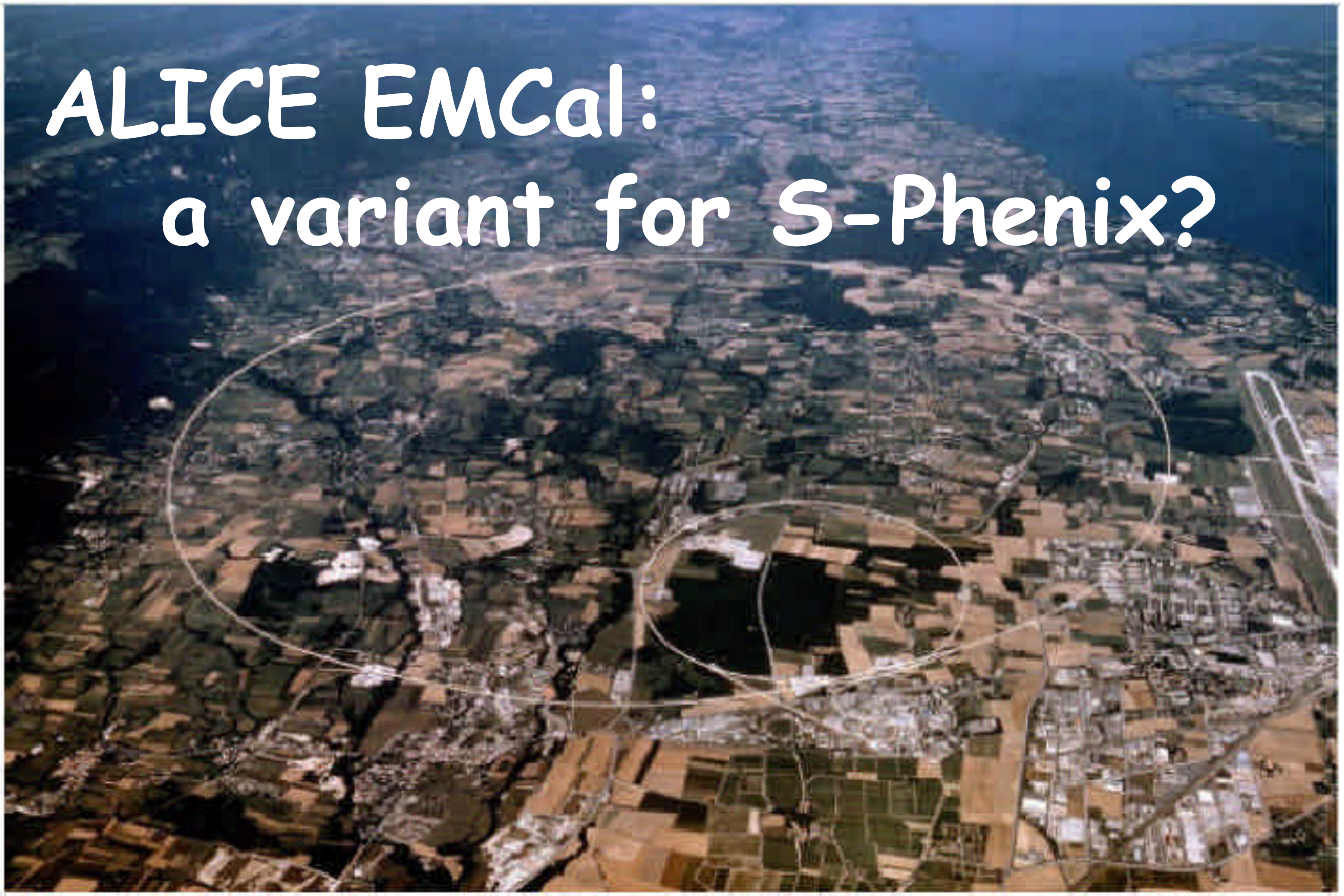
ALICE EMCal:
a variant for S-Phenix?



ALICE-EMCal

An EMCal for ALICE at the LHC for Jet Physics in PbPb collisions in the range of P_T = 20 GeV/c to 300 GeV/c and high P_T electrons and photons

Delivered on Schedule and significantly under budget

Expanded scope at constant TPC

An “off-the-shelf” option for S-PHENIX ??

EMCal Parameters

TABLE I: EMCal module physical parameters. Here, RL stands for Radiation Length and MR for the Moliere Radius.

Parameter	Value
Tower Size (at η=0)	$\sim$6.0 $\times$ $\sim$6.0 $\times$ 24.6 cm^3
Tower Size	$\Delta\phi \times \Delta\eta = 0.0143 \times 0.0143$
Sampling Ratio	1.44 mm Pb / 1.76 mm Scint.
Layers	77
Scintillator	Polystyrene (BASF143E + 1.5%pTP + 0.04%POPOP
Absorber	Pb (natural, standard mill spec.)
Effective RL X_o	12.3 mm
Effective MR R_M	3.20 cm
Effective Density	5.68 g/cm^3
Sampling Fraction	10.5
Radiation Length	20.1

The EMCal Physical Parameters.

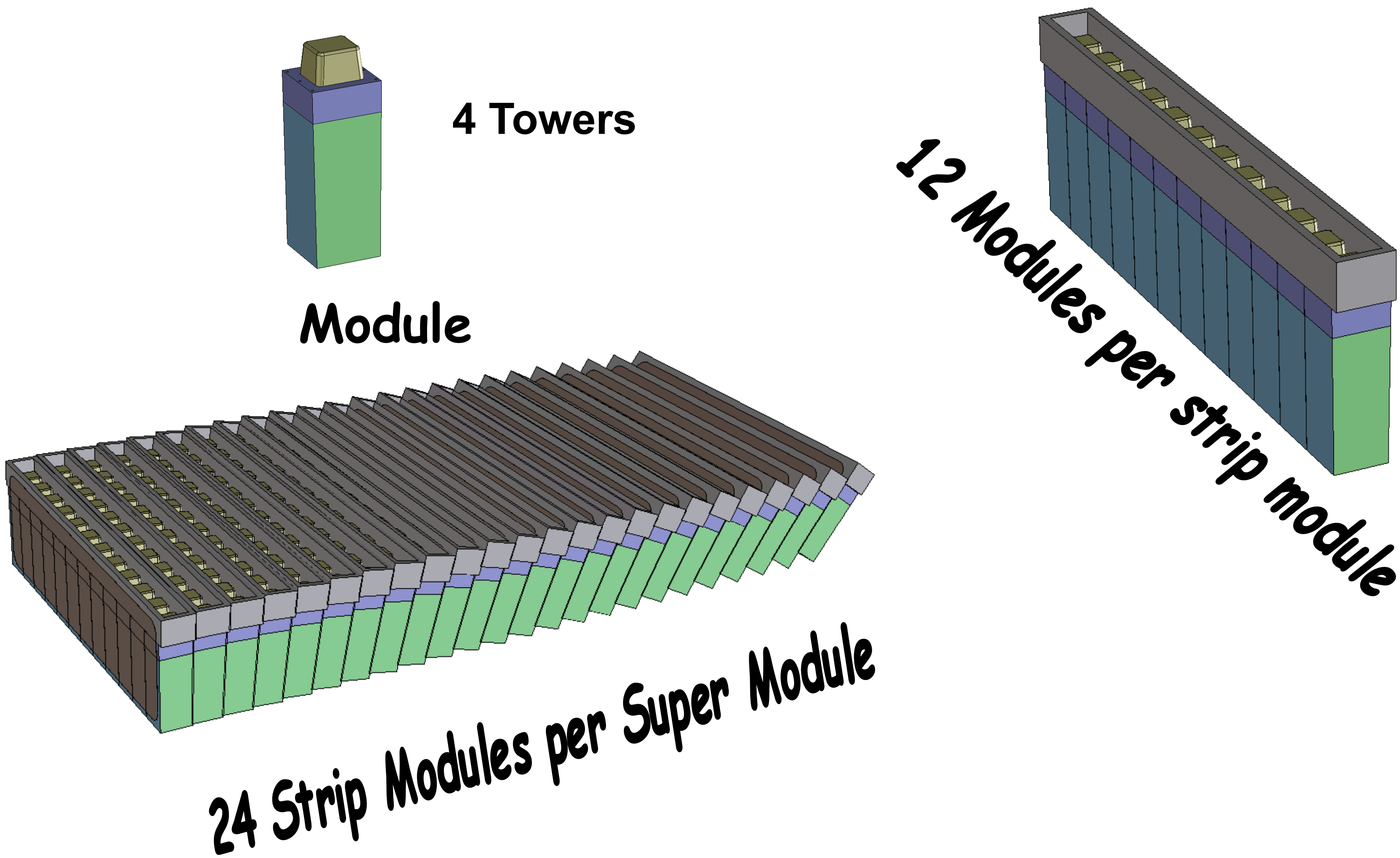
Quantity	Value
Tower Size (at η=0)	$\sim$6.0 $\times$ $\sim$6.0 $\times$ 24.6 cm^3 (active)
Tower Size	$\Delta\phi$ x $\Delta\eta$ = 0.0143 x 0.0143
Sampling Ratio	1.44 mm Pb / 1.76 mm Scintillator
Number of Layers	77
Effective Radiation Length X_o	12.3 mm
Effective Moliere Radius R_M	3.20 cm
Effective Density	5.68 g/cm^3
Sampling Fraction	10.5
Number of Radiation Lengths	20.1
Number of Towers	12,672
Number of Modules	3168
Number of Super Modules	10 full size, 2 half size
Weight of Super Module	$\sim$7.7 metric tons (full size)
Total Coverage	$\Delta\phi = 110^o$, $-0.7 < \eta < 0.7$

EMCal WLS Fiber properties

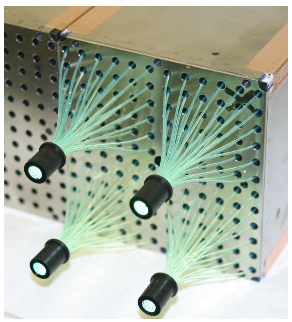
Table 4.3: Characteristics of the selected wavelength shifting fibers.

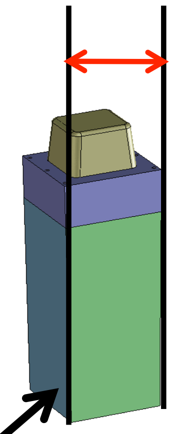
Quantity	Value
WLS fiber	Y-11 (200) M-DC
Manufacturer	Kuraray
WLS Fluor	K27 200 mg
Absorbtion Peak	430 nm
Emission Peak	476 nm
Decay Time	7 ns
Core material	PS
Refractive Index	1.59
Inner Cladding	PMMA
Refractive Index	1.49
Outer Cladding	FP
Refractive Index	1.42
Long fiber Attenuation Length	3.5 m
fiber Diameter	1.0 mm

Detector Concept



Detector Concept

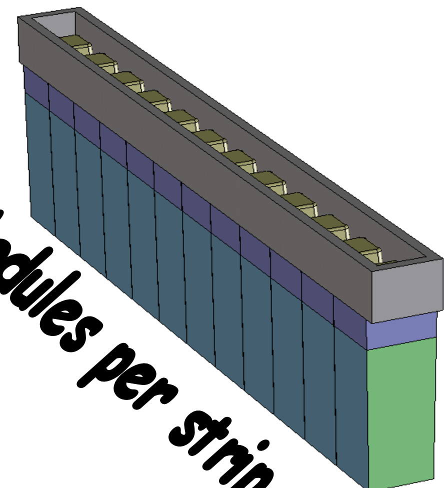




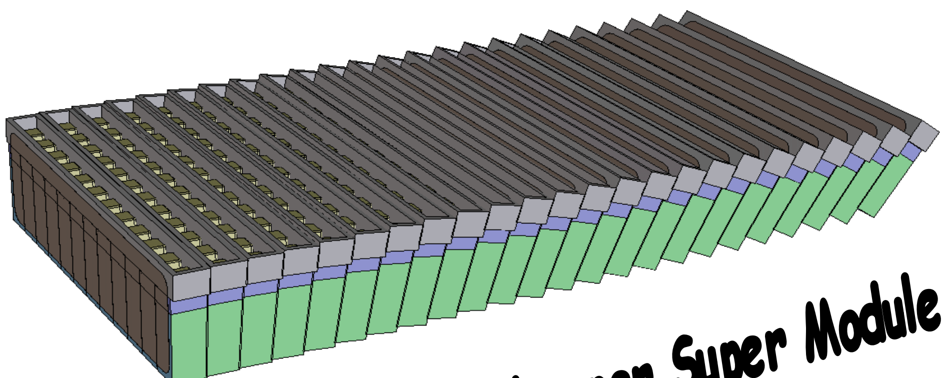
1.5° taper

Module

4 towers per module

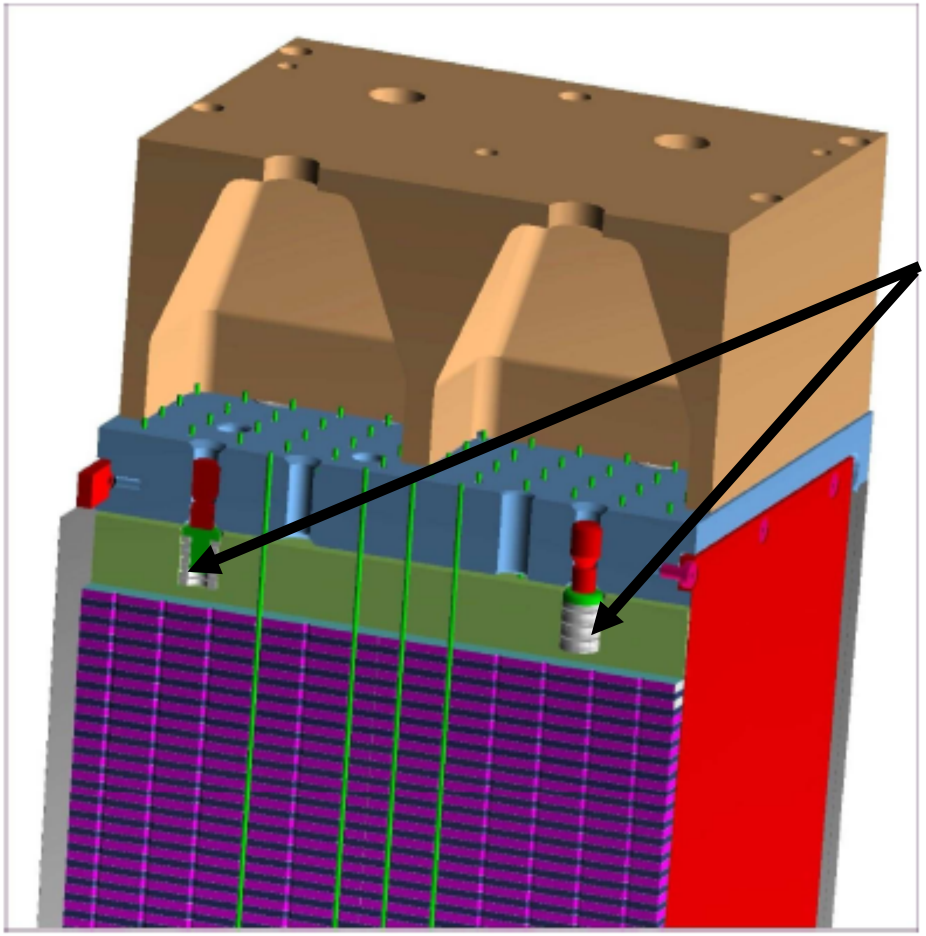


12 Modules per strip module



24 Strip Modules per Super Module

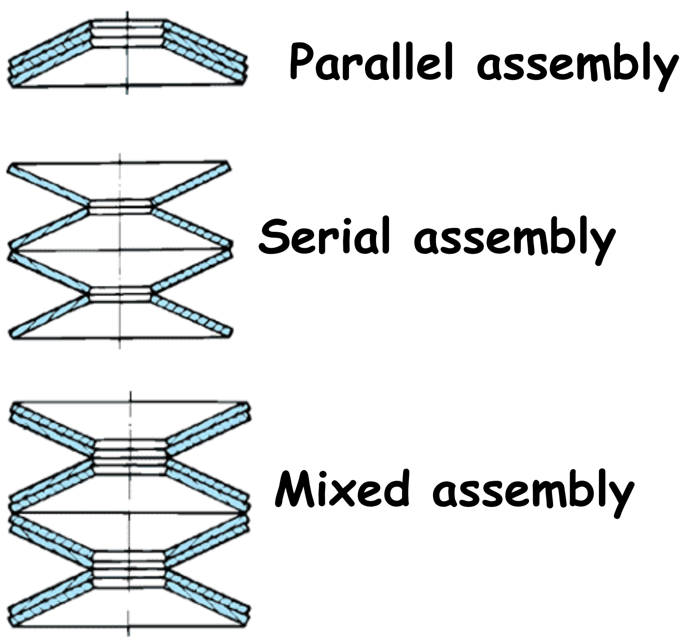
Module details: Stable in any orientation for any feasible temperature excursions

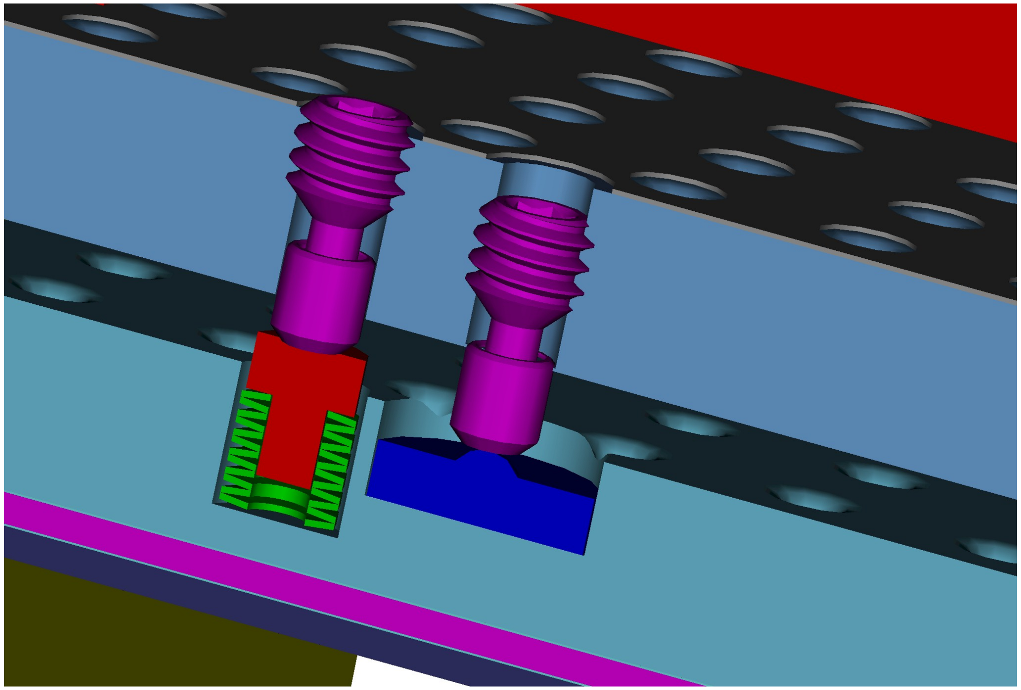


Module Mechanical Design incorporates non-linear springs for stability against thermal excursions

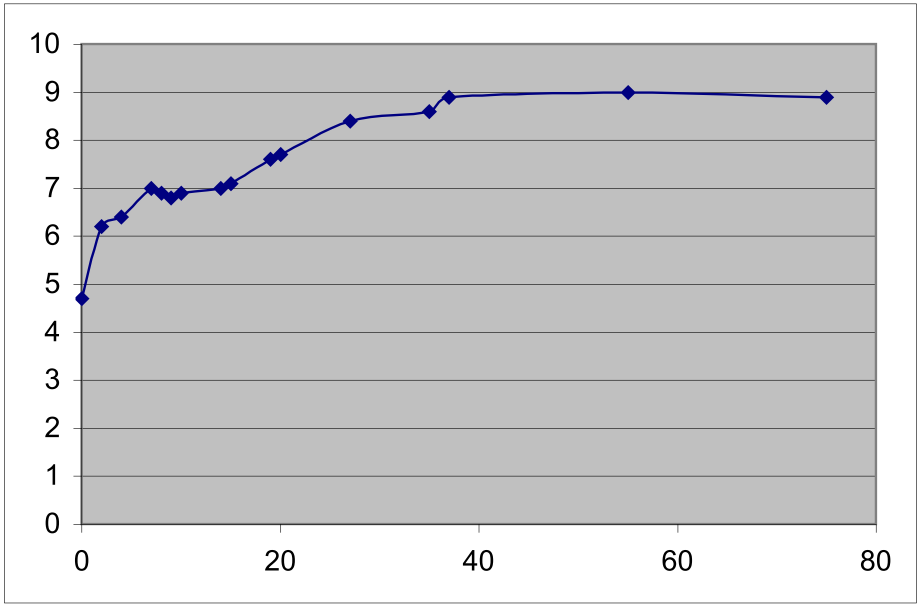
- During calorimeter life time, Pb flattening and creeping will “shorten” the module and this will lead to a loss of compression load : Non-linear Belleville washers are used to keep most of compression load

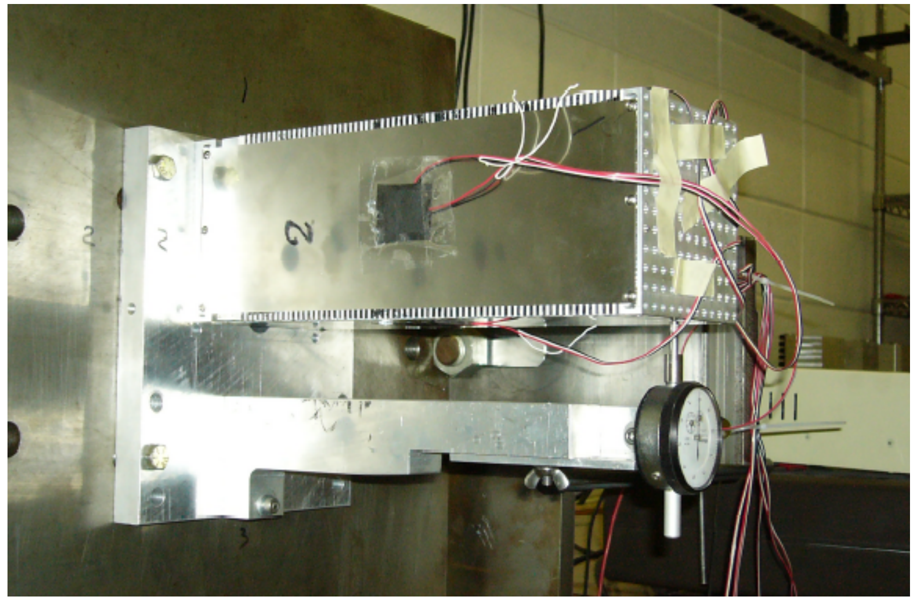
- Belleville washers is a non linear spring system, where variation of load is smaller than given by a pure spring (F = kX).



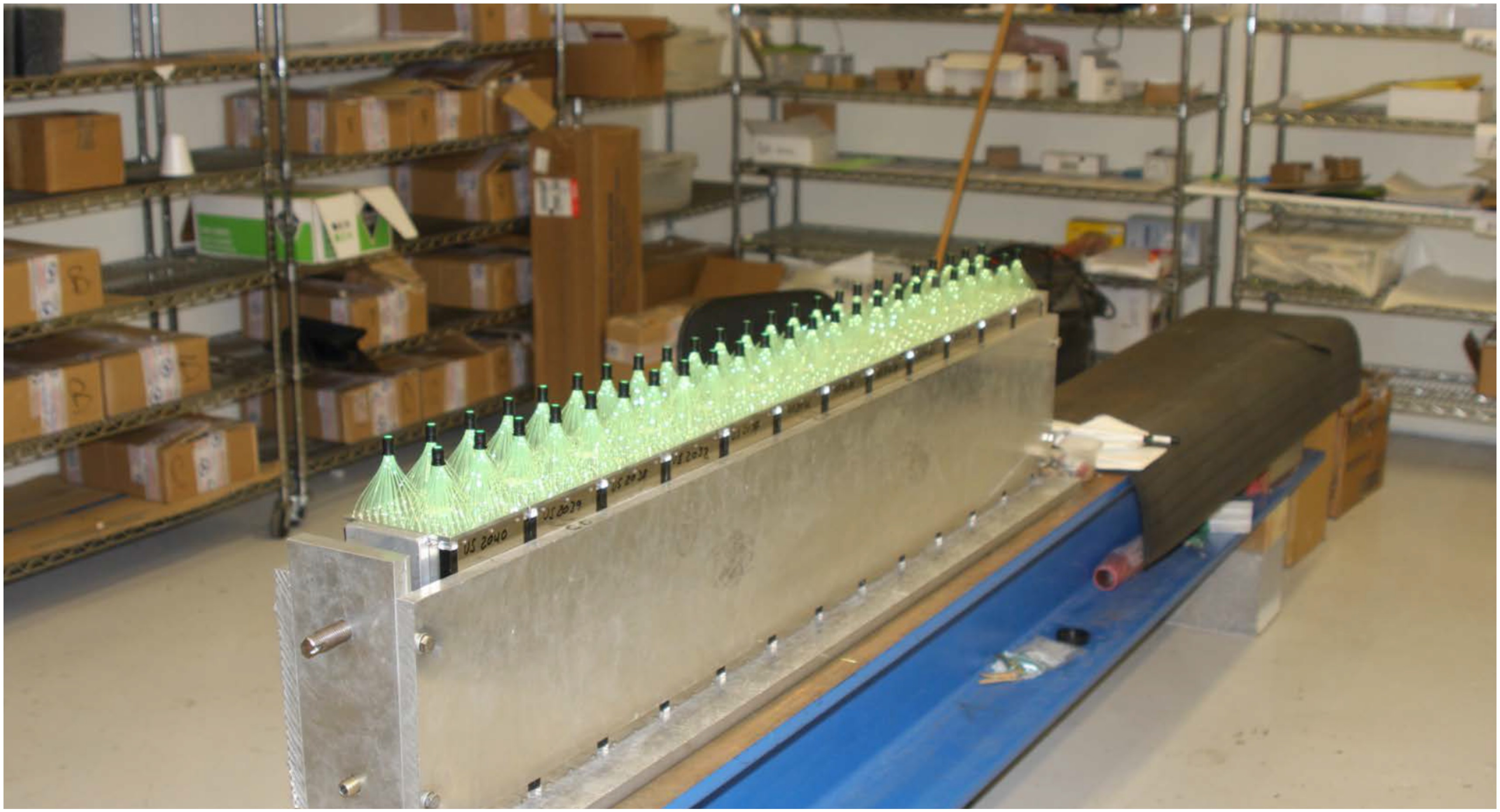


module in cantilever position

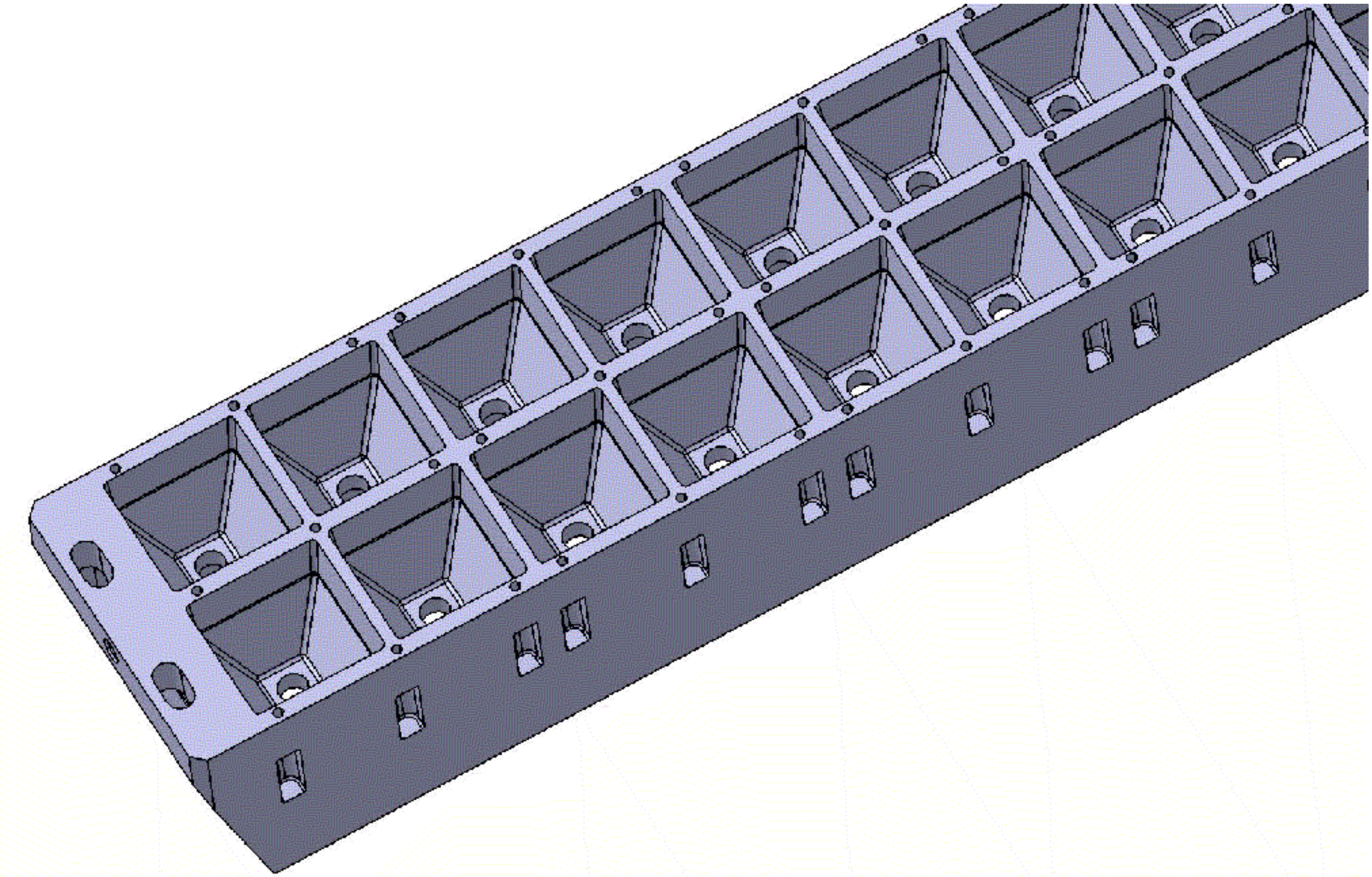




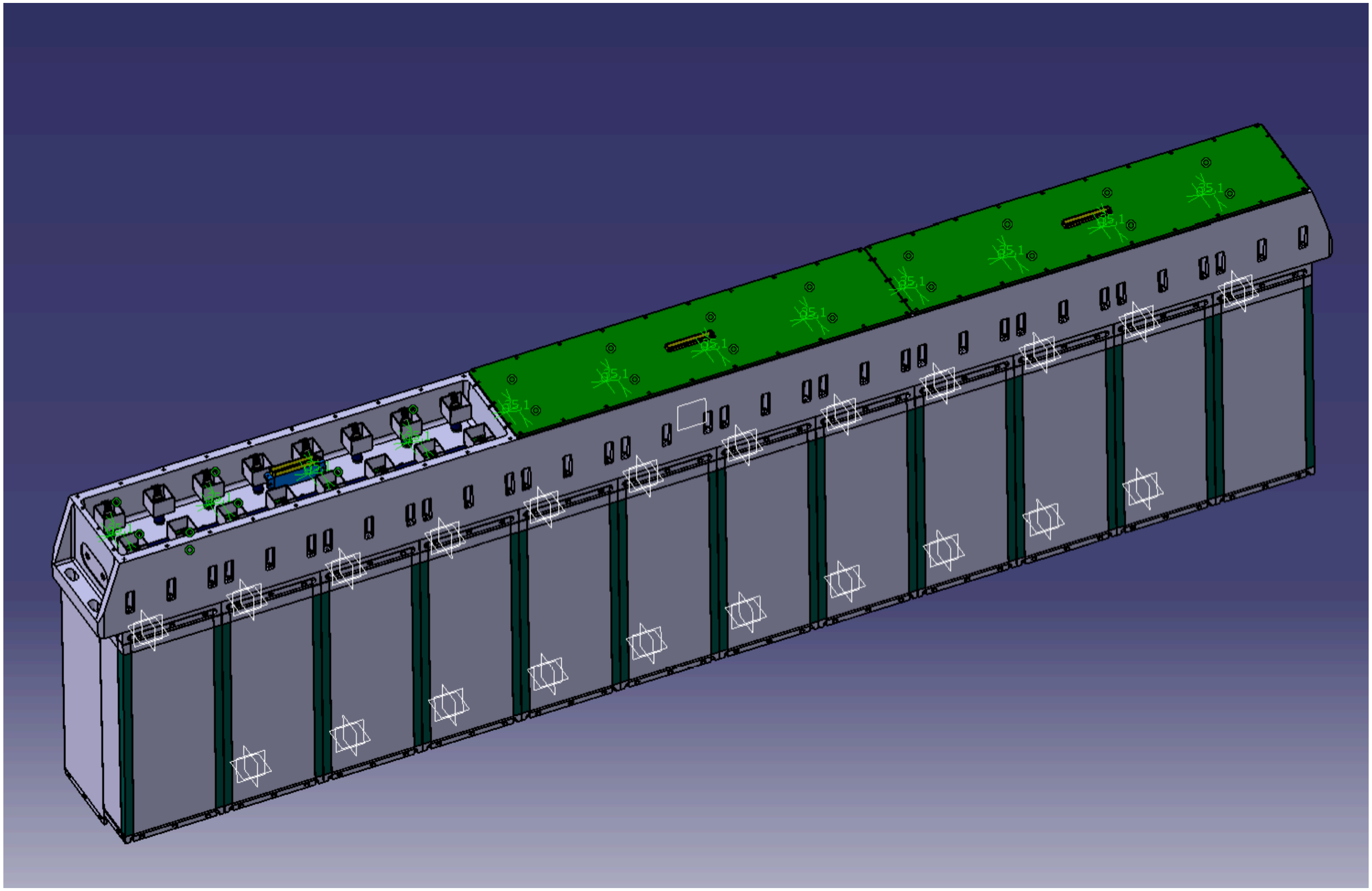
Deflection (0.001”) vs time (days)


US 2040

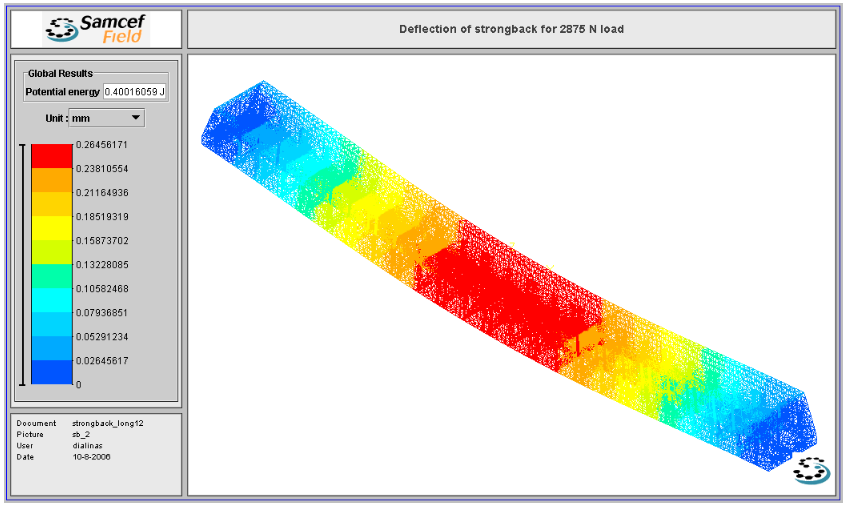
Strong-back : Bottom view



Strip Module – 48Towers 6cm x 6cm

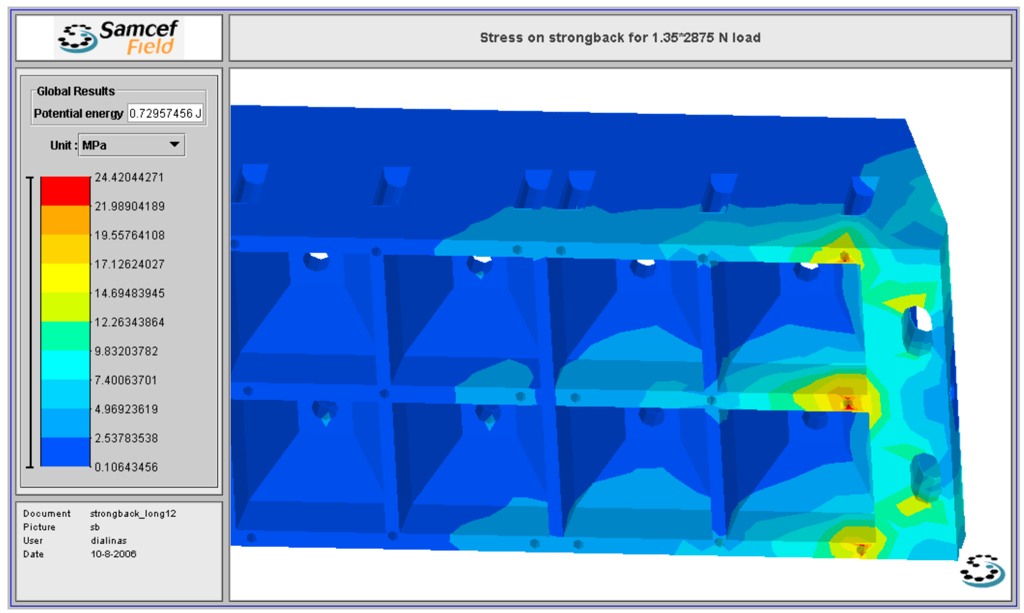


Strong-back : F.E.A. Simulations

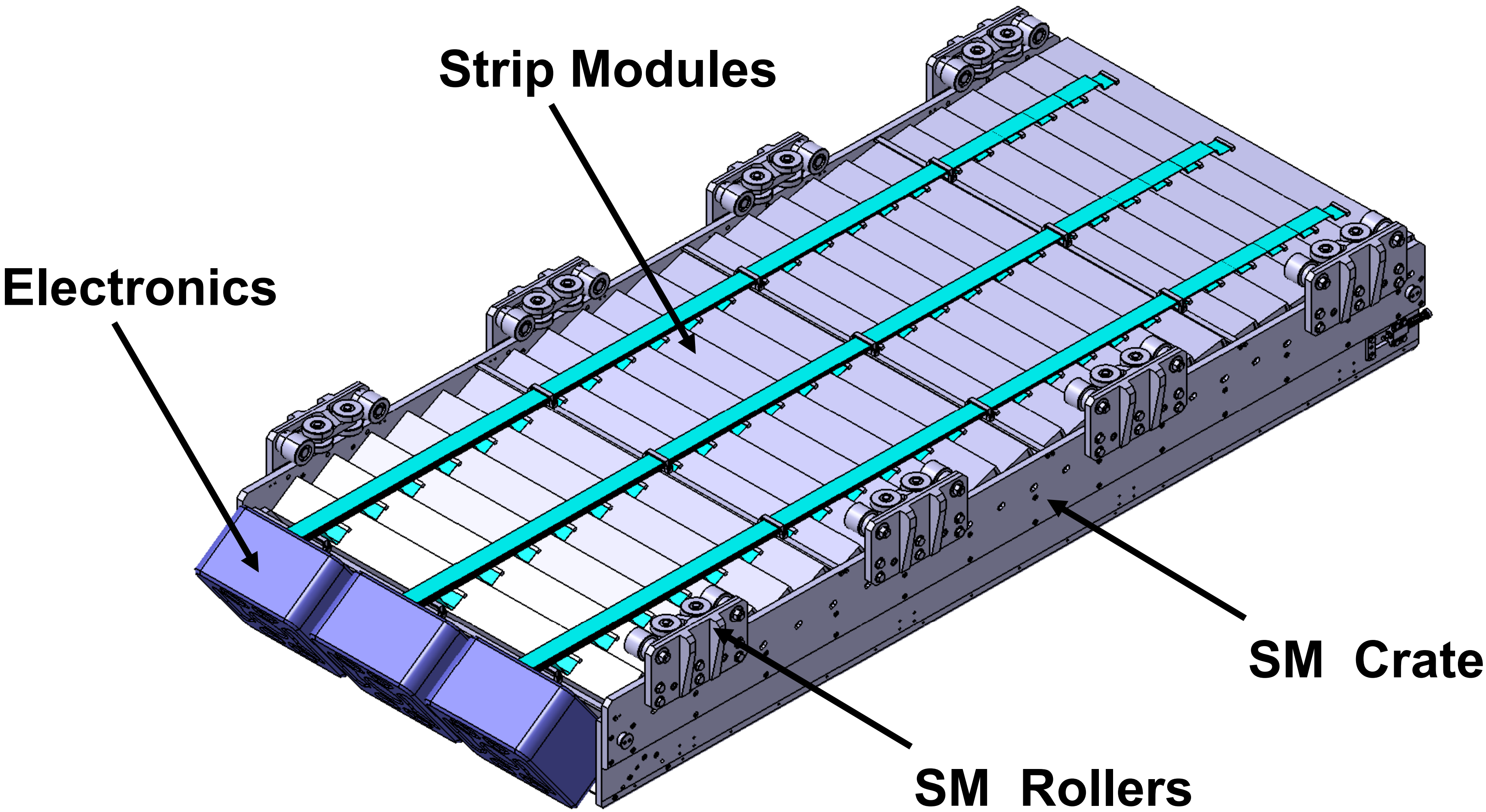


Deflection at 12:00 o'clock location:
0.3 mm with Ends clamped

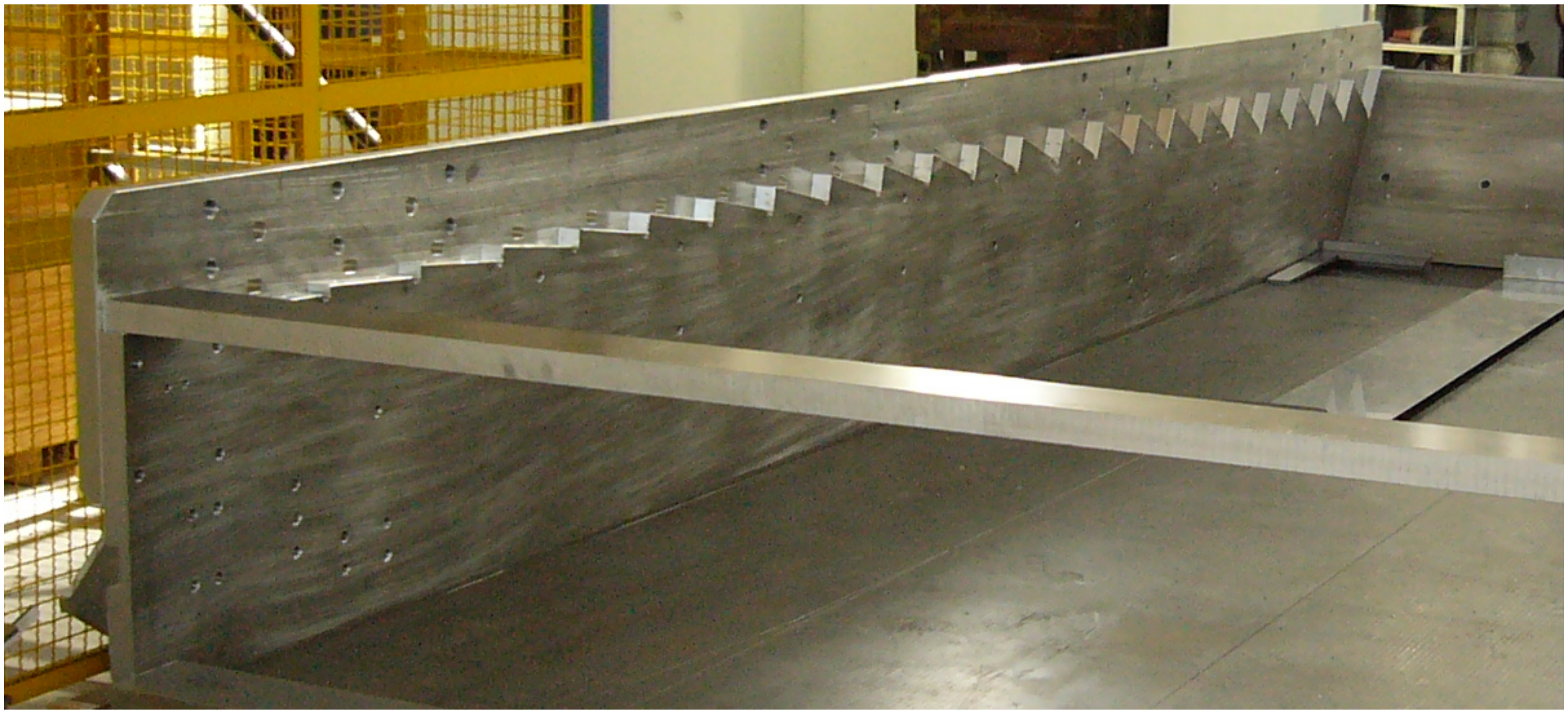
Max stress 25 Mpa
at 12:00 o'clock location

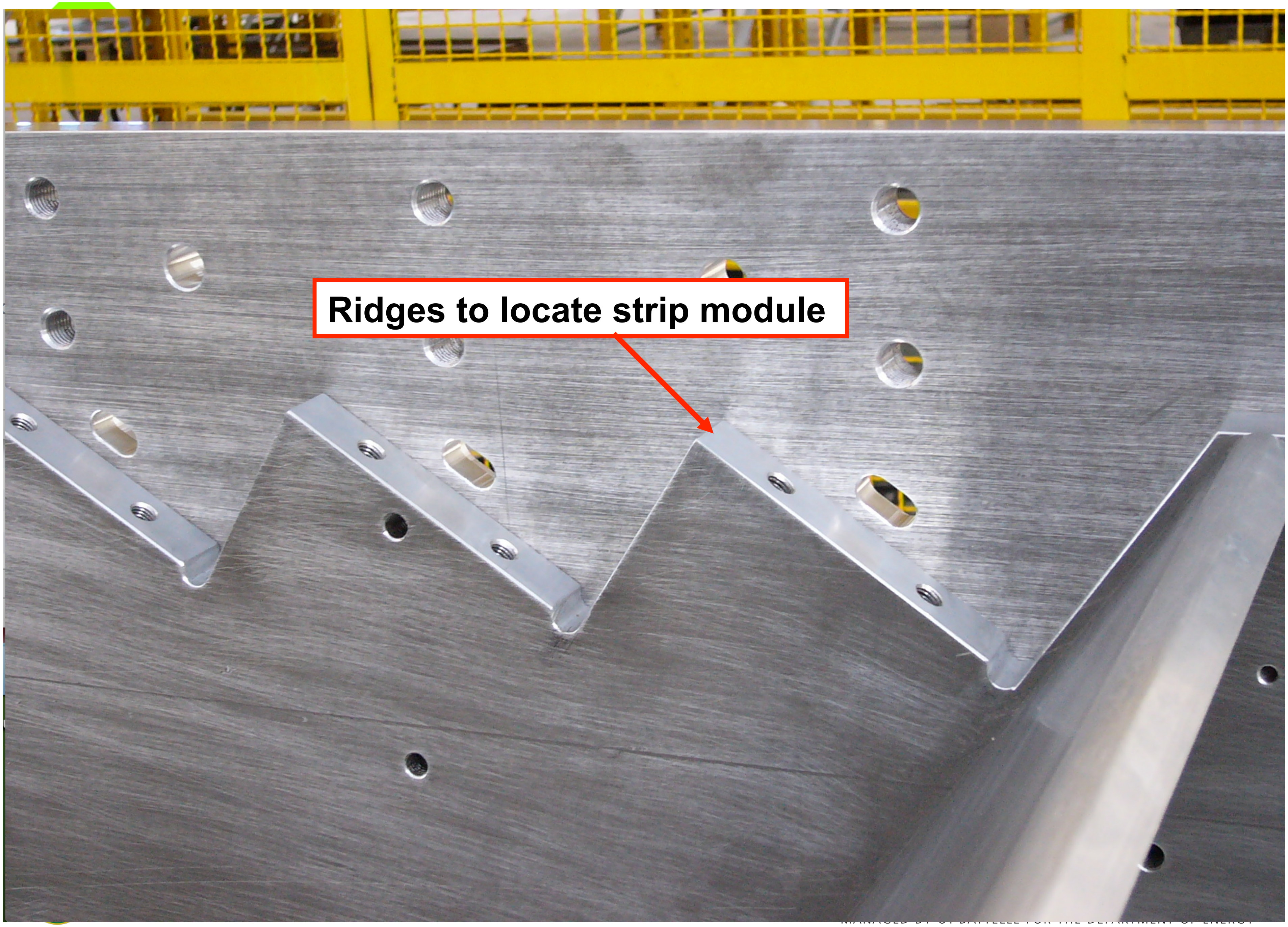


Super Module

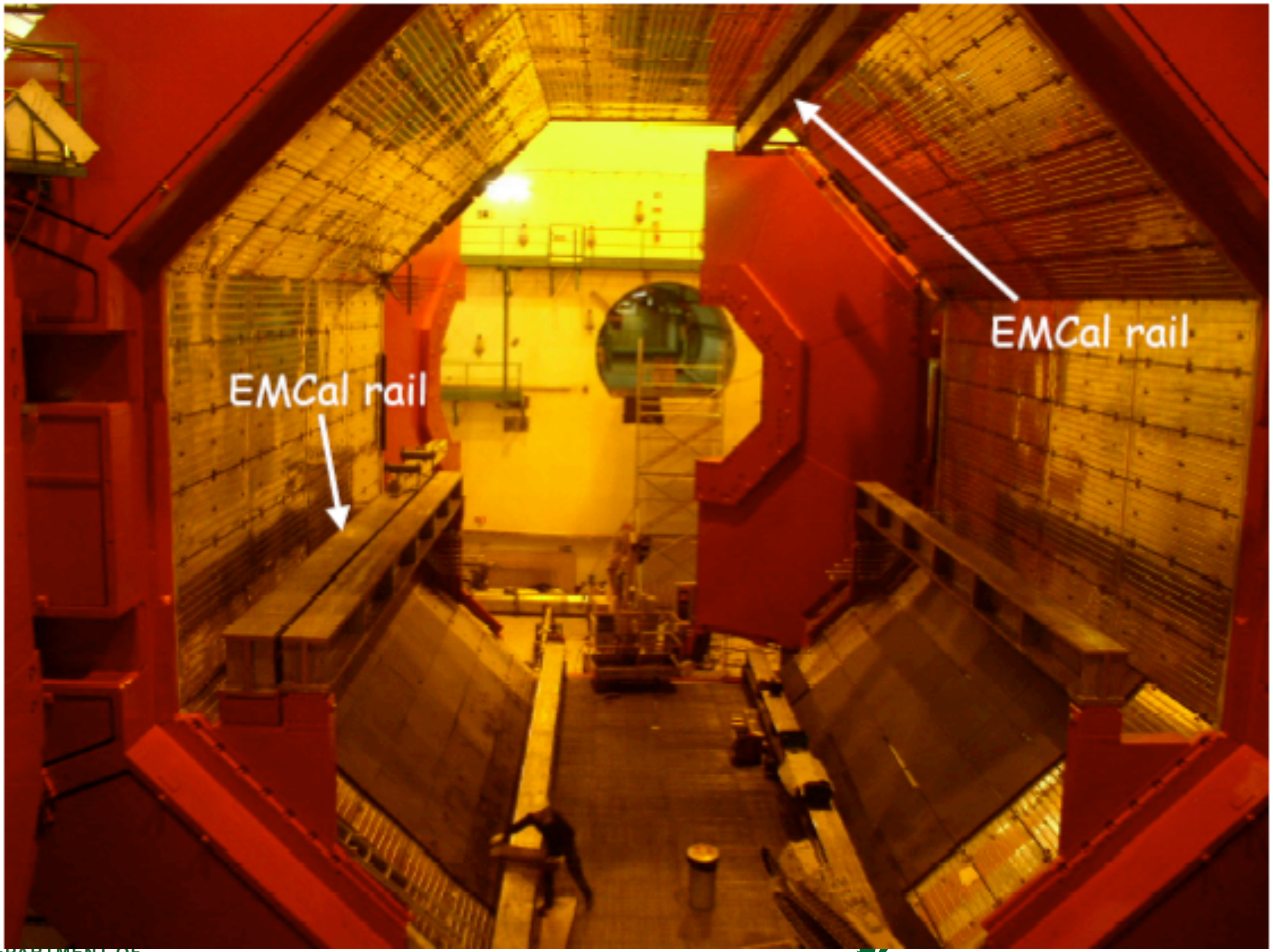


Super Module Crate

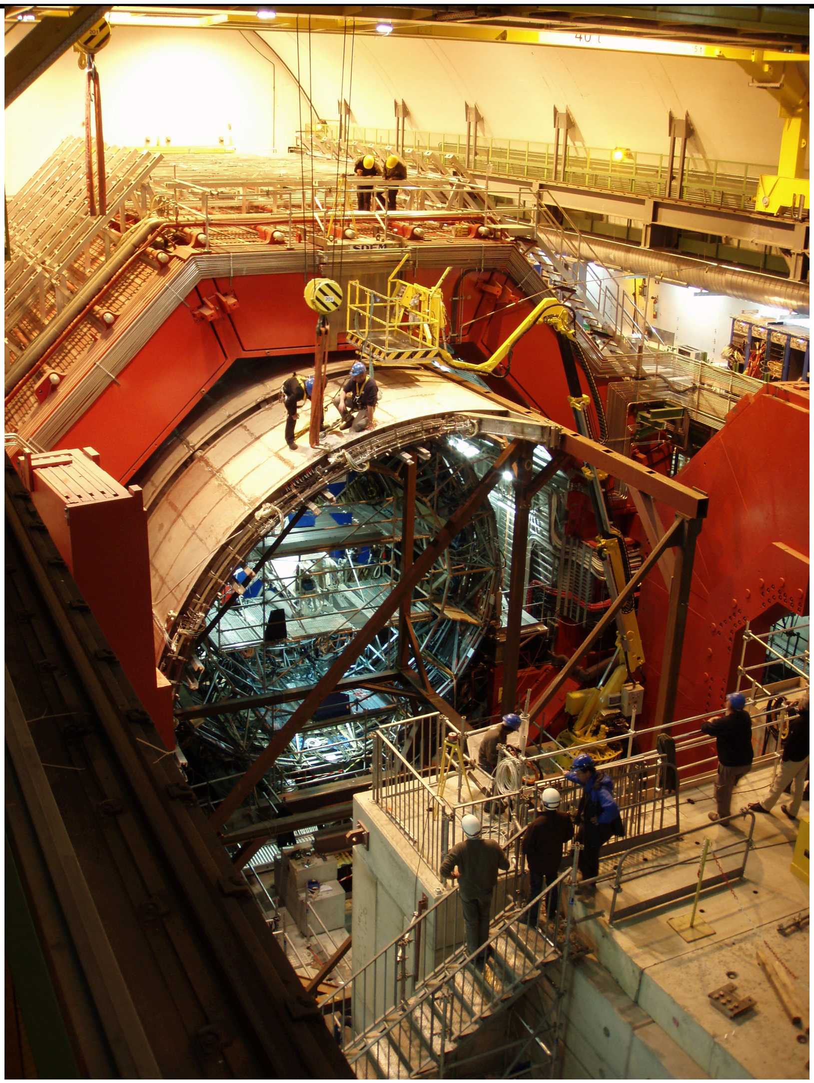



Ridges to locate strip module

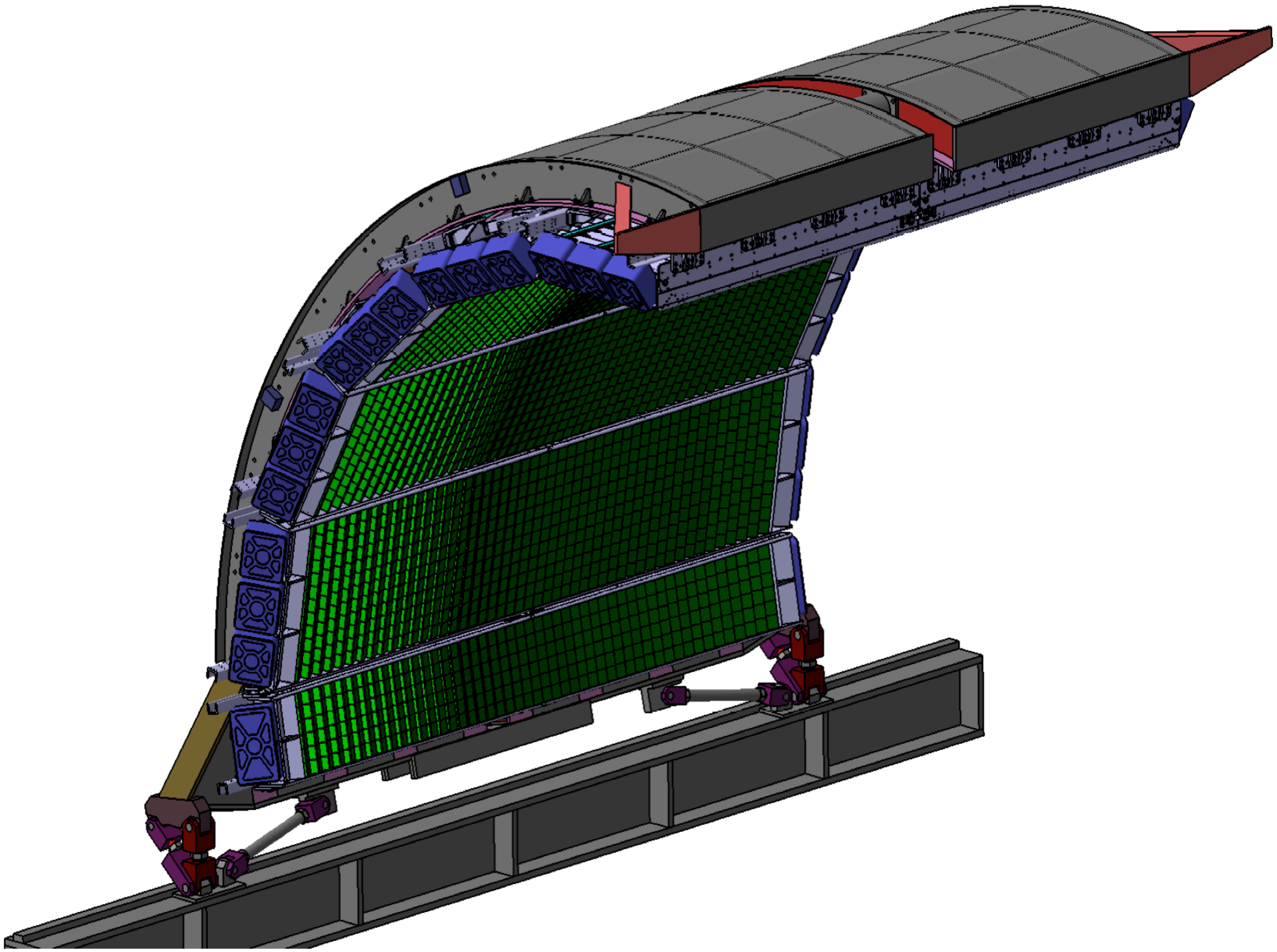
Two Point Support for 100 Tons of Calorimeter Drives the Integration Concept



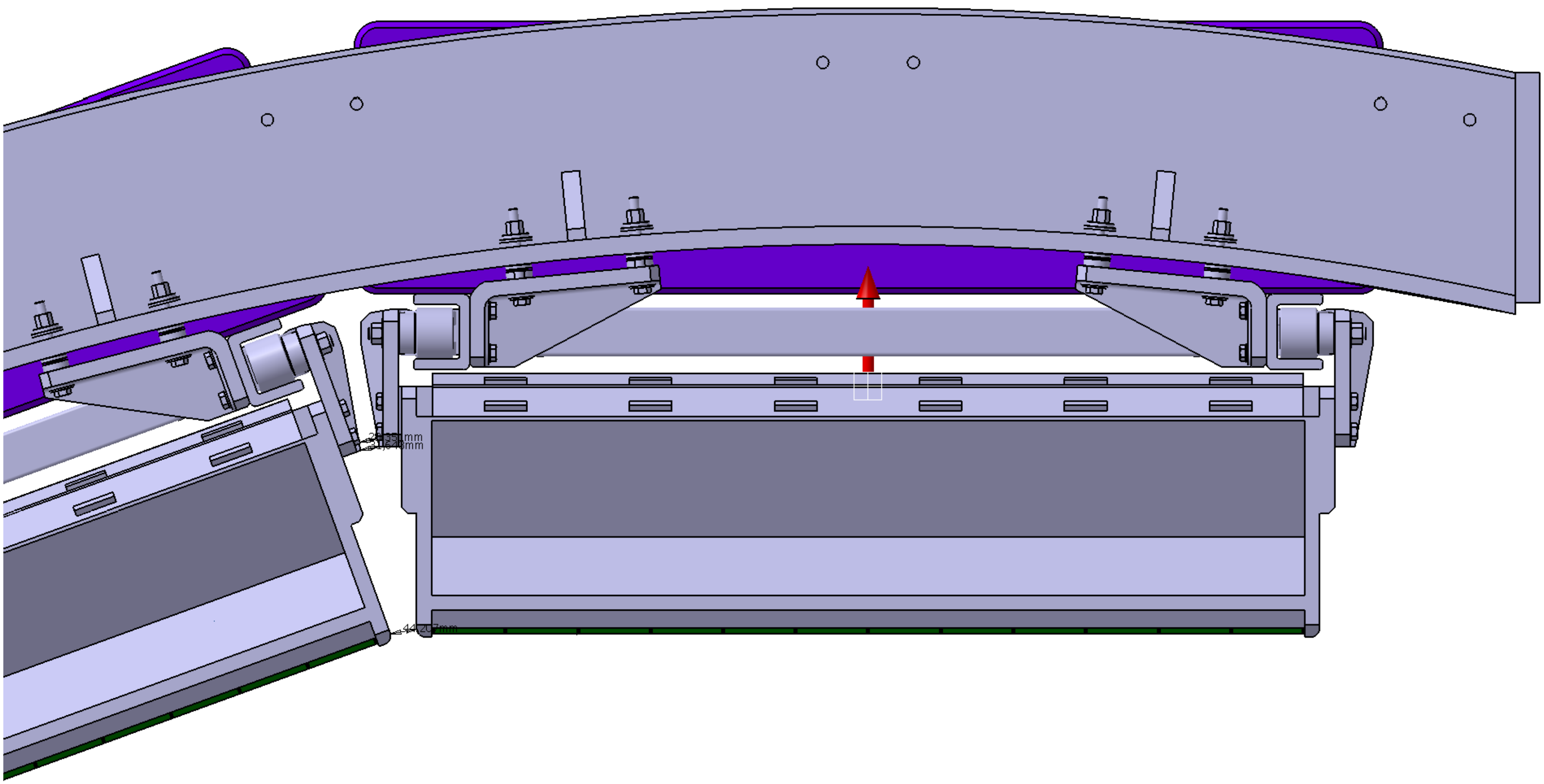
ALICE - EMCal Support Structure



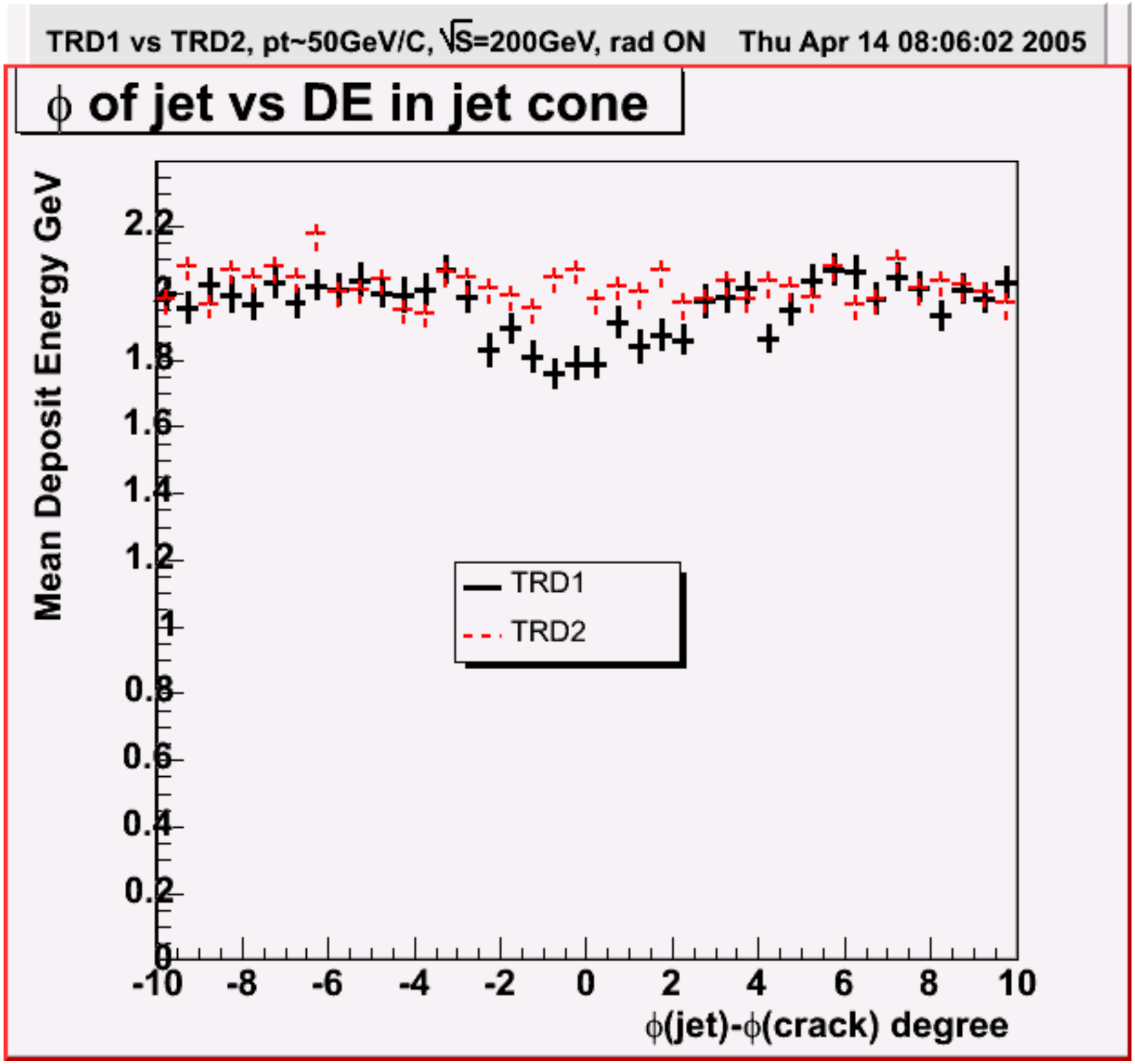
ALICE – EMCal: Individual Super Modules with Sufficient Cracks To Accommodate Substantial Support Structure Deformations



Super Module “Cracks”

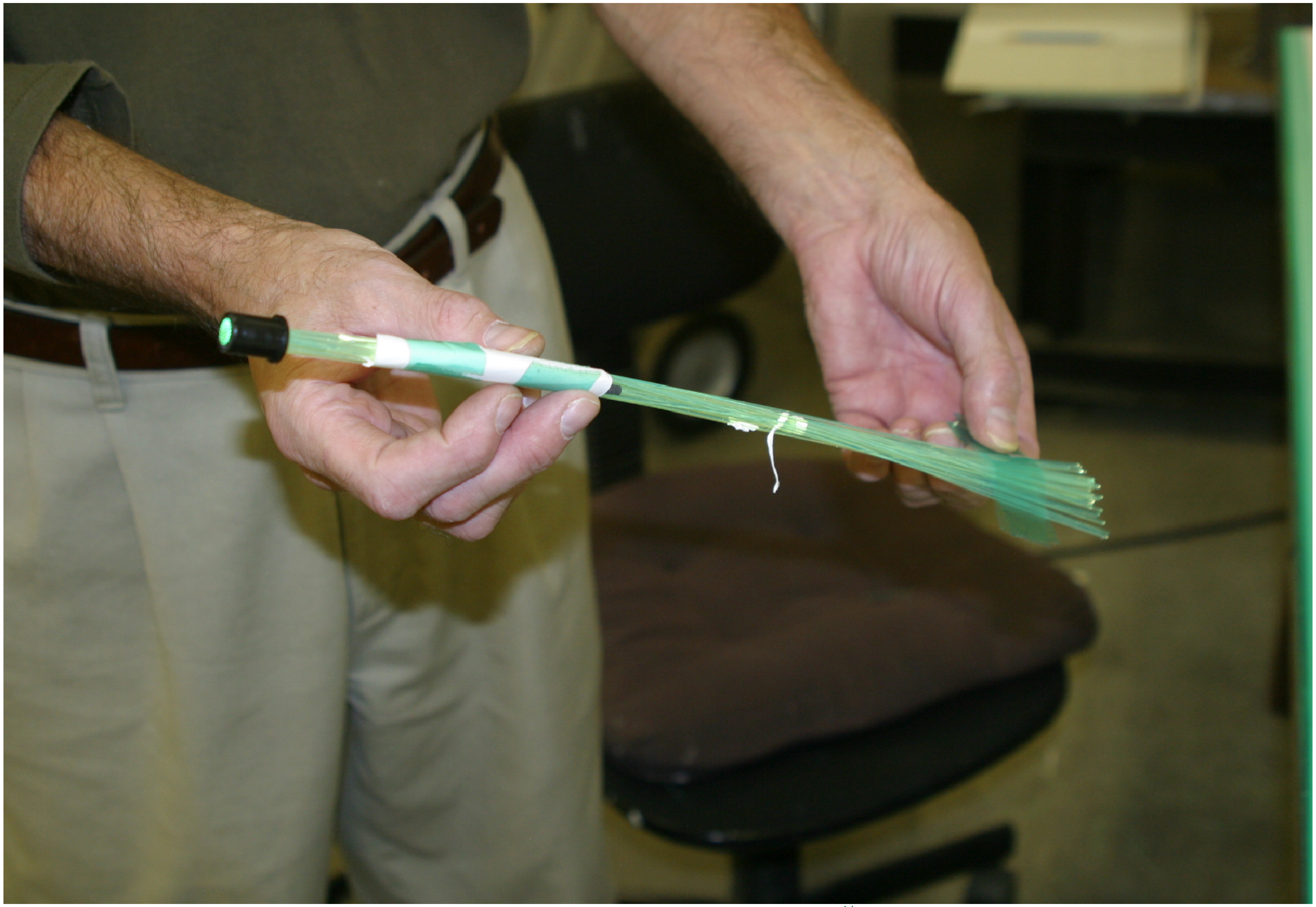


Cracks in STAR EMC

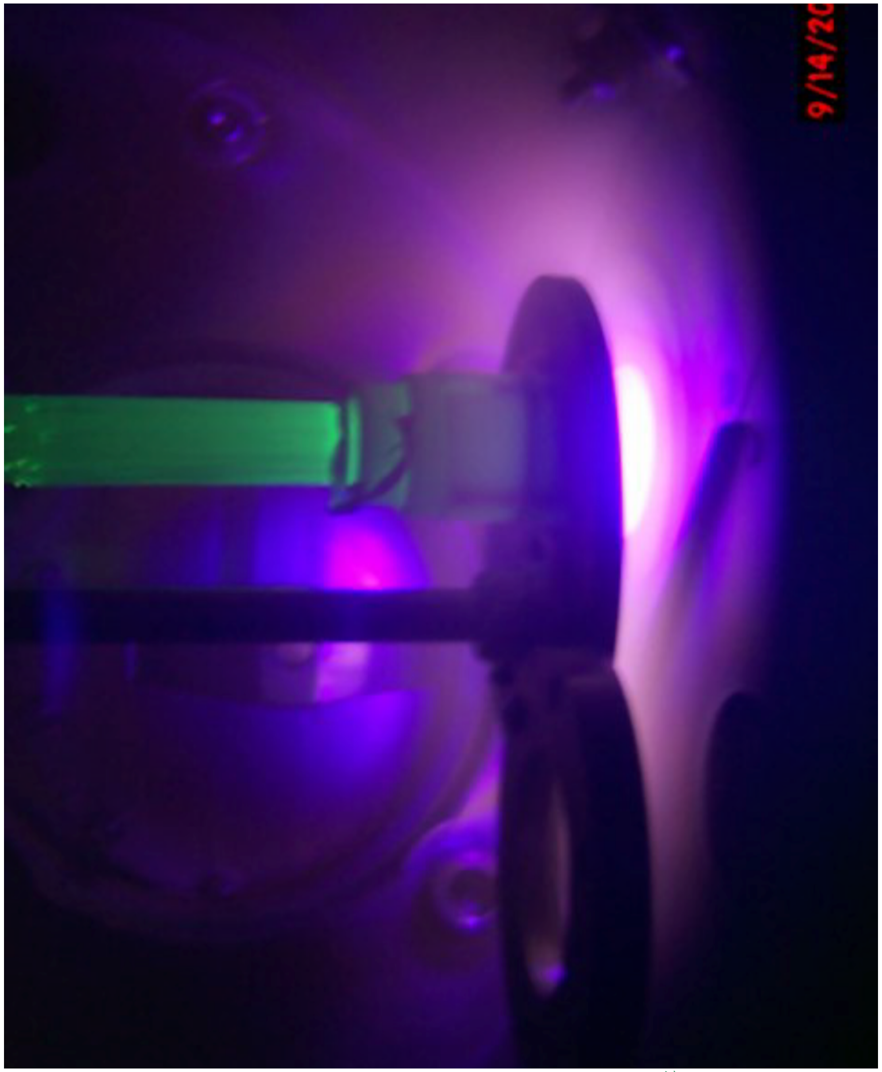


TRD1 vs TRD2, pt~50GeV/C, √S=200GeV, rad ON Thu Apr 14 08:06:02 2005
ϕ of jet vs DE in jet cone
Mean Deposit Energy GeV
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-10
-8
-6
-4
-2
0
2
4
6
8
10
ϕ(jet)-ϕ(crack) degree
TRD1
TRD2

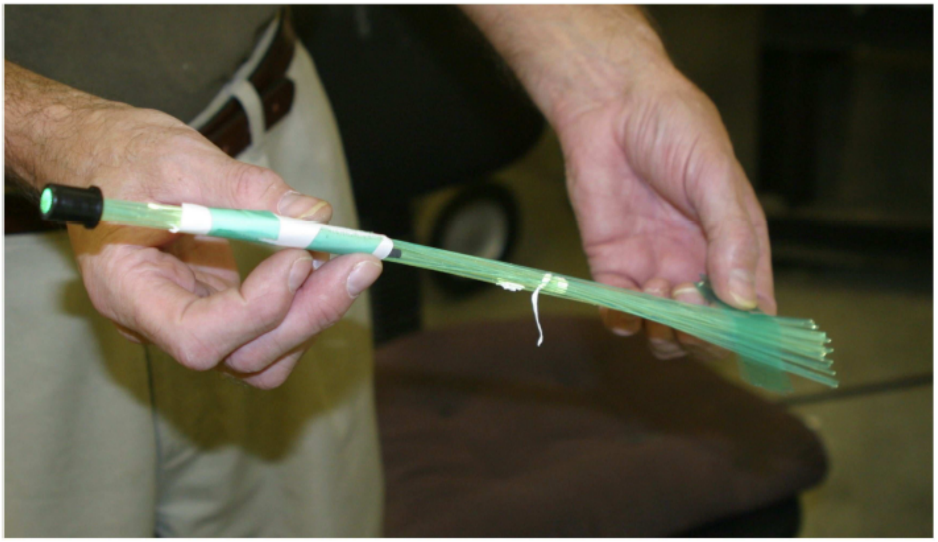
36 WLS Fibers - custom lengths with mirror and optical interface

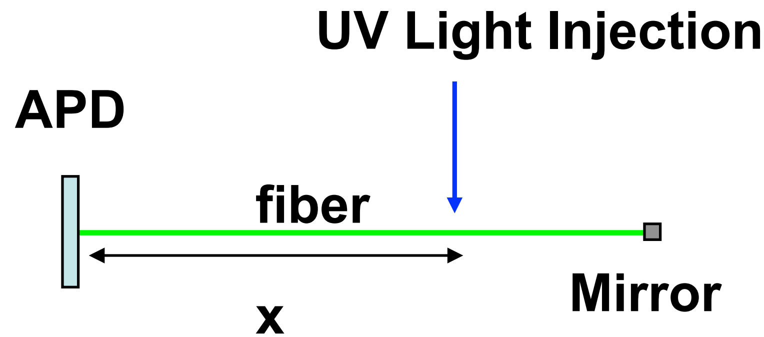


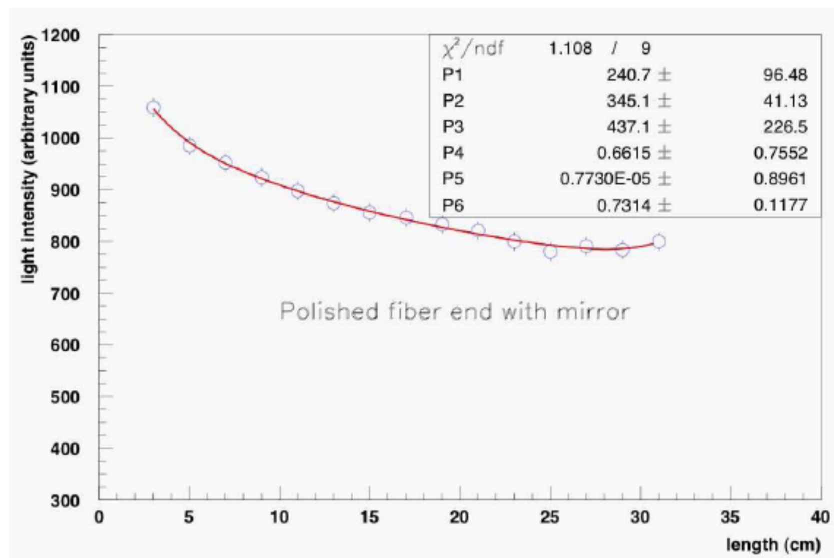
Fiber Mirror – 150 fibers at a time



WLS Fiber mirror quality

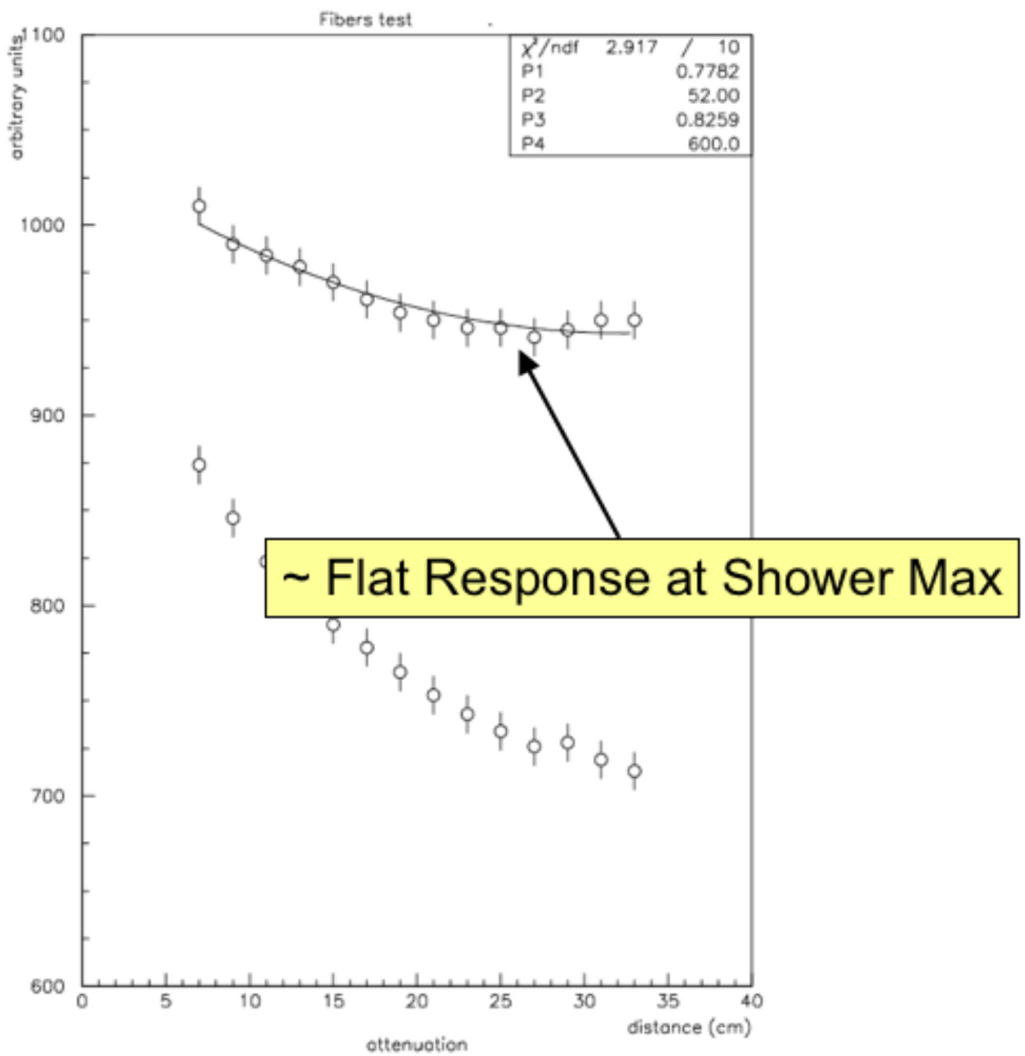






We find a very stable R =70% with procedures for mirror preparation.

Fiber Mirror Effect

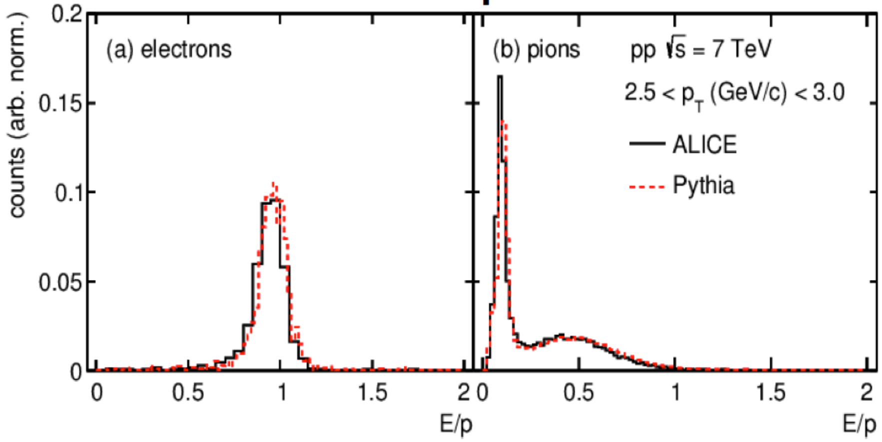


ONAL LABORATORY
R THE DEPARTMENT OF ENERGY

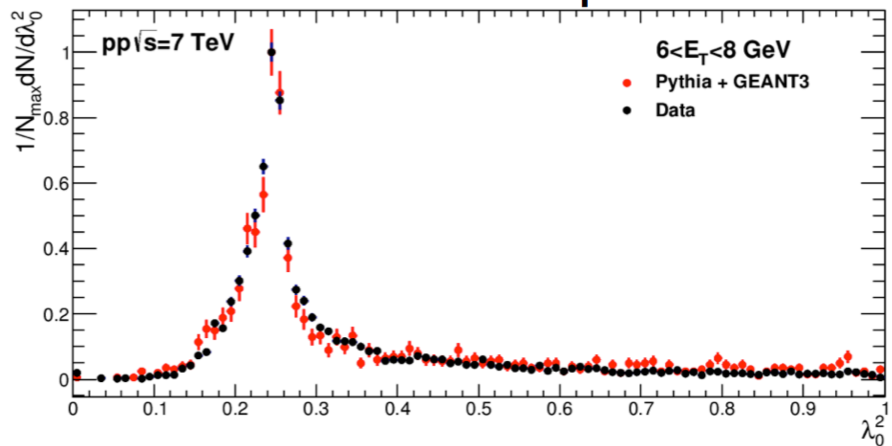
EMCal performance

ALICE performance paper, to be published

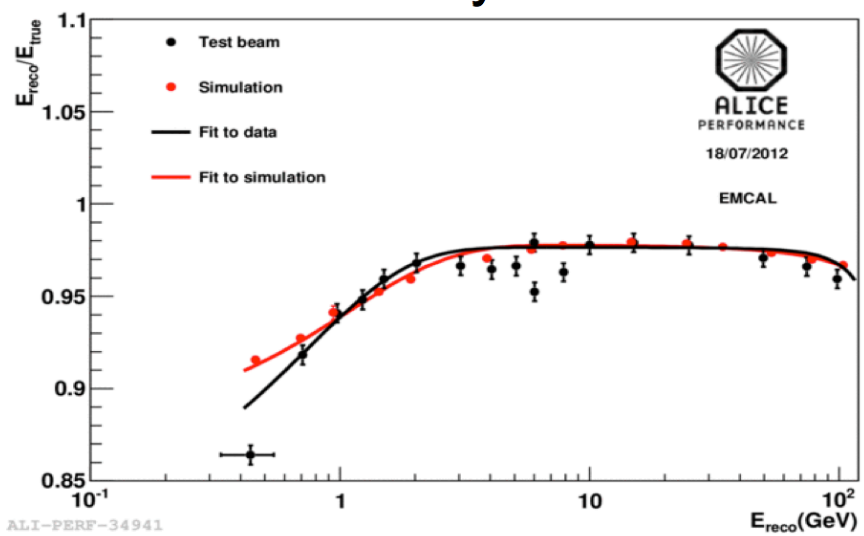
E/p



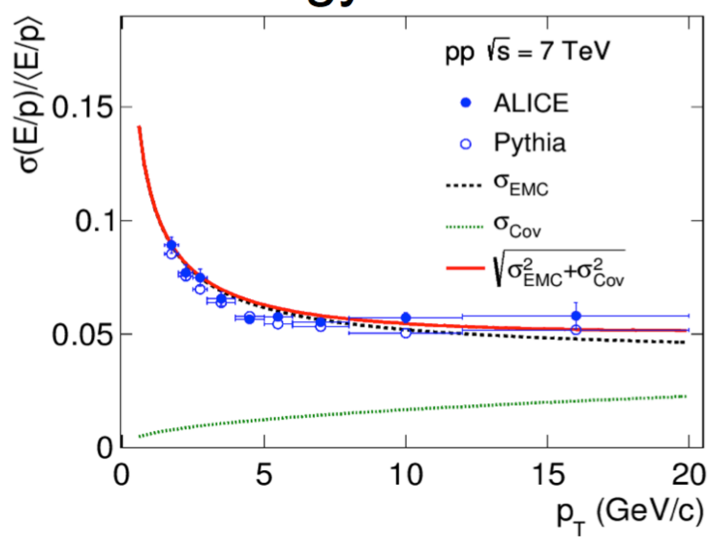
Shower shape



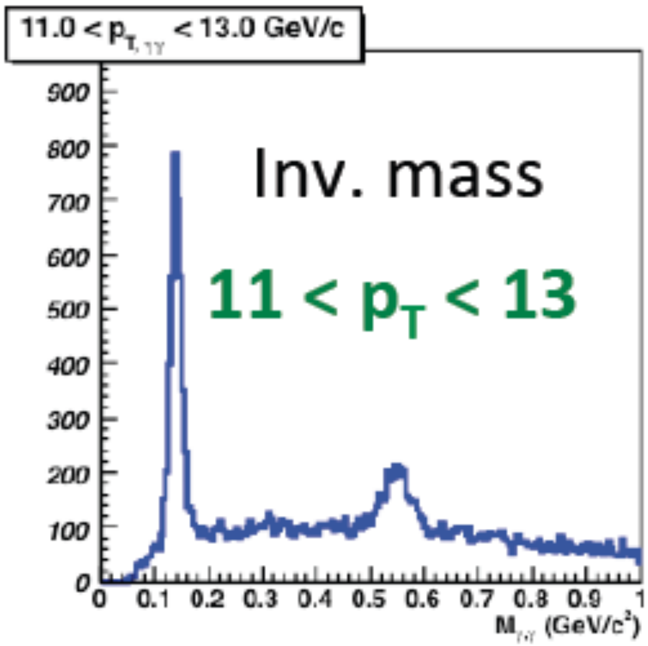
Non-linearity correction

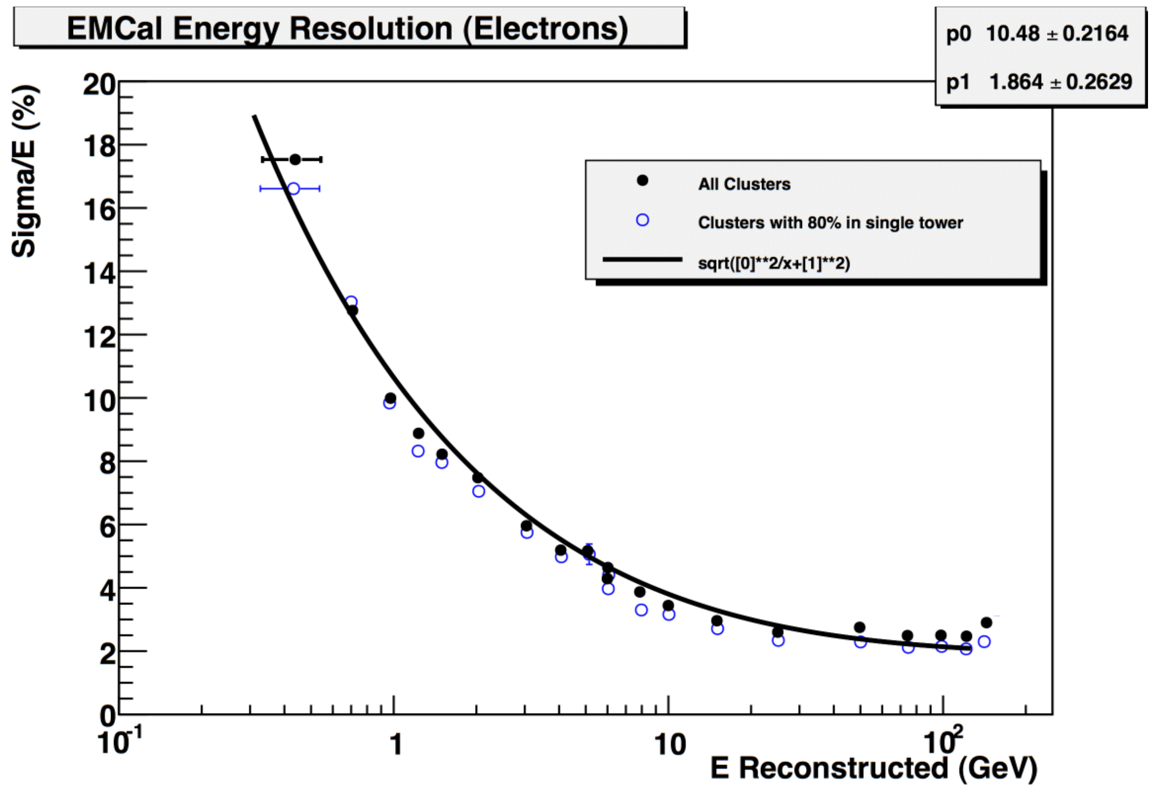


Energy resolution



EMCal works to design specifications

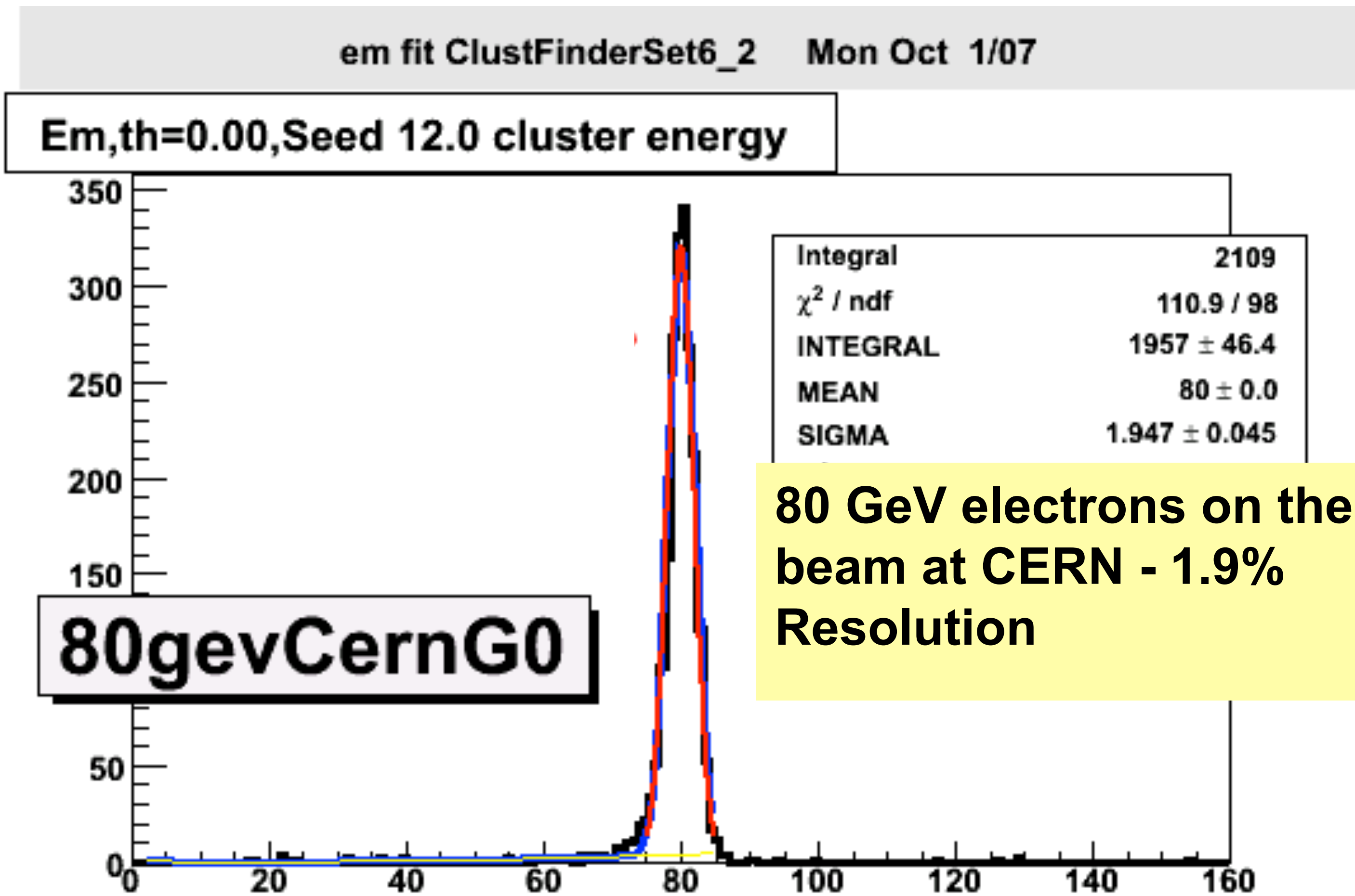




$$\sigma / E = 10.5\% / \sqrt{E} \oplus 1.8\%$$

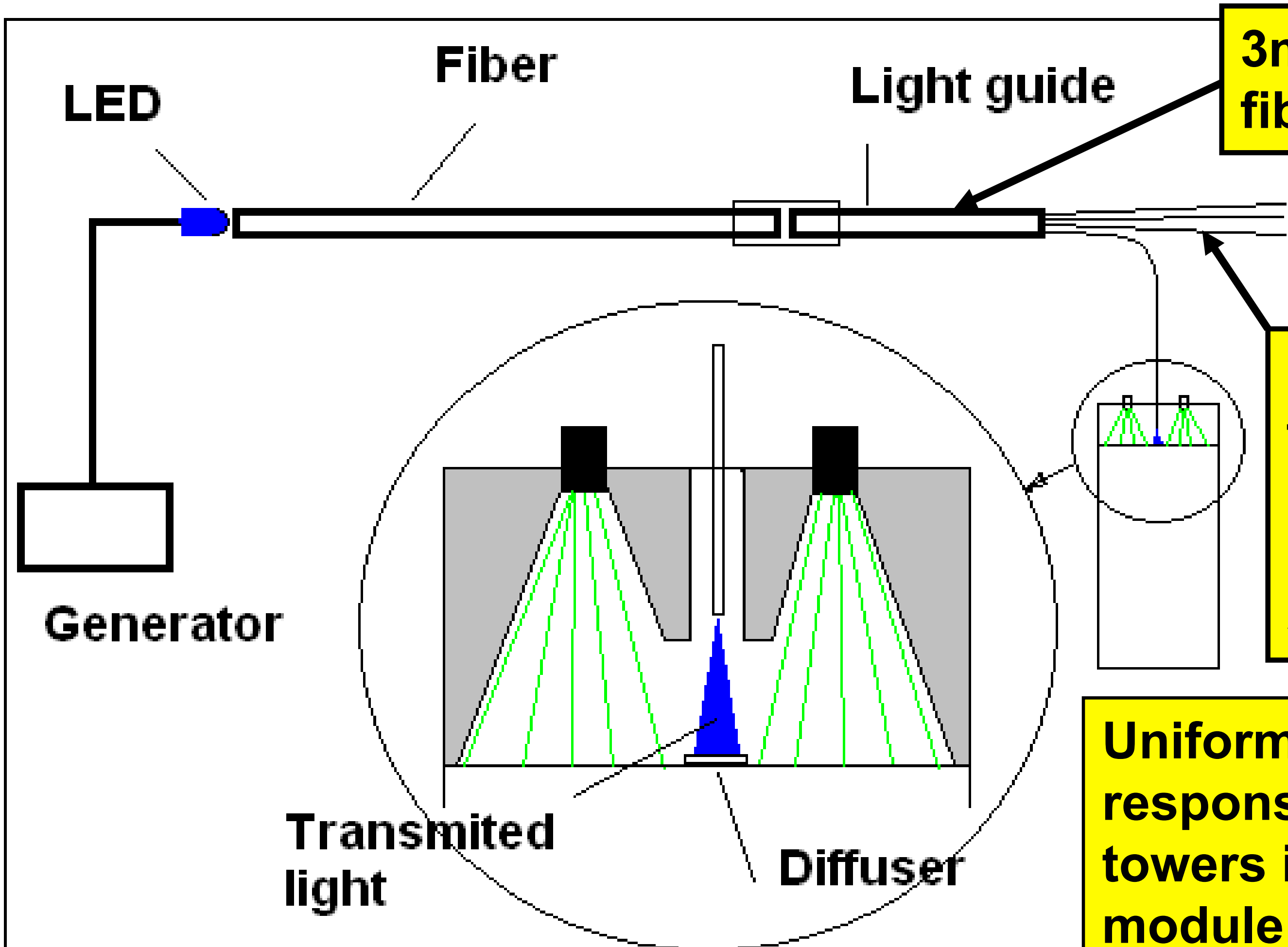
Technical progress since CD-1

Prototype Detectors



80 GeV electrons on the SPS beam at CERN - 1.9% Resolution

Strip Module Electronic and LED Integration

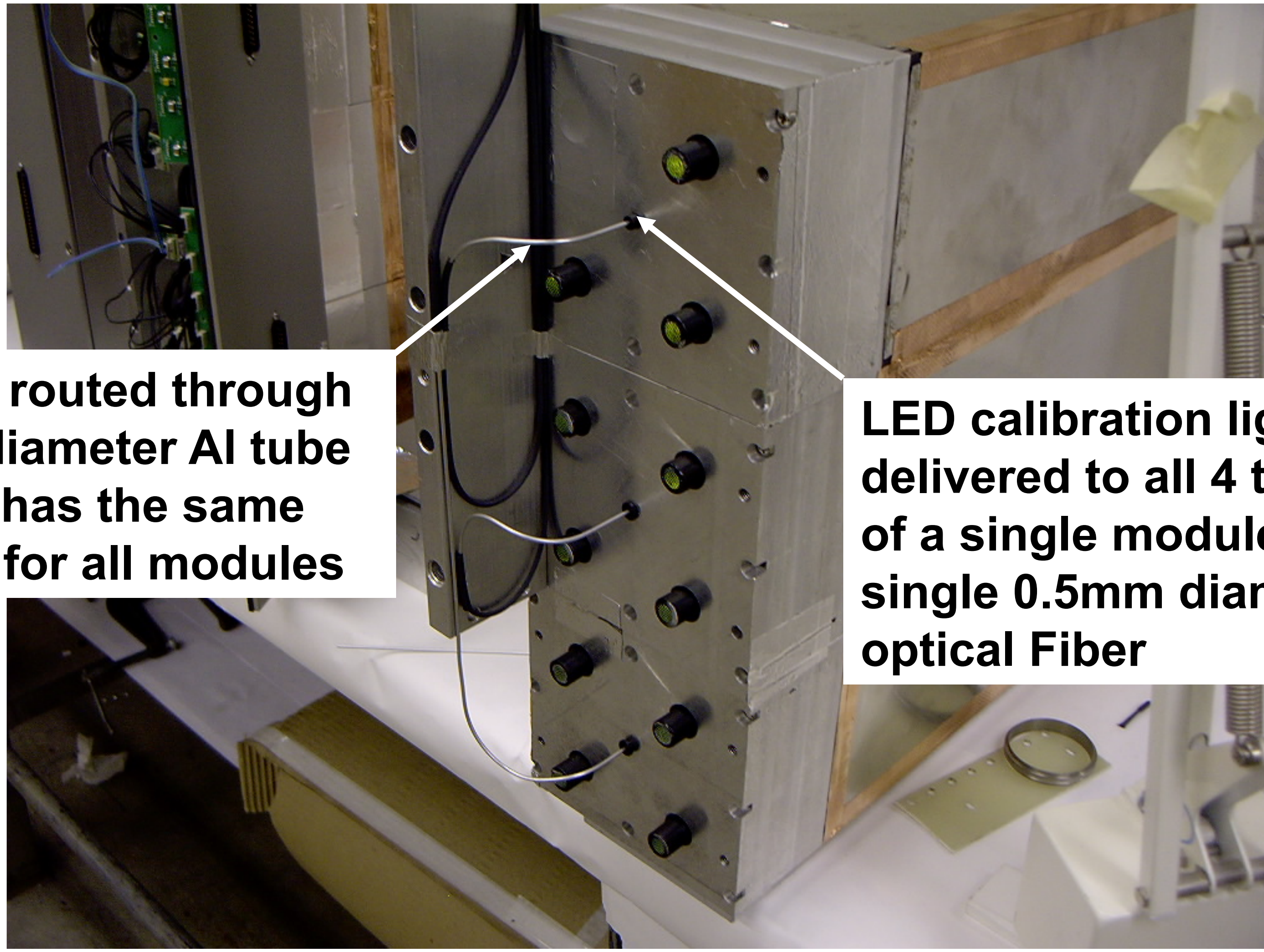


3mm diameter fiber

12, 0.5mm fibers distribute 1 pulse to entire strip module

Uniformity of response for all 48 towers in one strip module: σ ~10%

Strip Module Electronic and LED Integration



Fibers routed through 1mm diameter Al tube which has the same shape for all modules

LED calibration light delivered to all 4 towers of a single module via a single 0.5mm diameter optical Fiber

Table 4.4: Characteristics of the S8664-55 (S18148) Avalanche PhotoDiode.

Active Area	5×5 mm^2
Capacitance	90 pF
Wavelength min.	$\sim$ 320 nm
Wavelength max.	$\sim$ 1000 nm
Peak wavelength	600 nm
Quantum efficiency	$\sim$ 80% at 476 nm
1/M $\times$ dM/dT (M=50)	$\sim$ 2.2%
1/M $\times$ dM/dV (M=50)	$\sim$ 3.3%

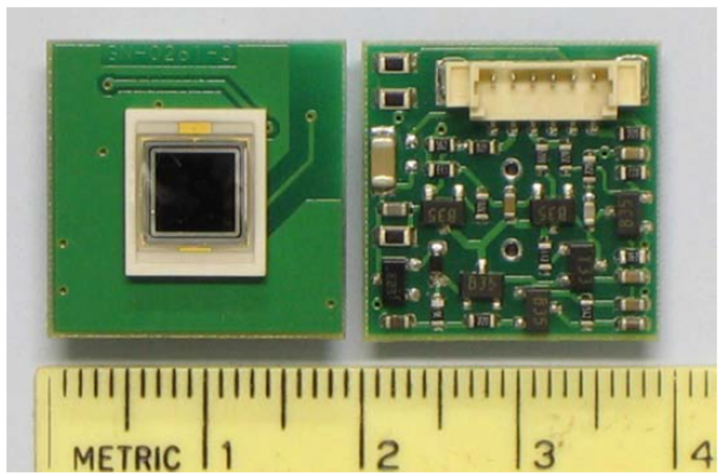
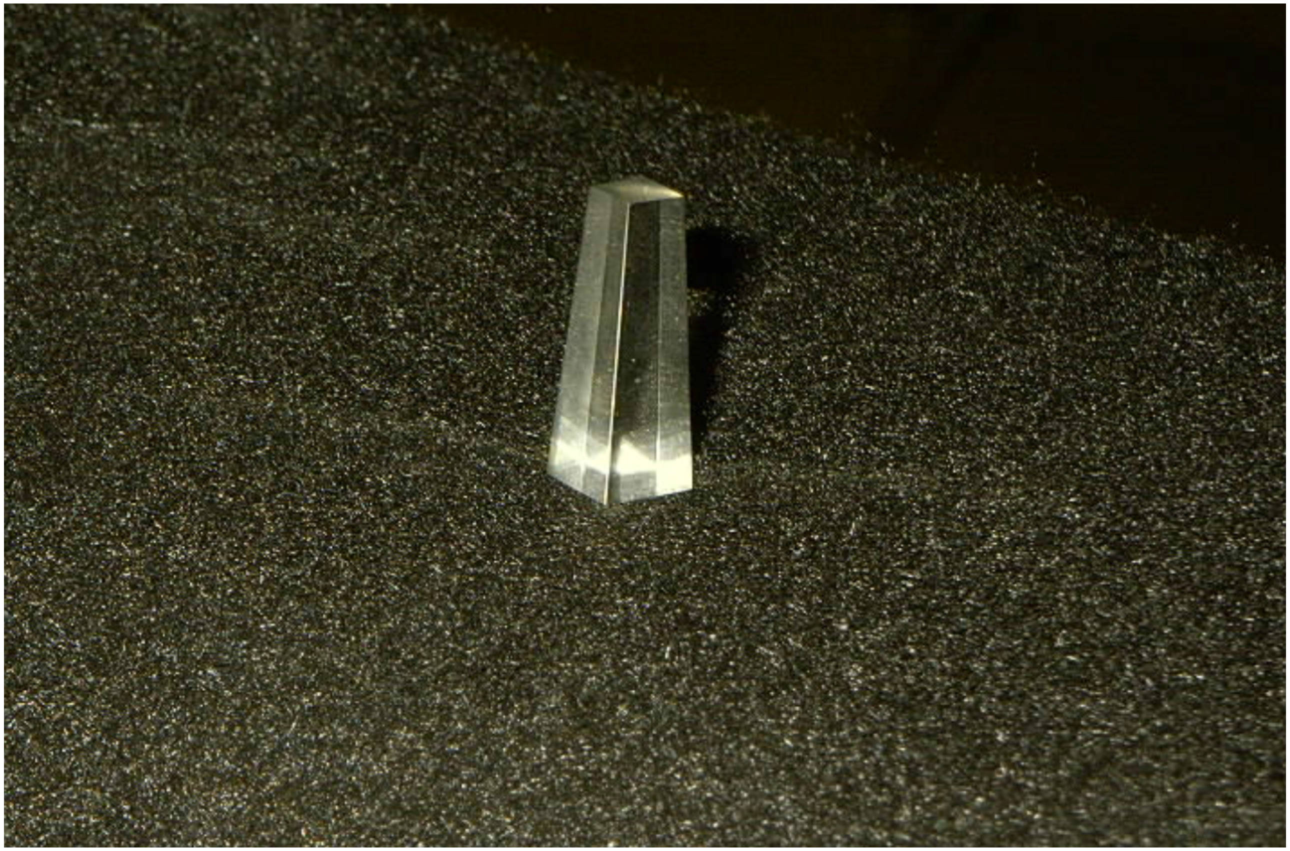
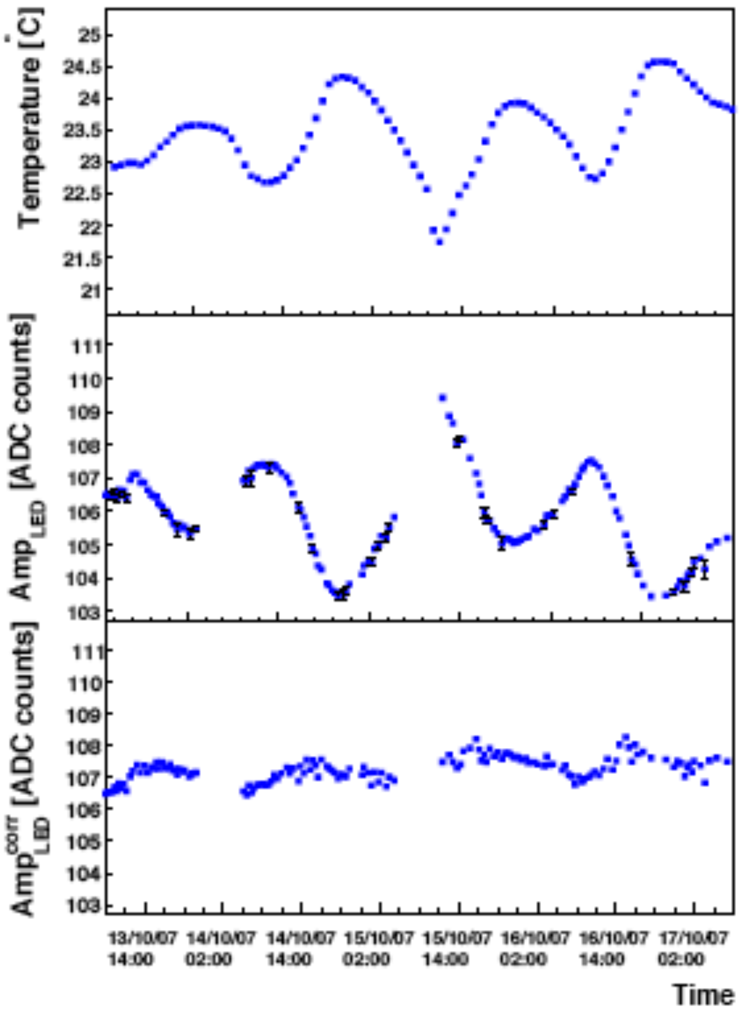


Figure 4.32: The Avalanche PhotoDiode (left) mounted on the back of the Charge Sensitive Preamplifer (right) used by PHOS and EMCal.

Light Guide Couples Fiber Bundle to APD



LED Gain stabilization



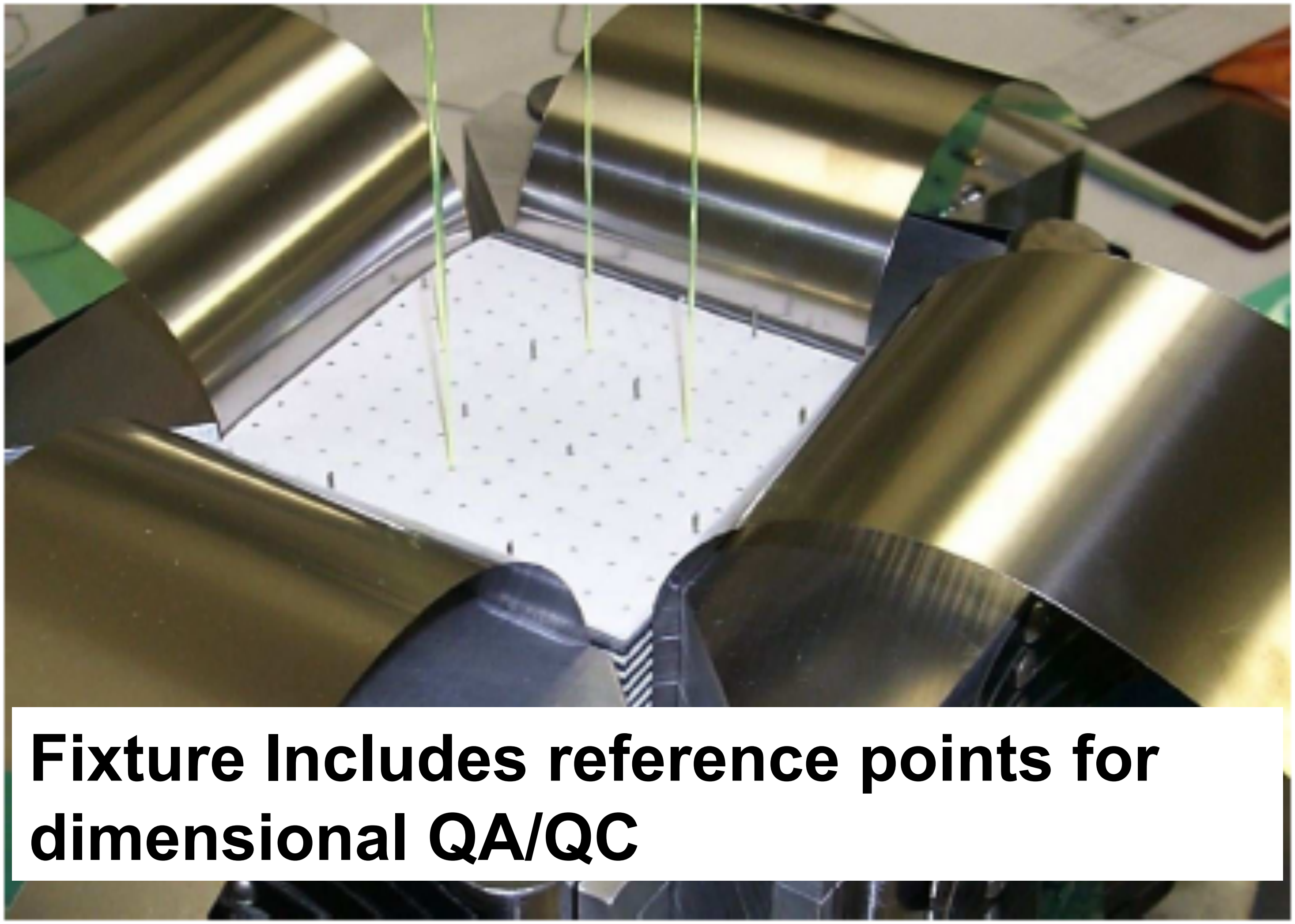
Strip Module Temperature

LED signal viewed by APD

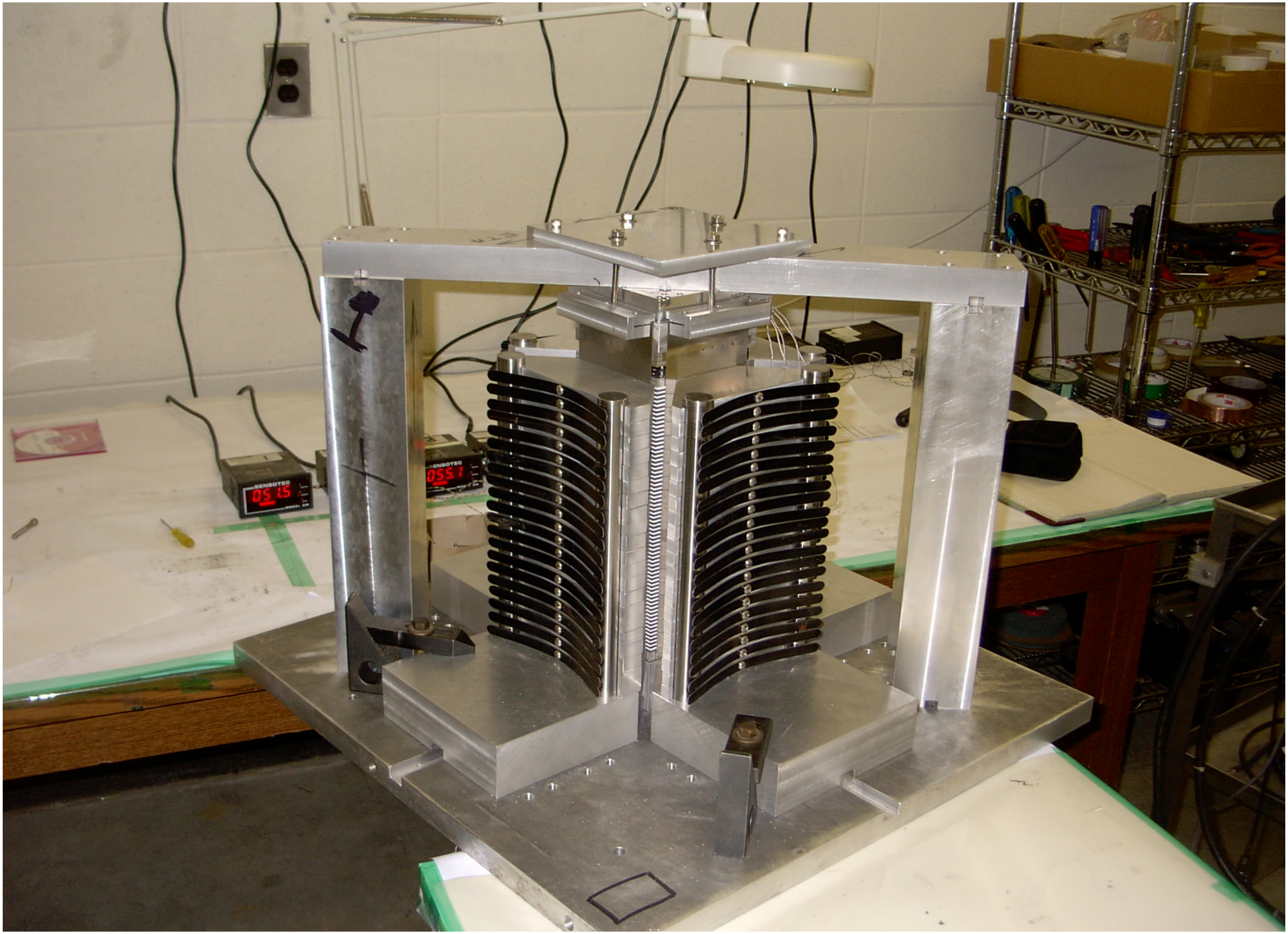
Temperature Corrected LED signal

Detector Assembly Methods and Tools

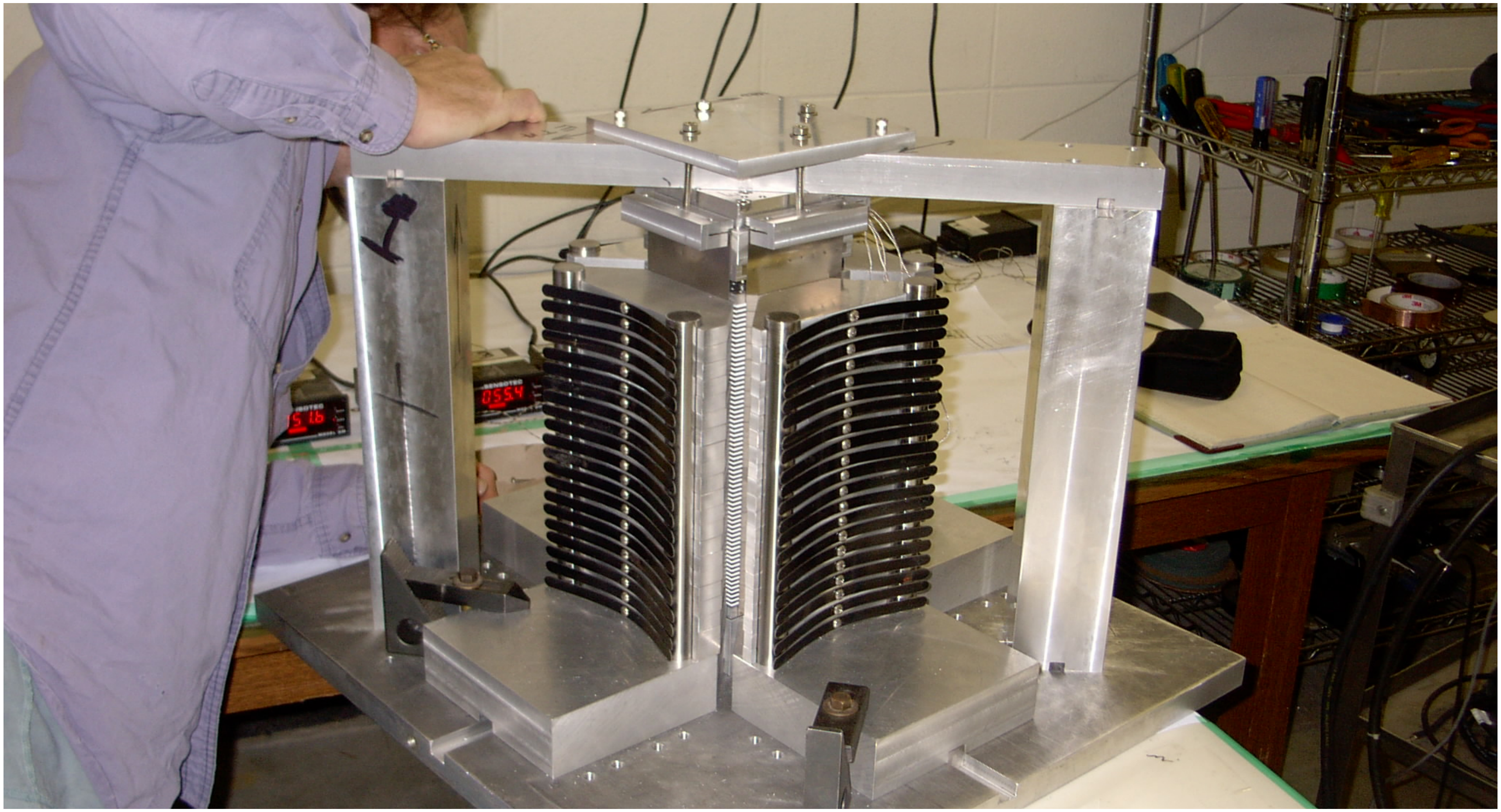
Module Stacking



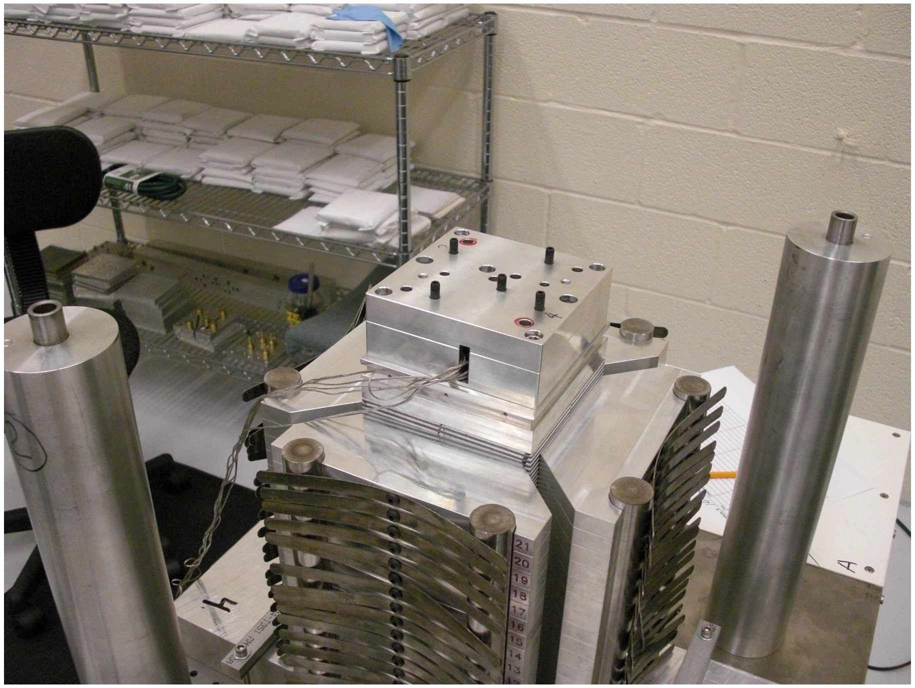
Fixture Includes reference points for dimensional QA/QC



Assembled Module under compression for 48 hours



Detector Production



8 Module Assembly Stations available at Wayne State as well as all other tooling: machine tools, laser welder, …

Following compression load for additional 48 hours

One Module showing fiber geometry at APD coupling

EMCal Requirements & Cost

What physics actually drives EMCal design?

Direct photons by pi-zero subtraction down to low P_T
=> most demanding – smallest Moliere/tower size

Electron ID at very low P_T (eventually with TPC dE/dx)
=> most demanding – smallest Moliere/tower size

Direct photon at higher P_T with hadron isolation
=> less demanding - need to be quantitative - needs real simulations to justify tower size

Electron ID at high P_T (eventually with TPC dE/dx)
=> less demanding - need to be quantitative - needs real simulations to justify tower size

EMCal Requirements & Cost

What physics actually drives EMCal design?

Jets
=> Not demanding on Moliere/tower/resolution

EMCal Requirements & Cost

What physics program actually drives EMCal design and cost?

I guess it's important not to appear to spend too much money to repeat your favorite RHIC measurements with S-PHENIX

S-PHENIX Integration Question

Portion of HCal inside magnet:

Probably fine for pp and e RHIC but what is impact on jet resolution?

The most important question for AuAu jets at RHIC is where is and what happens to the radiated gluon energy in quenching? Need to compare to LHC.

So, In AuAu, what is the impact on soft jet component of the intervening magnet in the middle of the HCal?

Need jet simulations with and without quenching to answer this.

ALICE-style EMCal scenarios and Cost

1. **present integration scheme (ignoring for the moment that only half the needed radial space is available)**

   ~ 15 m^2 of EMCal front surface area
   ~ 1050 ALICE EMCal Modules (4200 towers)

   Parts and material: $1400 per module
   includes estimated escalation

   Labor: 6 FTE-Years Technicians , One Foreman FTE-year
   $700k fully loaded

   Total Cost: $2.2M
   Excluding Integration, Conventional Systems, Electronics

   Comments: Highly Leveraged Tooling, Engineering
   Project Management Experience

ALICE-style EMCal scenarios and Cost

1. present integration scheme (ignoring for the moment that only half the needed radial space is available)

Extra Cost Options:

=> Increase Pb/Scint ratio
=> 9 towers/module 4 cm x 4 cm
=> Conversion to tungsten

Positive:

This option would review easily in short time
Completely Credible cost / schedule / Technical team

Negative:

Doesn't fit in present integration scheme

ALICE-style EMCal scenarios and Cost

2. **Move back to present Inner HCal position**
   - **Cost scales like surface area with (15m^2 = \$2.2M) => \$3.5M**
   - **Physics performance fully known – meets requirements (?)**
   - **Ready to Review in ~6 months**
   - **Completely credible cost / schedule / technical team**

Extra Cost Options:

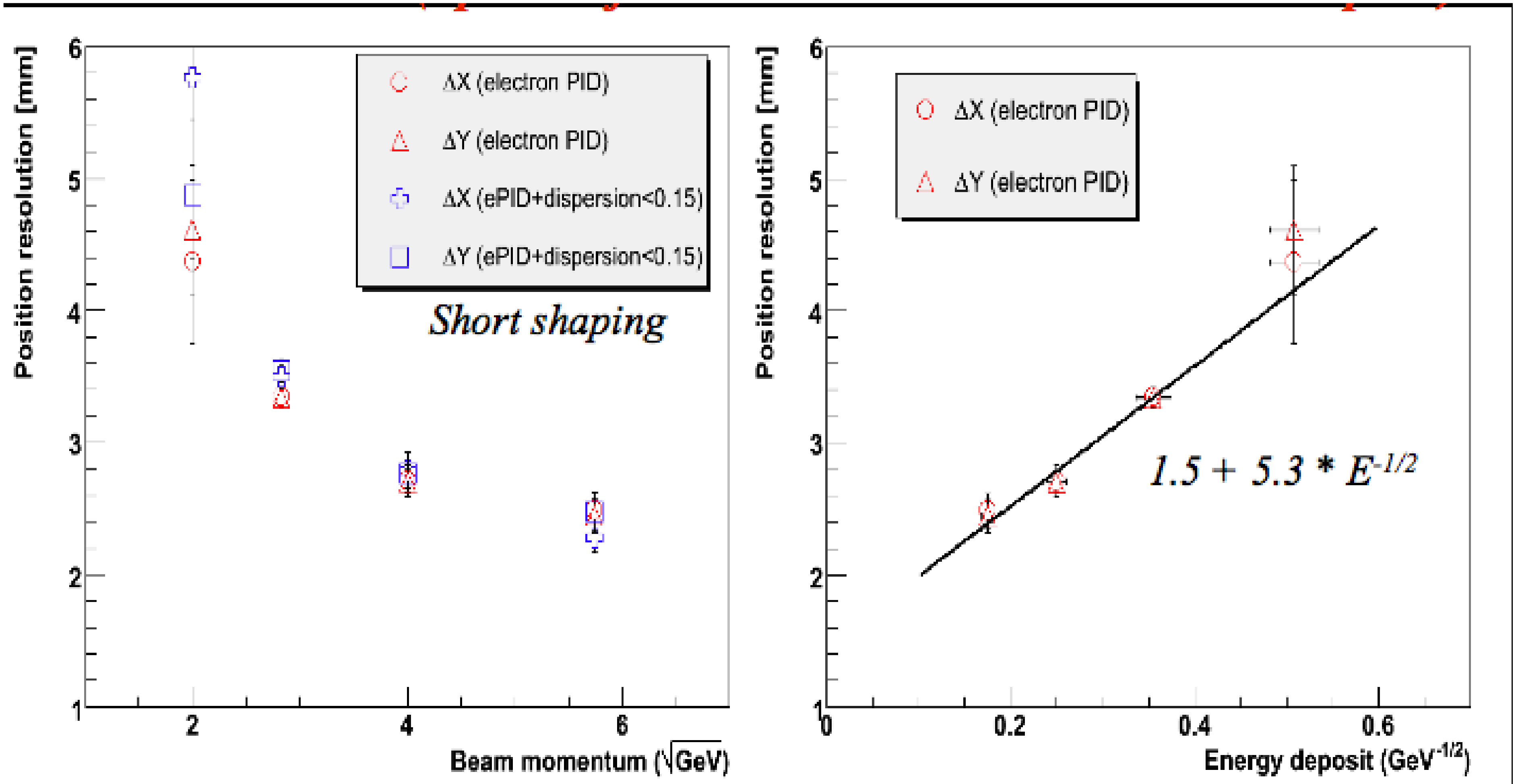
=> Increase Pb/Scint ratio

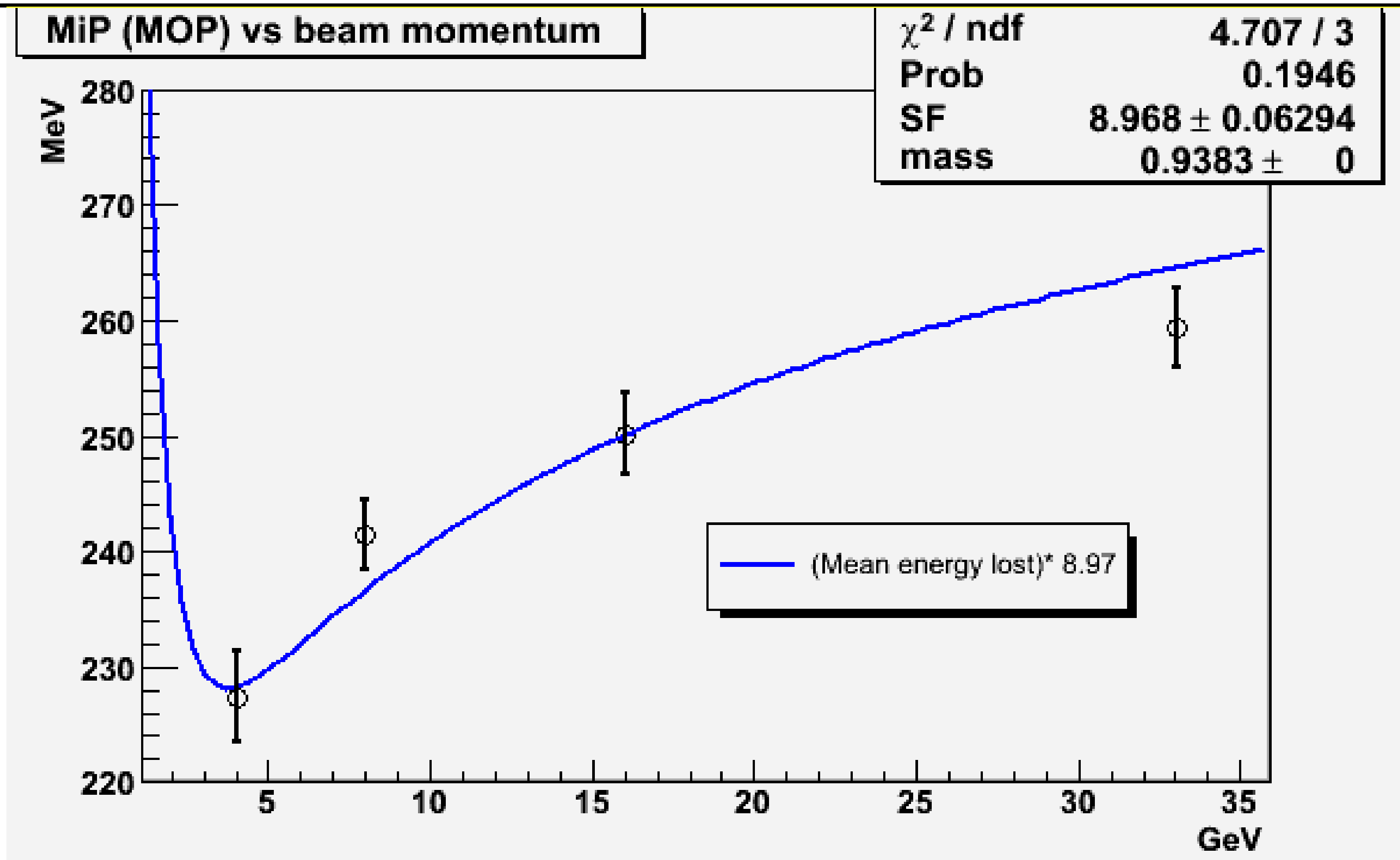
=> 9 towers/module 4 cm x 4 cm

=> Conversion to tungsten

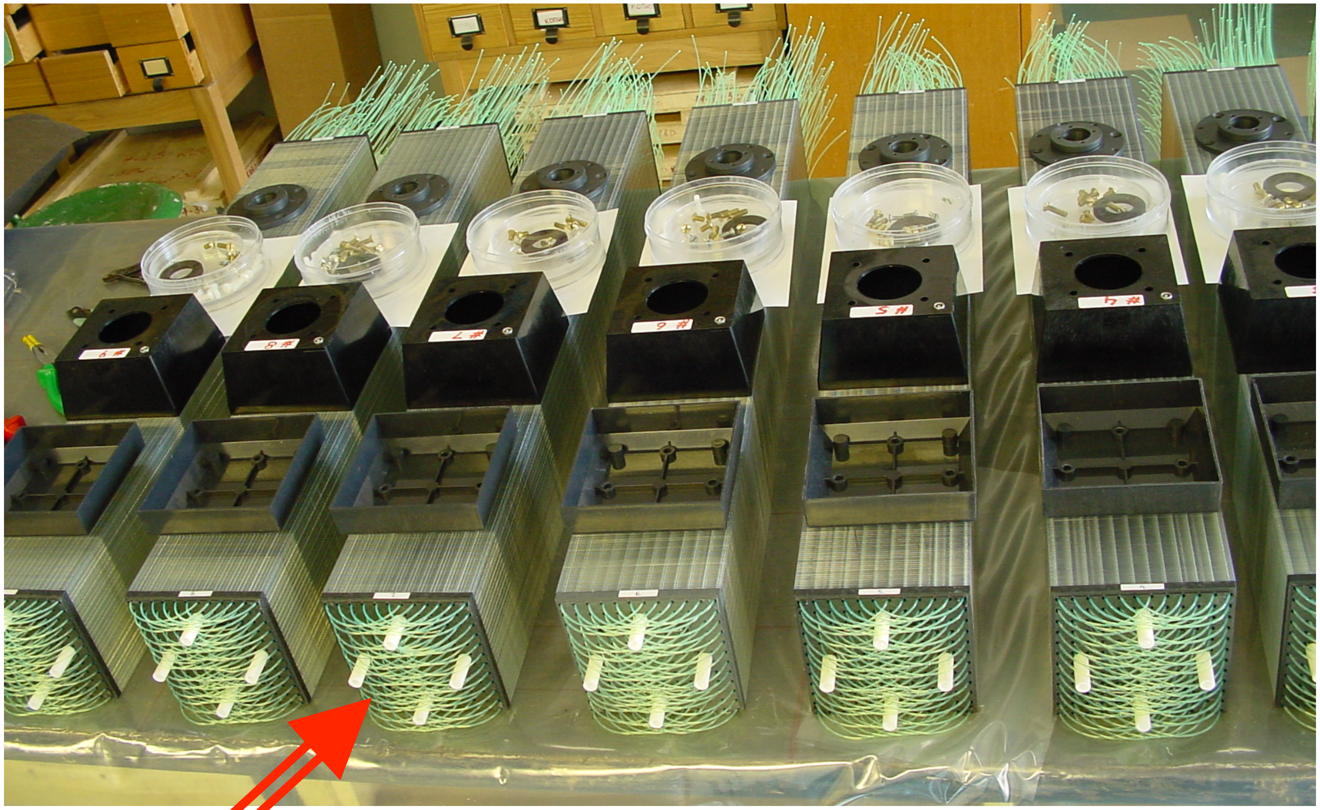
Extra Slides

Position Resolution in the range 4 - 2 mm for p=4 to 33 GeV/c




MiP (MOP) vs beam momentum
χ^2 / ndf 4.707 / 3
Prob 0.1946
SF 8.968 ± 0.06294
mass 0.9383 ± 0
MeV
280
270
260
250
240
230
220
5
10
15
20
25
30
35
GeV
(Mean energy lost)* 8.97

Alternate Fiber bundle method e.g. (IHEP):
Continuous fiber with a loop – no mirror
Cut and polish fibers after installation in module

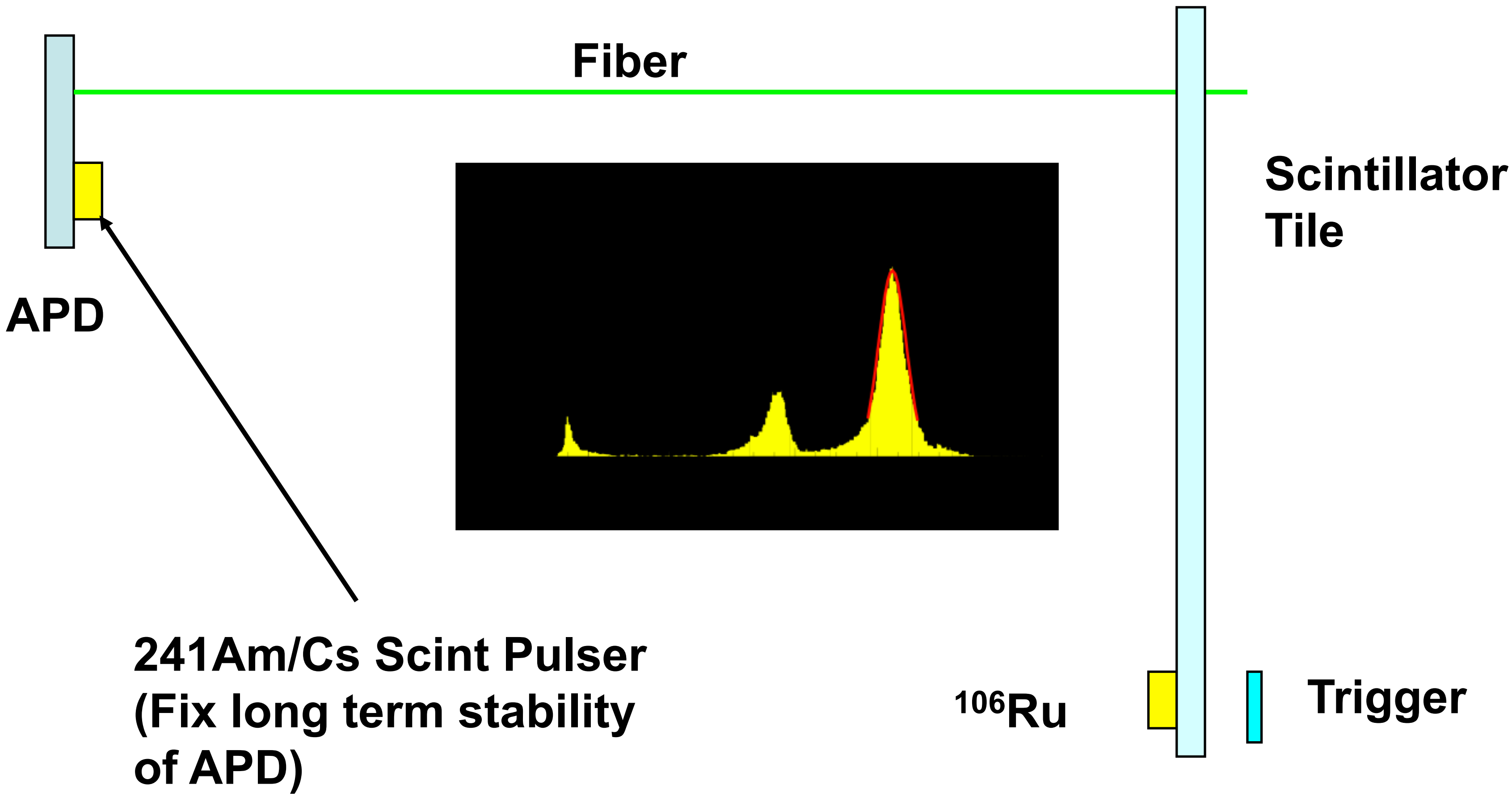


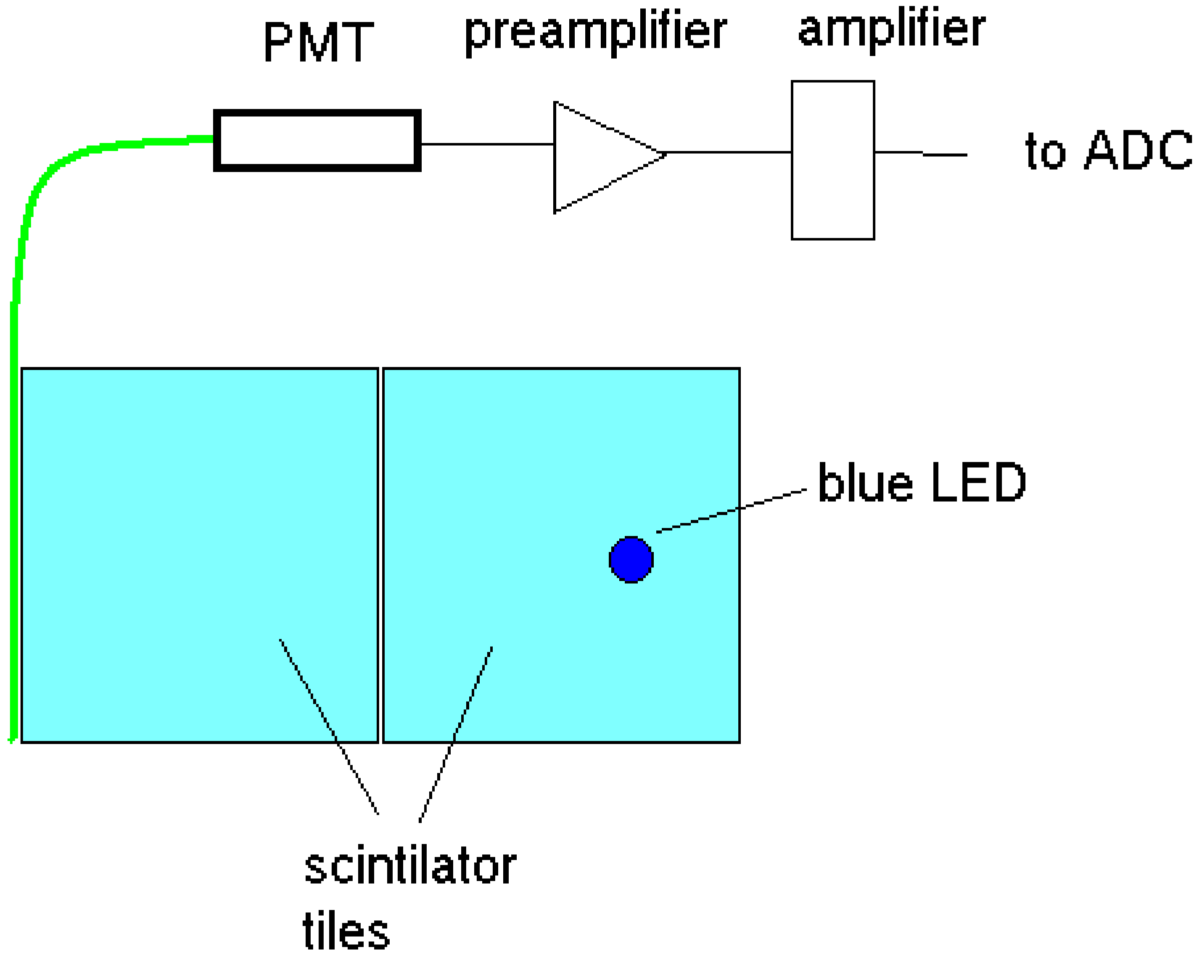
Fiber loop

Wayne State Group

Scintillator QC/QA

scintillator attenuation length and absolute fluorescence





Tile to Tile optical Cross Talk

Tile to Tile optical Cross Talk