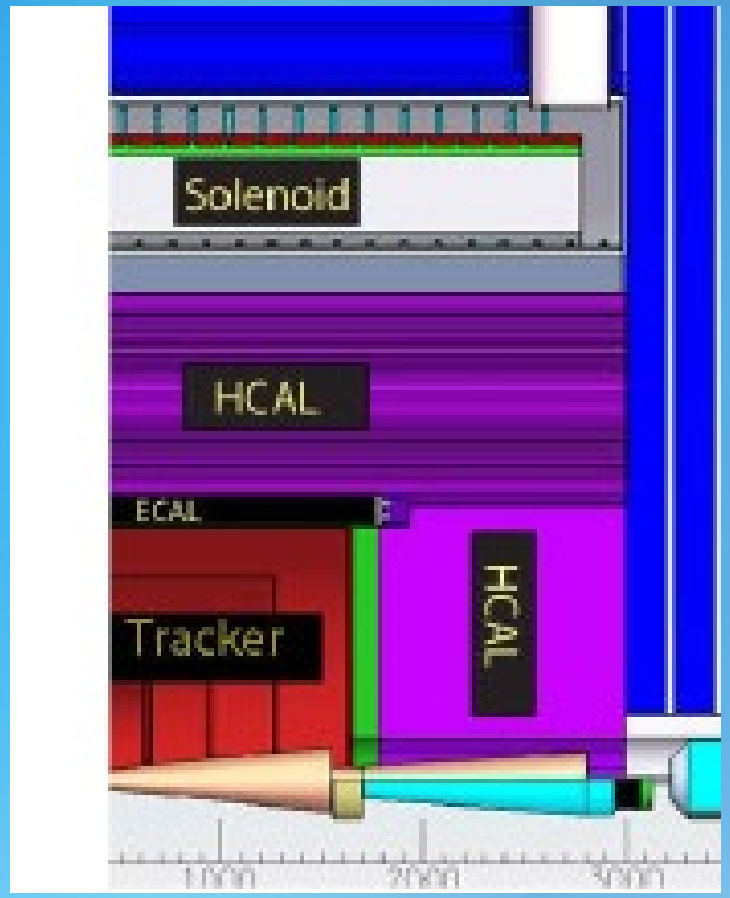
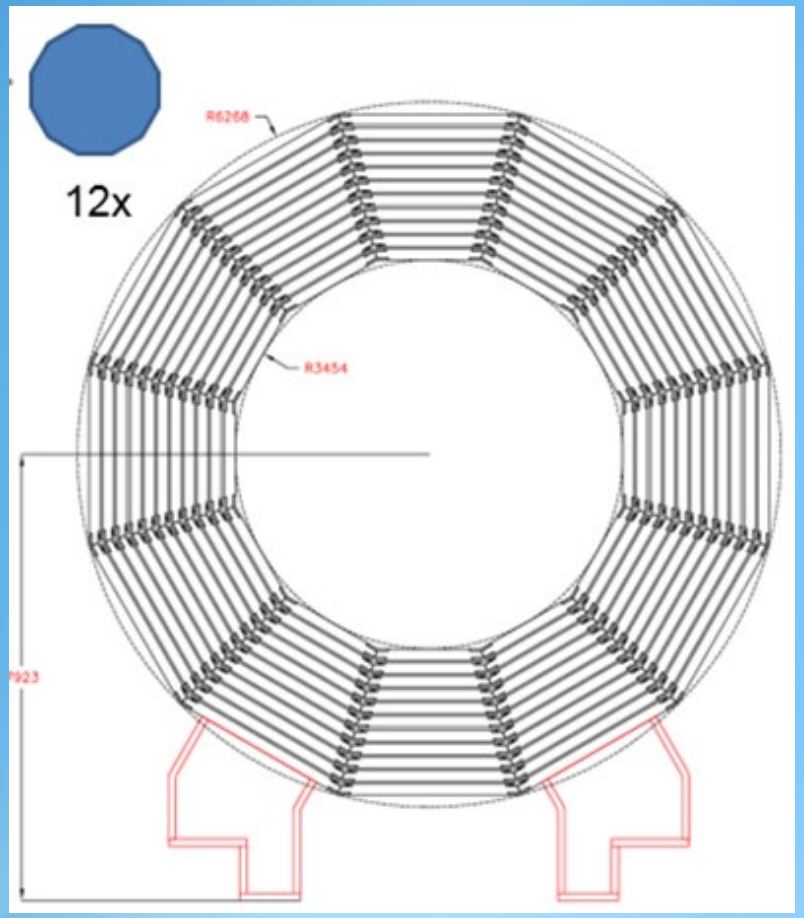
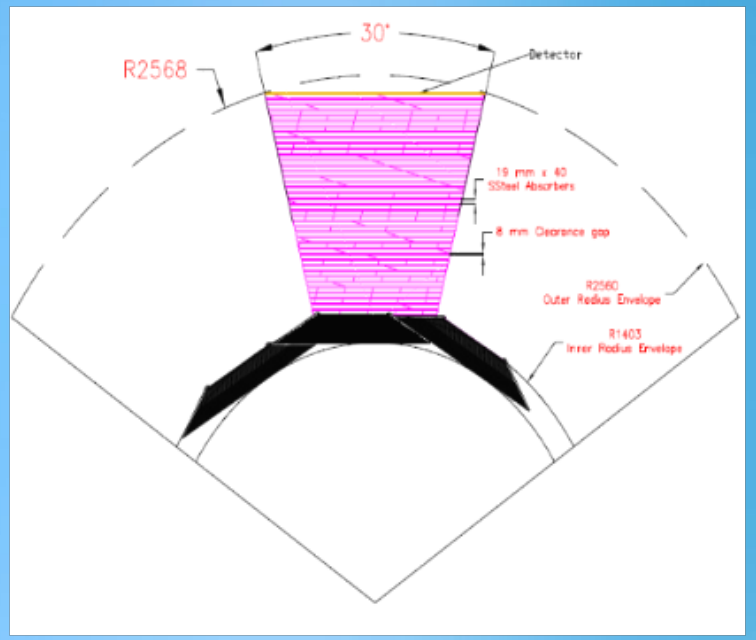
April 14, 2021

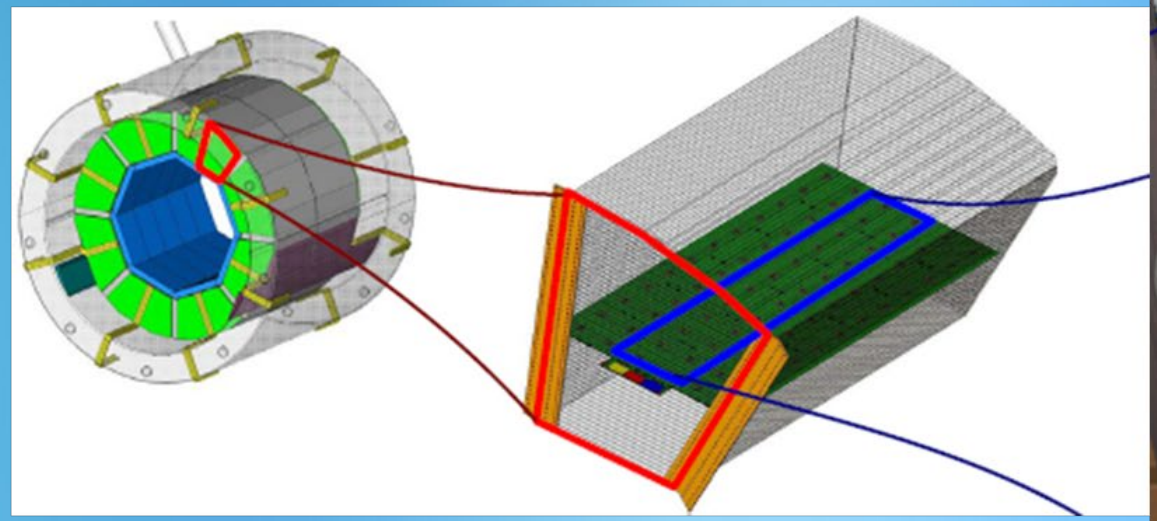
SiD Hadron Calorimeter

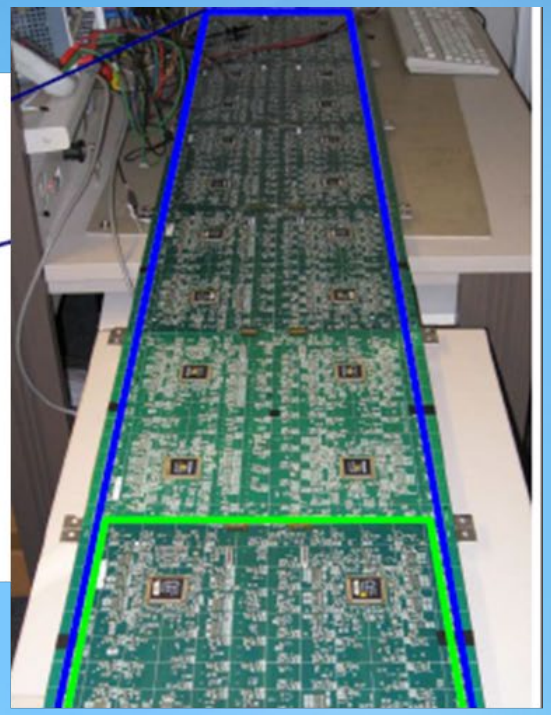






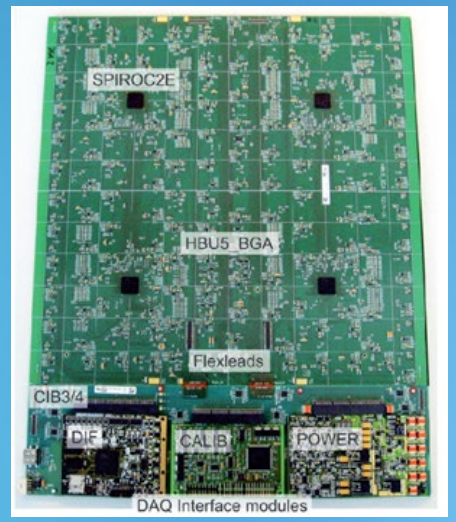
SiD Hadron Calorimeter





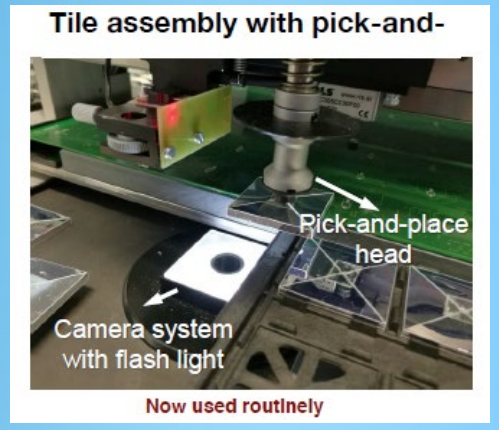
- Start to develop SiD-specific designs for barrel, endcaps (funding dependent).
  - Number of sections in z?
  - Signal/services routing along boards?
  - Readout – follow CALICE?
  - Plan for some timing layers?

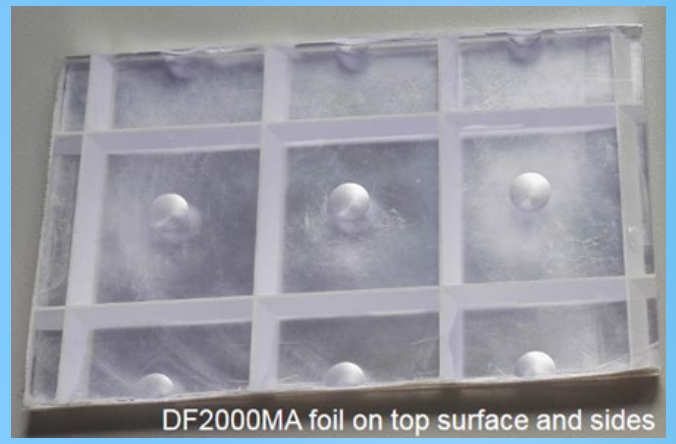
SiD Hadron Calorimeter

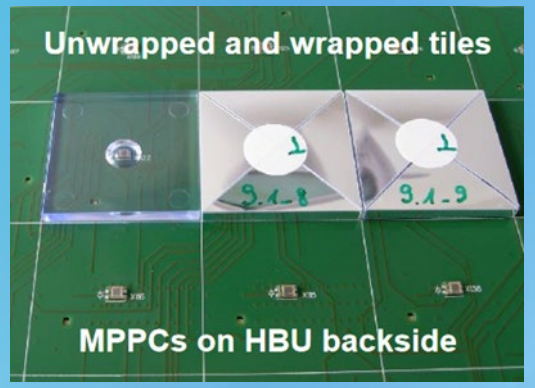


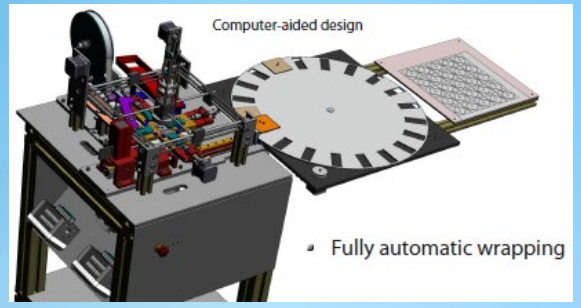
Hadron Base Unit (HBU)

Felix Sefkow







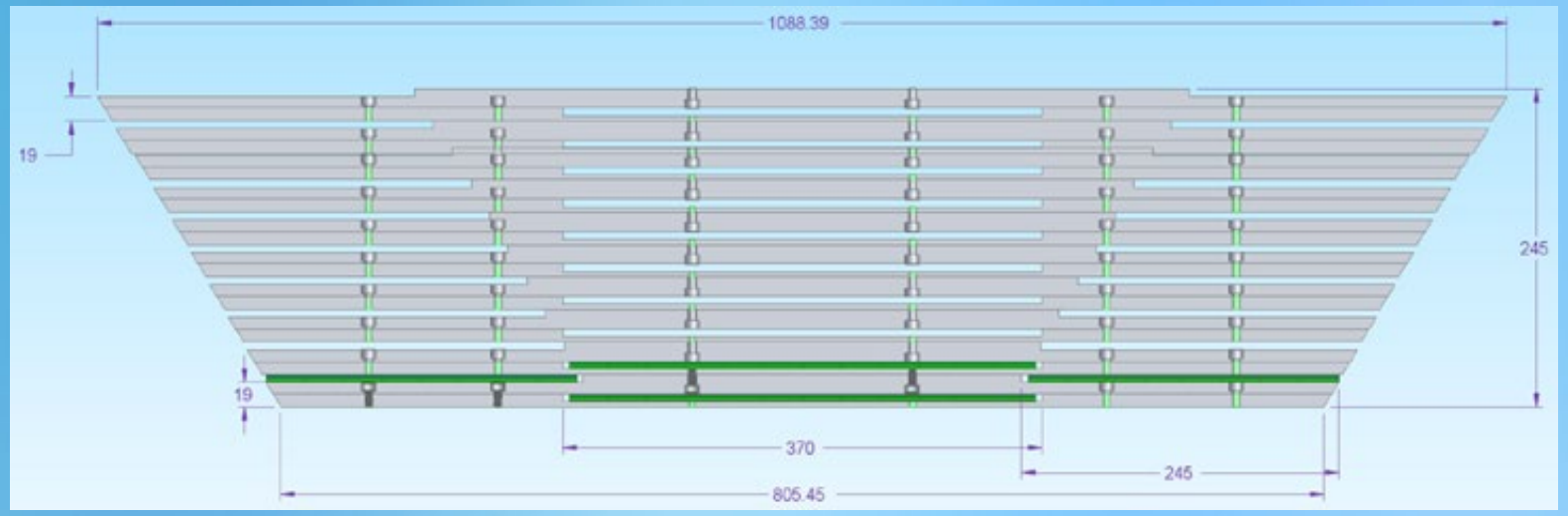


Alternative “megatile” approach
- Being developed in Japan (US-Japan program)

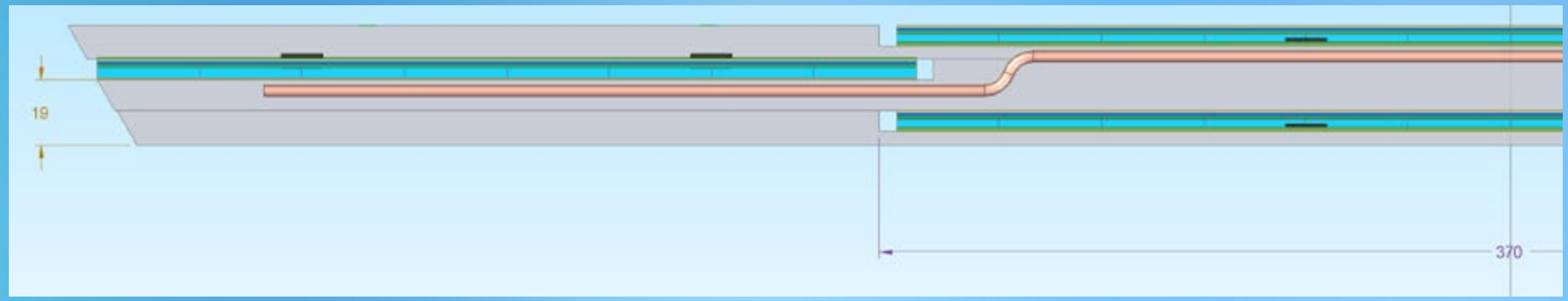
Robotic tile wrapping/placement

SiD Hadron Calorimeter

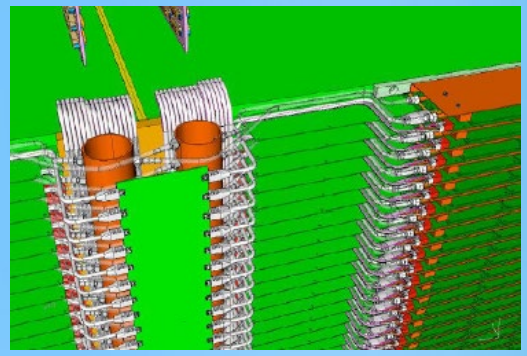
Initial mechanical design ideas – Marco Uriunno (SLAC)



SiD Hadron Calorimeter



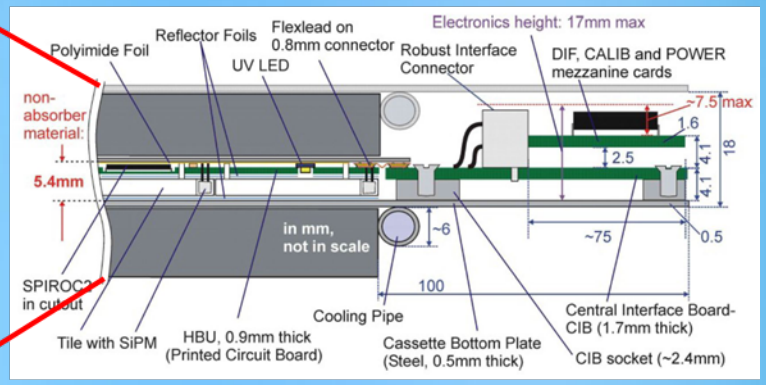
- Exploring possible cooling schemes
- Heat load/extraction



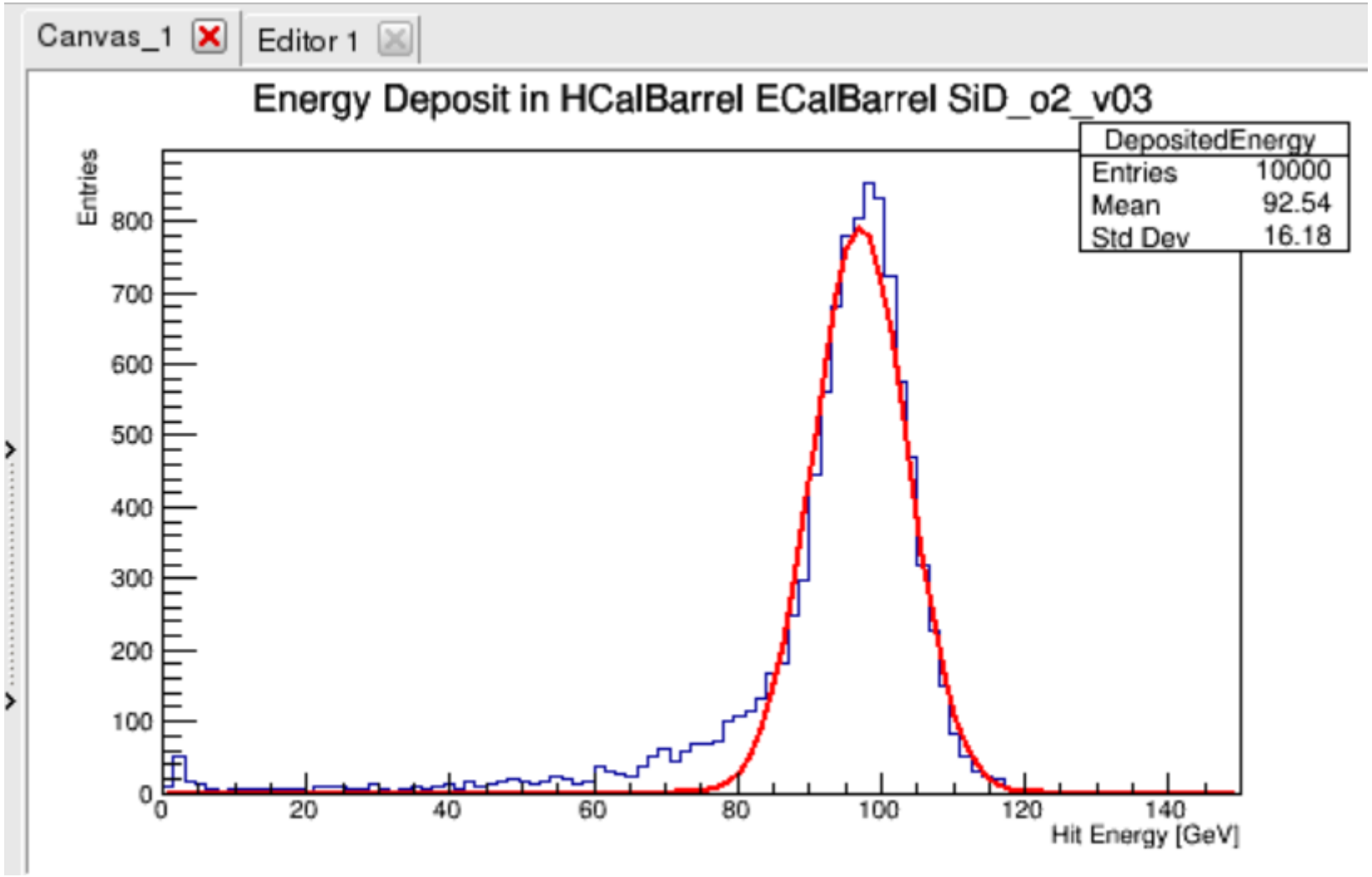
Marco Uriunno (SLAC)

SiD Hadron Calorimeter

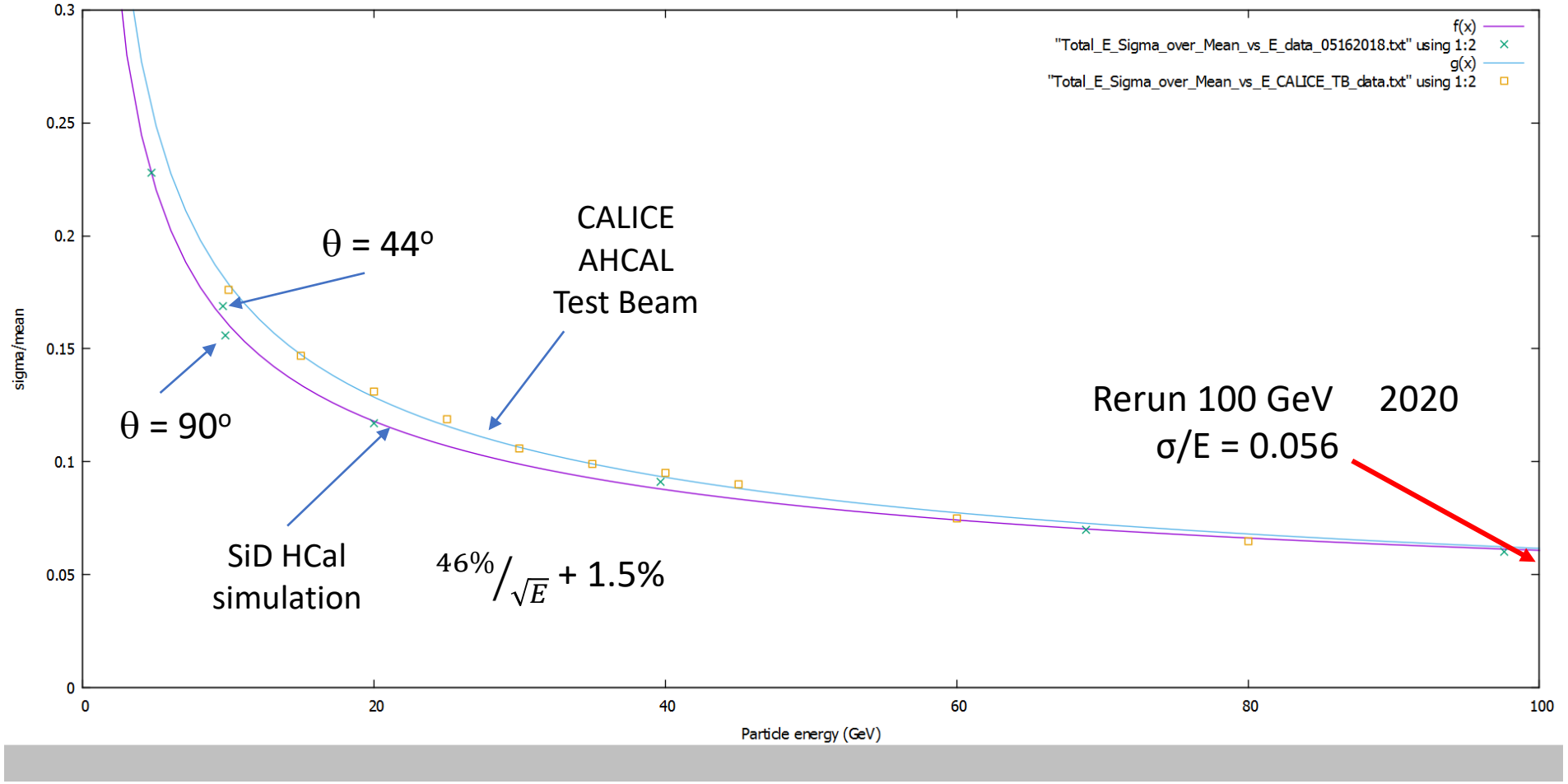
CALICE design



100 GeV pions – 2018 result



5-100 GeV charged pions: SiD simulation and CALICE 1m^3 test beam results



SiD Hadron Calorimeter – detailed simulation – potential variations

1) Tile size
(Austin compared the HCal energy resolution and peak position for 3mm and 6mm tile sizes. There is a degradation of both the peak position and resolution at the few percent level using the larger tile size - for single pions.)

2) Positioning of tiles, tile-tile gaps, and tile thickness variations.

3) Absorber plate thickness variations.

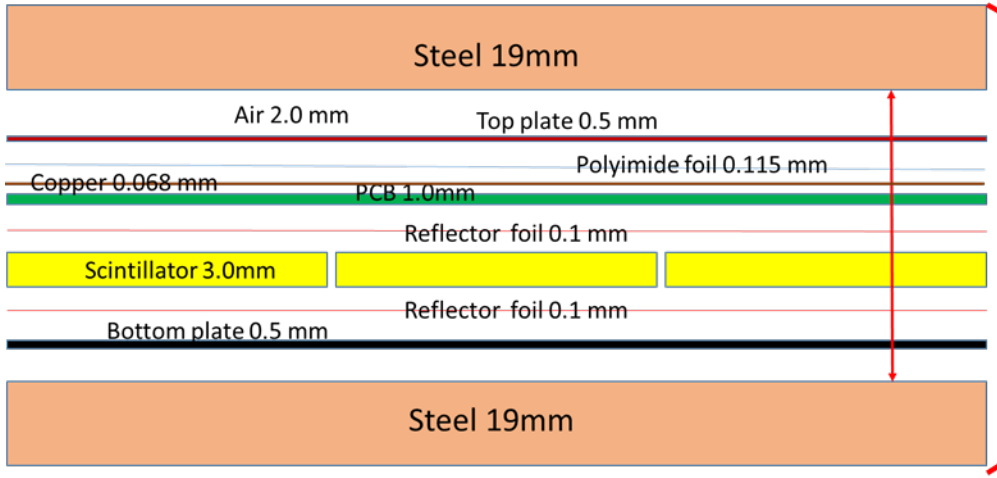
4) Regular front section/Coarse rear section?

5) Model of light collection for tile/SiPM. We know that a dimple under the SiPM help with uniformity of response across the tile, but there is still a residual variation.

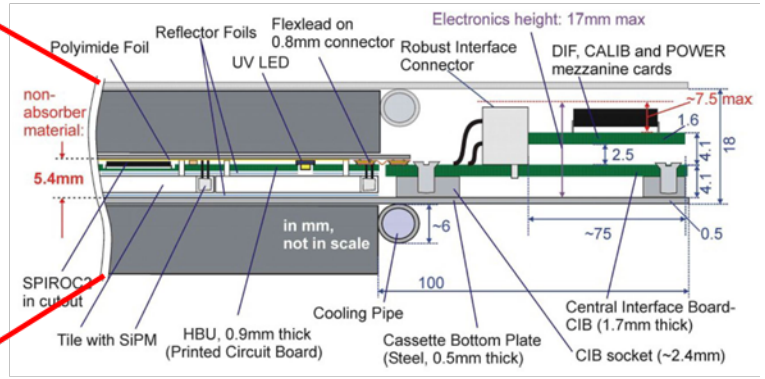
6) HCal sampling fraction

7) Calibration of HCal. How to evaluate, projected error(s). Setting energy scale(s).

8) PFA-related items - what parameters are input/can be varied for the HCal?



CALICE design



Active layer thickness = 7.383 mm

SiD Hadron Calorimeter – Layer geometry

```
<staves />
<layer repeat="40">
  <slice material = "Steel235"   thickness = "19.0*mm" />    <!-- Absorber -->
  <slice material = "Air"        thickness =  "2.0*mm" />
  <slice material = "Steel235"   thickness =  "0.5*mm" />    <!-- Top plate -->
  <slice material = "Kapton"    thickness = "0.115*mm" />    <!-- Polyimide foil -->
  <slice material = "Copper"    thickness = "0.068*mm" />
  <slice material = "PCB"       thickness =   "1.0*mm" />    <!-- PCB made of FR4 -->
  <slice material = "Polystyrole" thickness = "0.1*mm" />    <!-- Reflector foil -->
  <slice material = "Polystyrene" thickness = "3.0*mm" sensitive="yes" limits="cal_limits" />
  <slice material = "Polystyrole" thickness = "0.1*mm" />    <!-- Reflector foil -->
  <slice material = "Steel235"    thickness = "0.5*mm" />    <!-- Bottom plate -->
  <slice material = "Air"       thickness = "0.617*mm" />    <!-- Clearance gap between active layer and next absorber -->
</layer>
<!--layer repeat="1"-->
<!--slice material = "Steel235"   thickness = "19.0*mm" /--><!-- Terminator plate (if needed) -->
<!--/layer-->
</detector>
```

SiD Hadron Calorimeter - Digitization

```
<!-- digitisation for scintillator HCAL barrel hits -->
<processor name="HCalBarrelDigi" type="RealisticCaloDigiScinPpd">
  <parameter name="inputHitCollections"> HCalBarrelHits </parameter>
  <parameter name="outputHitCollections"> HCalBarrelDigi </parameter>
  <parameter name="outputRelationCollections"> HCalBarrelDigiRelation </parameter>
  <parameter name="threshold"> 0.5 </parameter>
  <parameter name="thresholdUnit"> MIP </parameter>
  <parameter name="timingCut"> 1 </parameter>
  <parameter name="timingCorrectForPropagation"> 1 </parameter>
  <parameter name="timingWindowMin"> -10 </parameter>
  <parameter name="timingWindowMax"> 100 </parameter>
  <parameter name="calibration_mip">0.0004825</parameter>
  <parameter name="elec_noise_mip"> 0.1 </parameter>
  <parameter name="elec_range_mip"> 500 </parameter>
  <parameter name="CellIDLayerString"> layer </parameter>
  <parameter name="ppd_mipPe"> 15 </parameter>
  <parameter name="ppd_npix"> 1600 </parameter>
  <parameter name="ppd_npix_uncert"> 0 </parameter>
  <parameter name="ppd_pix_spread"> 0 </parameter>
  <parameter name="Verbosity" type="string"> WARNING </parameter>
</processor>
```

Minimum signal level

Electronic noise

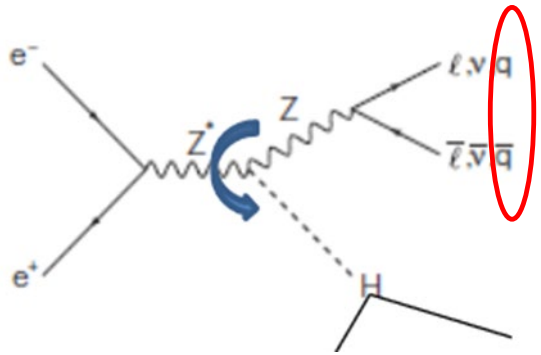
SiPM parameters

Also have mis-calibration - correlated across cells, dead cell fraction, timing window,…

SiD Hadron Calorimeter - Reconstruction

```
<!-- reconstruction for scintillator HCAL barrel hits -->
<processor name="HCalBarrelReco" type="RealisticCaloRecoScinPpd">
  <parameter name="inputHitCollections"> HCalBarrelDigi </parameter>
  <parameter name="inputRelationCollections"> HCalBarrelDigiRelation </parameter>
  <parameter name="outputHitCollections"> HCalBarrelReco </parameter>
  <parameter name="outputRelationCollections"> HCalBarrelRecoRelation </parameter>
  <parameter name="calibration_layergroups"> 100 </parameter>
  <parameter name="calibration_factorsMipGev">0.022065151036</parameter>
  <parameter name="ppd_mipPe"> 15 </parameter>
  <parameter name="ppd_npix"> 1600 </parameter>
  <parameter name="CellIDLayerString"> layer </parameter>
  <parameter name="Verbosity" type="string"> WARNING </parameter>
</processor>
```

SiD Hadron Calorimeter – Physics Impact
SiD H -> Invisible as example



Hadronic Z decays
For max statistics

Which HCal parameters are the most sensitive in driving the best limit for H -> Invisible?

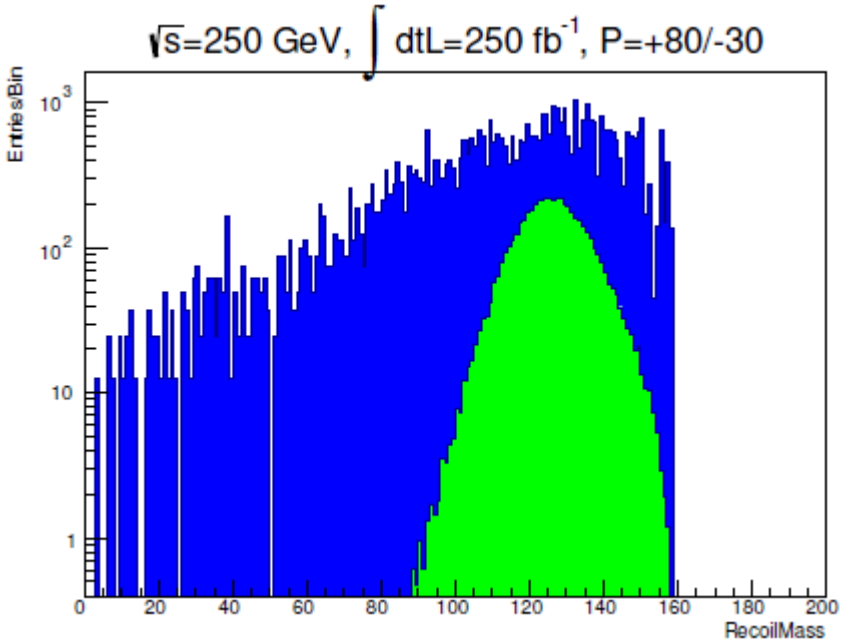
Analysis variables potentially affected by HCal performance

cut-and-count
Full Simulation

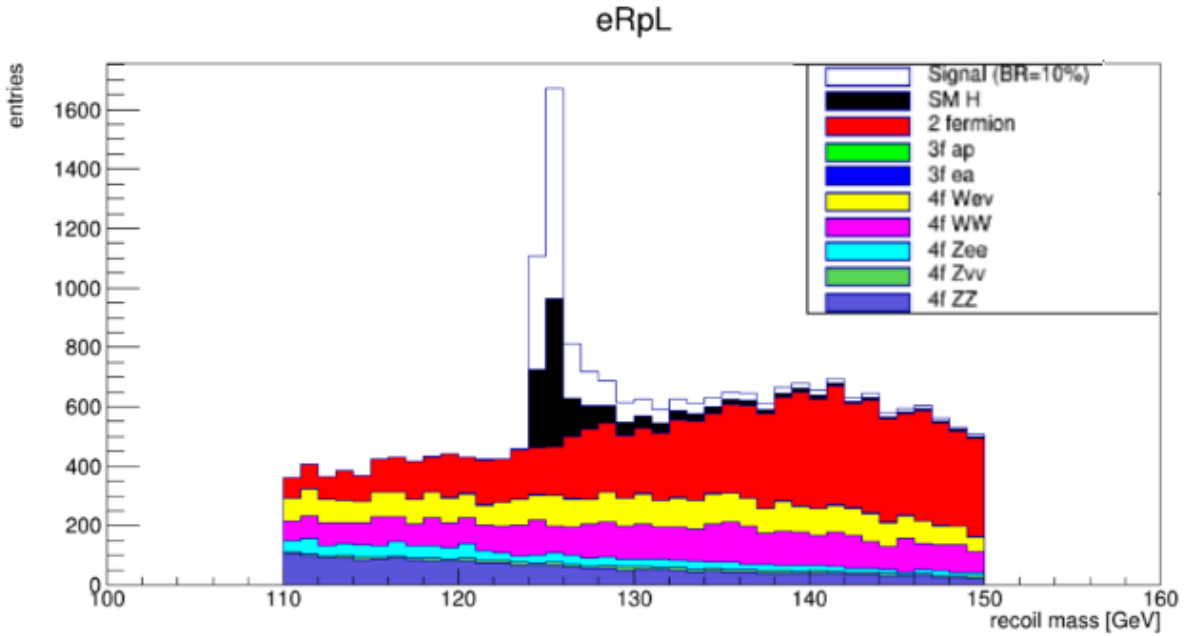
Requirement (Full)	S(LR)	B(LR)	$\frac{S}{\sqrt{S+B}}$	S(RL)	B(RL)	$\frac{S}{\sqrt{S+B}}$
$20 \leq p_T^{vis} \leq 70$ GeV	1.25e+04	7.71e+06	4.48	8.84e+03	1.07e+06	8.53
$75 \leq m_{vis} \leq 105$ GeV	1.16e+04	1.79e+06	8.63	8.21e+03	3.14e+05	14.5
$N_{jet} = 2$	1.16e+04	1.79e+06	8.63	8.21e+03	3.14e+05	14.5
$-0.9 \leq \cos\theta_{jj} \leq -0.2$	1.08e+04	8.68e+05	11.5	7.65e+03	1.78e+05	17.7
$110 \leq m_{recoil} \leq 150$	1.03e+04	3.6e+05	17	7.33e+03	8.39e+04	24.2

Combined SiD Limit: $\mathcal{B}_{H\to\text{inv.}} \lesssim 0.3\%$

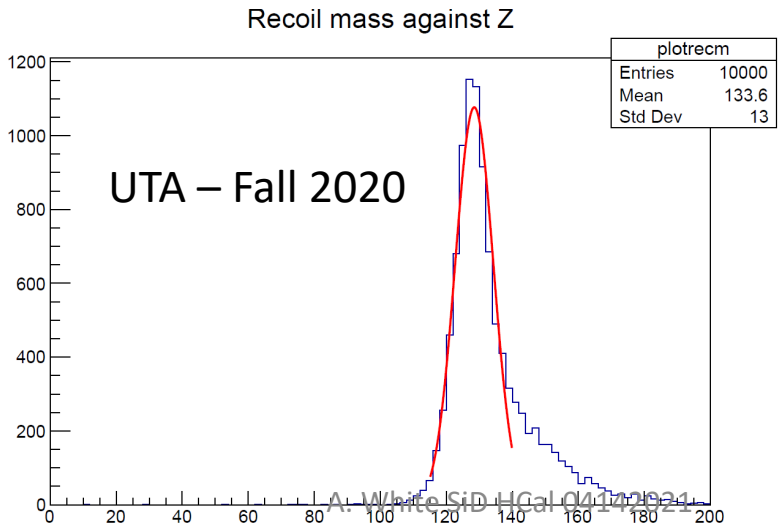
Recoil Mass against Z



Chris Potter – Fall 2020



Amanda Steinhebel – LCWS 2021



UTA – Fall 2020

SiD Hadron Calorimeter – Physics Impact
SiD H -> Invisible as example

- Making HCal more “realistic” can lead to broadening of distributions.
- More events fall outside fixed cuts, complicate jet identification/reconstruction via PFA
- Look at effect on e.g. $S/\sqrt{(S+B)}$
- Worse resolution -> wider cuts -> significance?

SiD Hadron Calorimeter – Physics Impact

- Understand all HCal parameters
- Are parameters appropriate for SiD?
- Many parameters are “fixed” – what/how can some be varied?
- Consider design choices (Fine/forward, Coarse/backend? Aspect ratio? …)
- Other physics processes?