# A Shashlik e.m. Calorimeter with Longitudinal Segmentation for a Linear Collider experiment

## CONTENTS



[a] Bologna, CERN, Lund, Milan, Padua, Serpukov

## Requirements from L.C. Physics

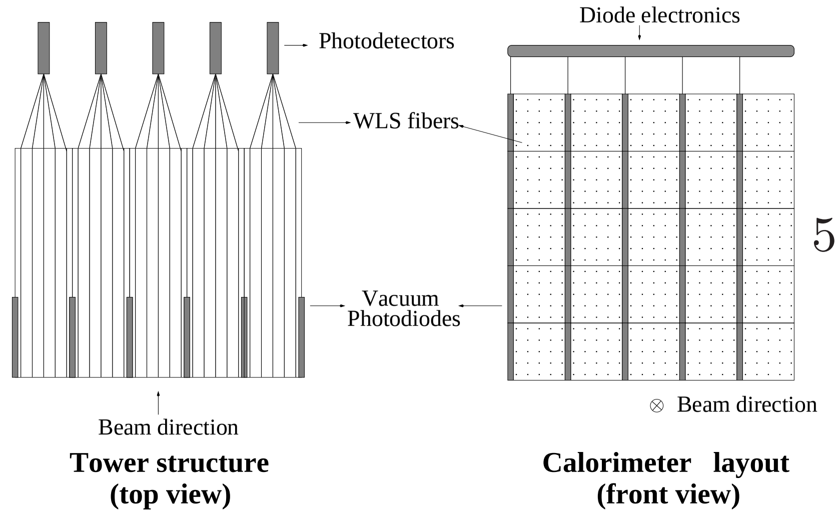
- **Jet energy reconstruction**
  **disentangle showers (charged-neutral)**
- **High granularity**
- **Longitudinal segmentation**
  $e/\pi$ **separation**
- **Good resolution at High Energy** ($\mathcal{O}(1\%)$)
- **Working in high magnetic field**
- **Reasonable length** ($25 \div 30 X_0$ **in** $\sim 50$ **cm**)
- **Reasonable cost**

**Shashlik Calorimeters**

## Shashlik

- Ligh collection via WLS fibers perpendicular to the Pb/sci tiles
- Compact, modular, easy to operate, no dead zones
- Longitudinal segmentation?

## CALEIDO



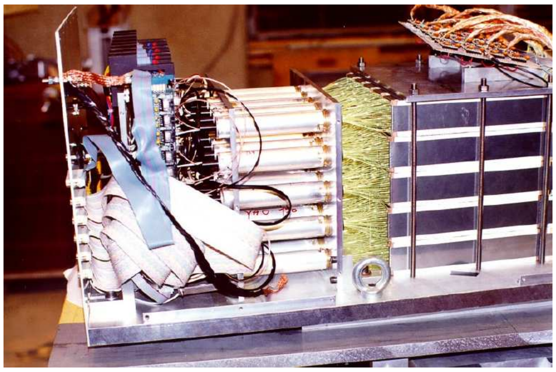

$5 \times 5$ cm$^2$

- Study longitudinal segmentation options:

- a) Insertion of thin vacuum photodiodes in the first $X_0$'s
- b) Use two scintillators with different time response

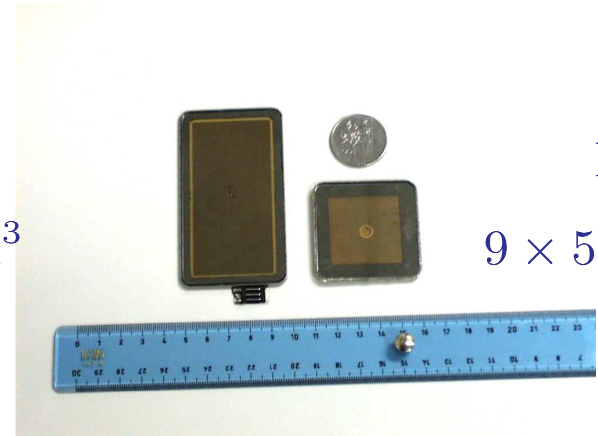
# CALEIDO 1 published results [b]

**Vacuum Photodiodes in the first** 8 (5) $X_0$



Tower: $5 \times 5 \times 28$ cm$^3$ $\quad$ $5 \times 5$ WLS fibers

EMI $9 \times 5 \times 0.5$ cm$^3$

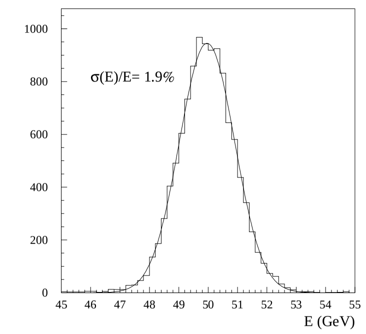


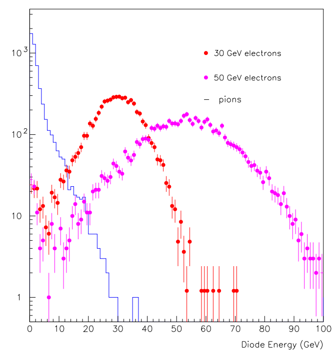
Hamamatsu $9 \times 5 \times 0.5$ cm$^3$

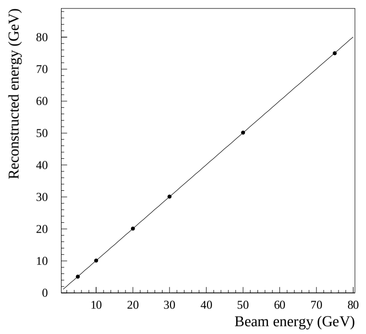
25 towers, 1 mm Pb + 1 mm scintillator sampling

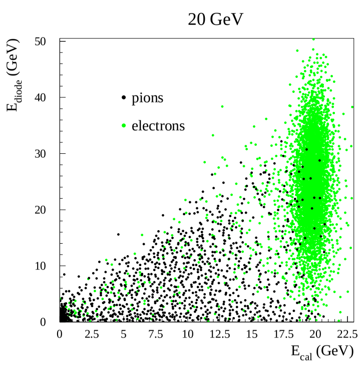
[b] N.I.M. **A432** (1999) 232

# Results




$$\frac{\sigma(E)}{E} = \sqrt{\left(\frac{9.6\%}{\sqrt{E}} + 0.5\%\right)^2 + \left(\frac{0.130}{E}\right)^2}$$

$$\sigma_X(E) = \sqrt{\left(\frac{0.9}{\sqrt{E}}\right)^2 + (0.1)^2}\ \mathrm{cm}$$

$e \div \pi$ separation: $\epsilon_\pi < 5 \times 10^{-4}$ (50 GeV)

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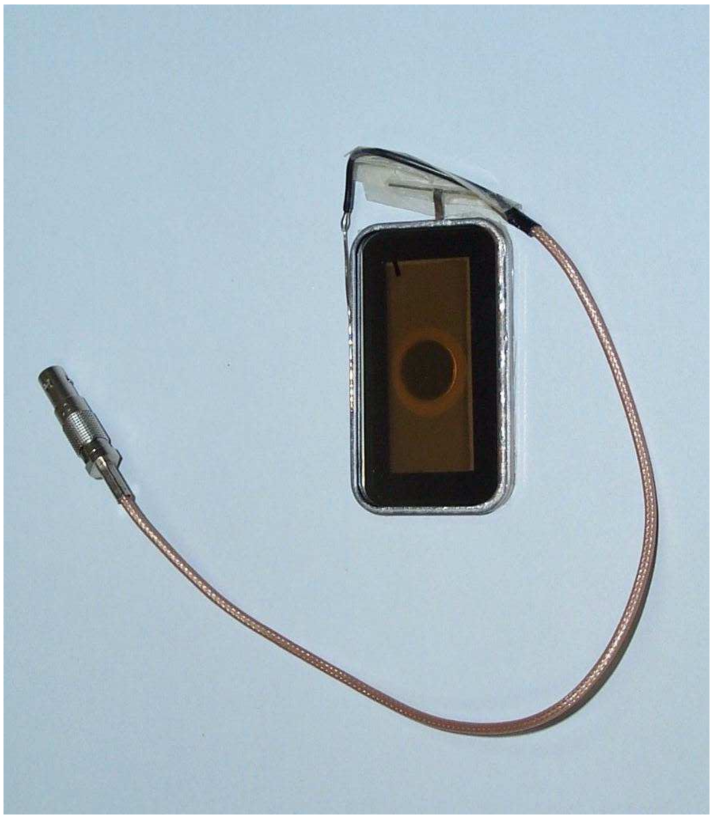
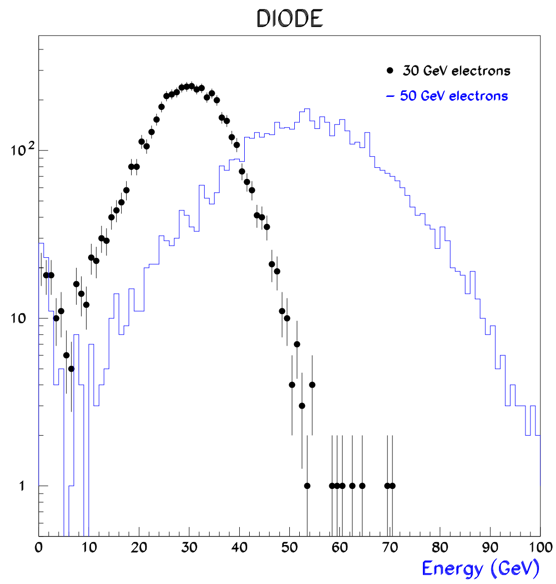
## NEW

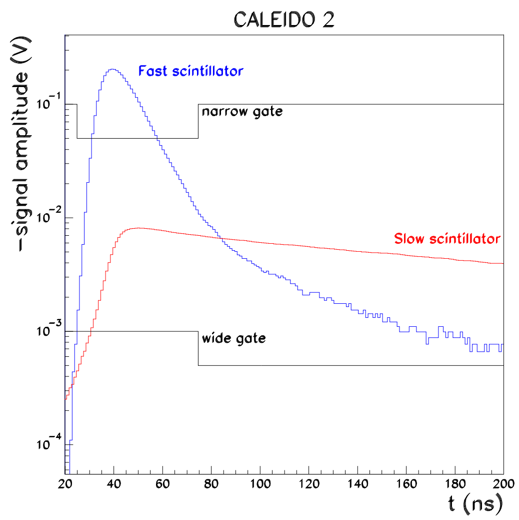
- $3 \times 5\ cm^2$ Hamamatsu diode for $3 \times 3\ cm^2$ cells





## 2 Scintillators with different time response

- First 5 $X_0$ with long $\tau$ scintillator
  same geometry, WLS fibers ....




- Slow scint.: BC444 from Bicron $\tau \sim 250$ ns
- e/$\gamma$: early shw.$\Rightarrow$ high $E_{slow}$ and $E_{fast}$
  hadrons: late shw. $\Rightarrow$ small $E_{slow}$
- 9 counters ($3 \times 3$) with (fast) PM's
  FEU-84-3 FEU-115M
- RO: narrow and wide gate (50 and 150 ns)
- $Q_n$ and $Q_w$ mix the two components

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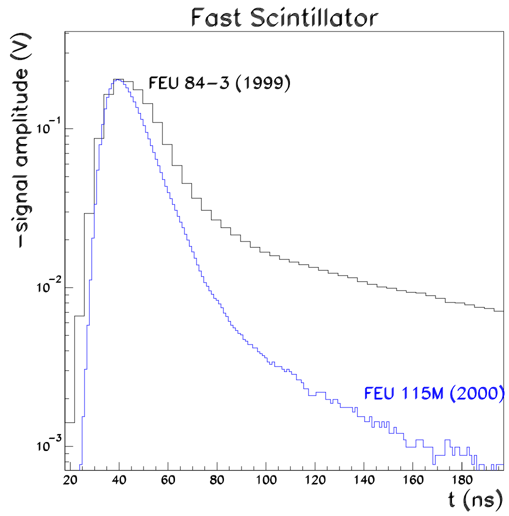
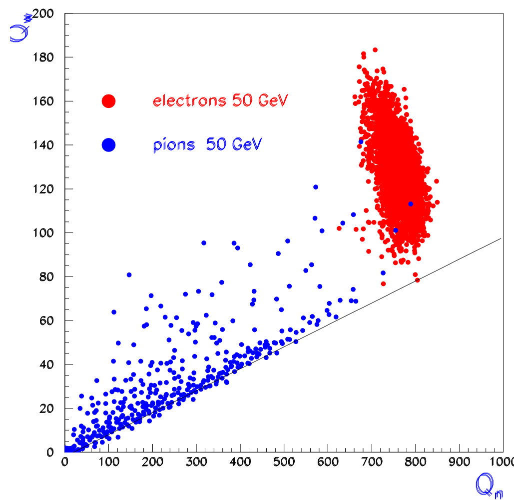
## Fast component on the wide gate:

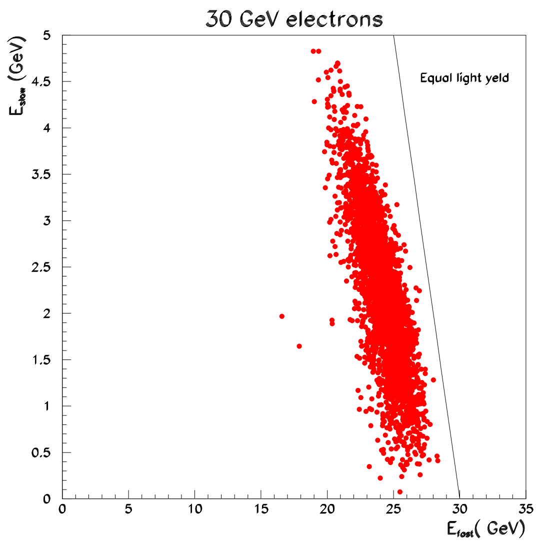
- gate width
- PM



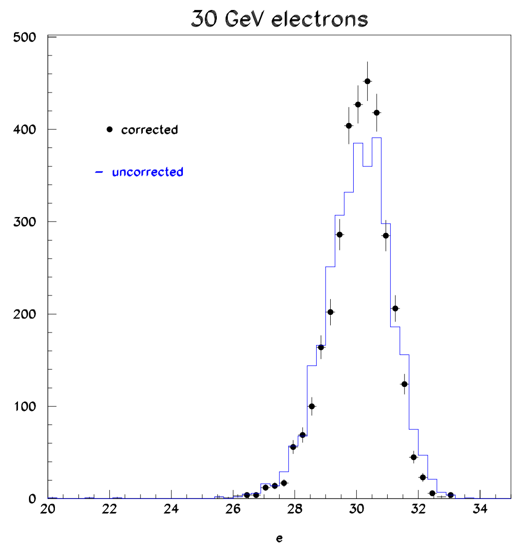

- Linear transformation: $Q_w, Q_n \rightarrow E_{slow}, E_{fast}$



# Different light yeld slow÷fast




- correction allows to minimize the effect of shower longitudinal fluctuations

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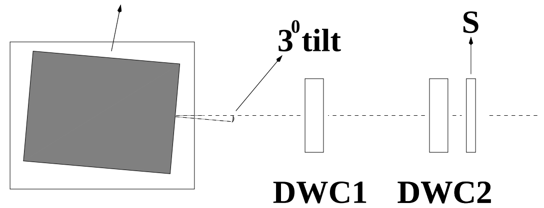
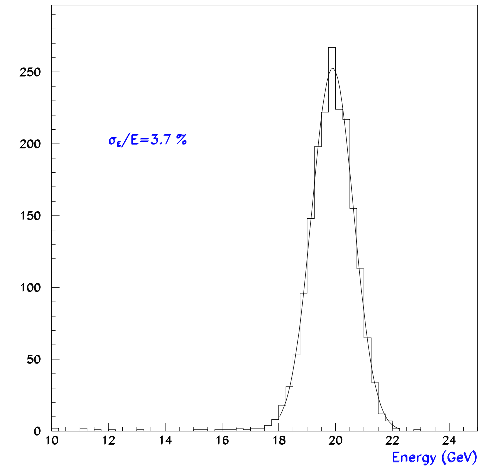
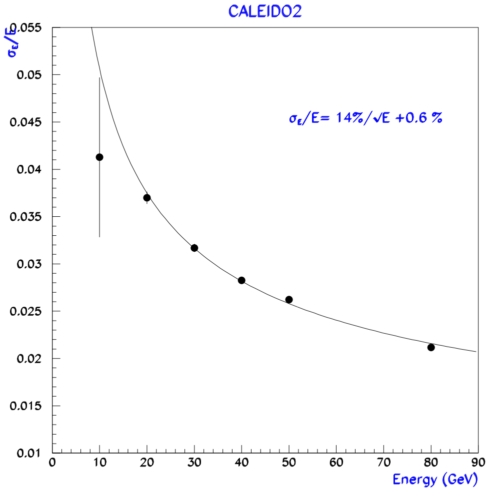
# Testbeam results




## - CERN X5 and H6 beams




## - Energy resolution (still preliminary):

$$\frac{\sigma(E)}{E} = \frac{14.2\%}{\sqrt{E}} + 0.6\%$$

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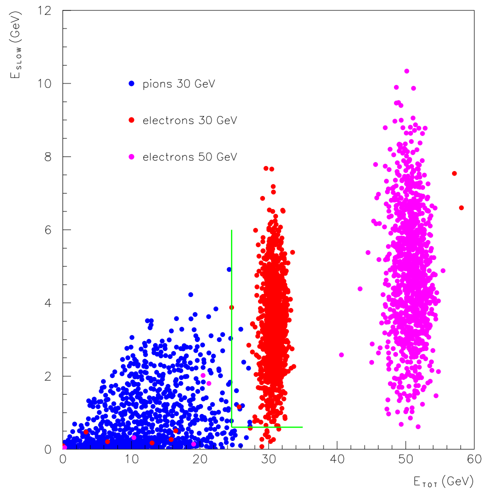
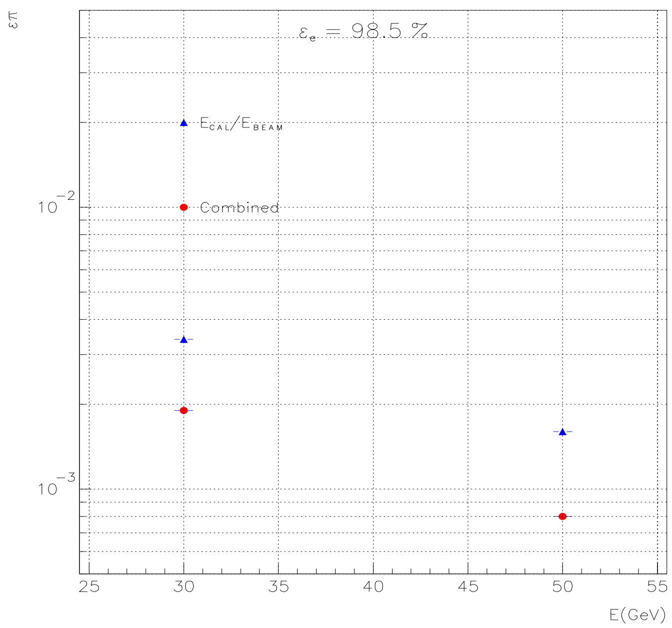
# e÷$\pi$ separation (1999)




$$\epsilon_\pi = 8 \times 10^{-4} \text{ for } \epsilon_e = 98.5\%$$

$$\epsilon_\pi < 5.6 \times 10^{-4}\ (95\%\ C.L.) \text{ for } \epsilon_e = 95\%$$

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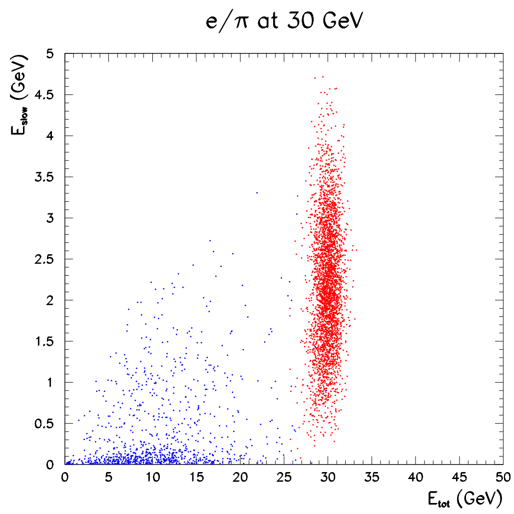
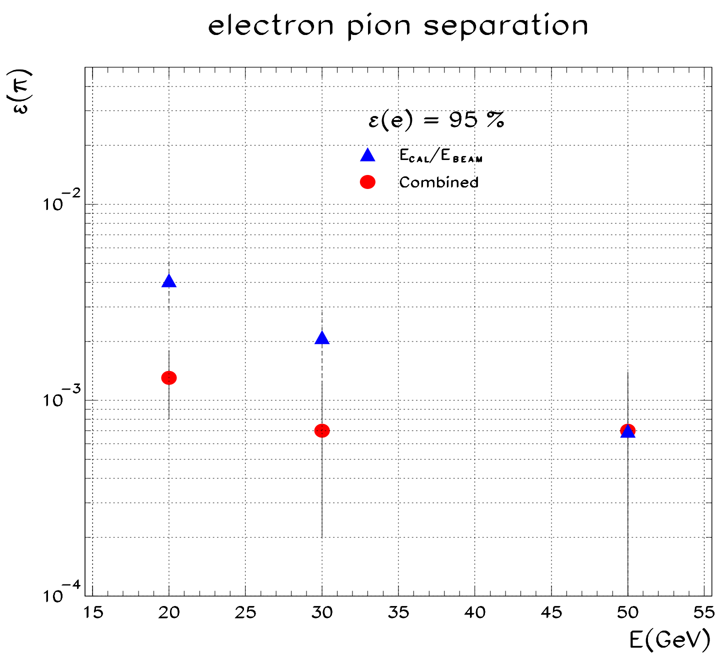
# e÷$\pi$ separation (2000)




$$\epsilon_\pi = 7 \times 10^{-4} \text{ for } \epsilon_e = 95\%$$

# Testbeam Summary

**First prototype:**

- Energy Resolution: $< \frac{10\%}{\sqrt{E}}, \quad < 1\%$ c.t.
- $e/\pi$ separation with lateral diode works:
  $< 5.0 \times 10^{-4}$ at 50 GeV
- Good Position Reconstruction
- No significative cracks

**Second prototype:**

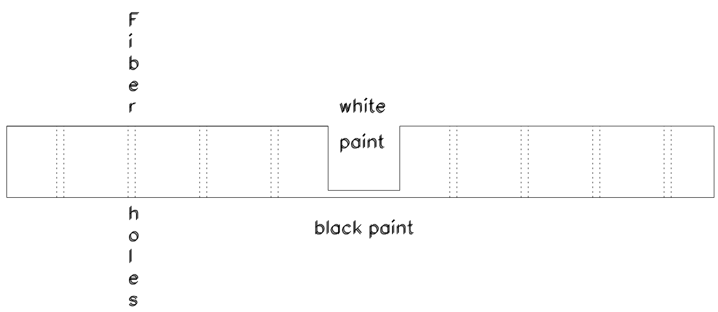
- Energy Resolution: $< \frac{15\%}{\sqrt{E}}, \quad < 1\%$ c.t.
- $e/\pi$ separation with 2 decay time scint. works:
  $< 6.0 \times 10^{-4}$ at 50 GeV
- See prototype 1...
- Possibility for more compact mechanics

**Both prototypes meet requirements!**

# Mechanical solution for a barrel E.M. calorimeter at TESLA LC

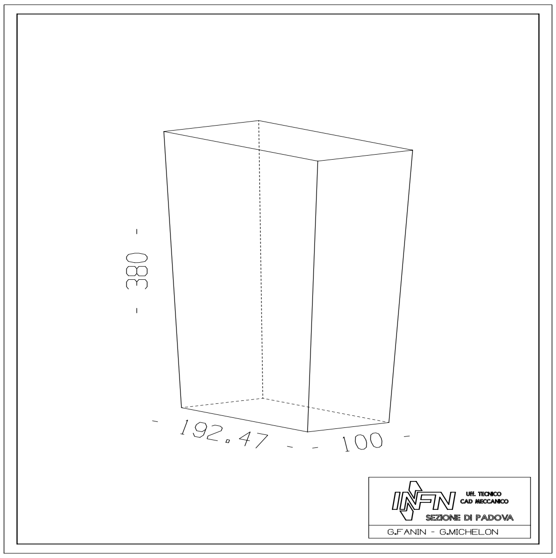
- The **2** $\tau$ prototype opens many solutions in addition to the cell-size structure
- Large $(20\ cm \times 10\ cm)$ absorber plates with small $(3\ cm \times 3\ cm)$ scintillator tiles
- Large $(20\ cm \times 10\ cm)$ absorber plates with large scintillator tiles segmented

SCINTILLATOR TILE SEPARATION



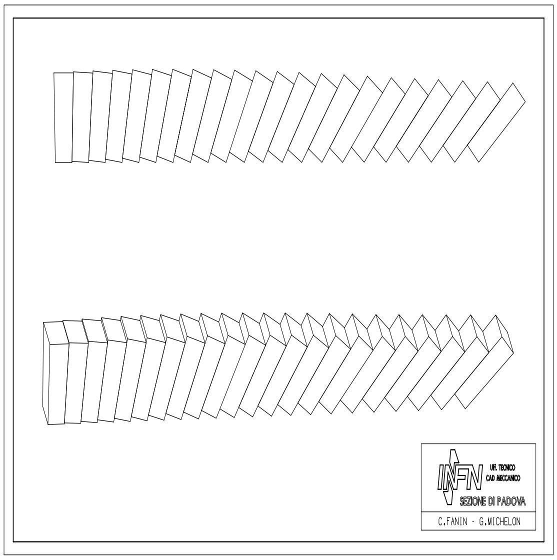
## In both case Supermodule:

18 channels




21 S.modules

43344 channels




56 rows

- **WLS fibers coupled to long clean fibers**
- **PM RO outside magnetic field**
- **Tungstene absorber (!?)**

**Proposal to TESLA TDR**

# Conclusions

- Shashlik calorimeters with longitudinal segmentation are possible

- Two solutions successfully tested by CALEIDO

- New technique for channel separation under development

- Contribution to TESLA TDR $\sim$ available

**Shashlik is a good candidate for an ElectoMagnetic Calorimenter at a future Linear Collider!**