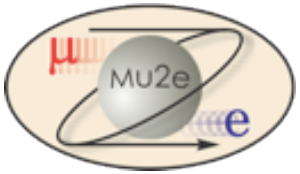
# MU2E Calorimeter System: An Overview

S.Miscetti
LNF INFN Frascati

MUSE General meeting
28-Sep-2016 Pisa

# Physics and Calorimeter Requirements

The Mu2e Calorimeter should:

- Provide high e- reconstruction efficiency for μ rejection of 200
- Provide cluster-based seeding for track finding
- Provide online software trigger capability
- Survive in a high radiation environment (100 krad, $10^{11}$ n/cm$^2$)
- Operate for 1 year w.o. interruption in DS w/o reducing performance

**In order to do so the calorimeter should have the following capability**

→ Provide energy resolution $\sigma_E/E$ of O(5 %)

→ Provide timing resolution $\sigma(t) < 500$ ps

→ Provide position resolution < 1 cm

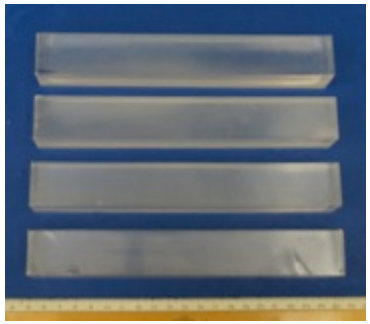
→ Provide almost full acceptance **for Conversion Electron @ 100 MeV**

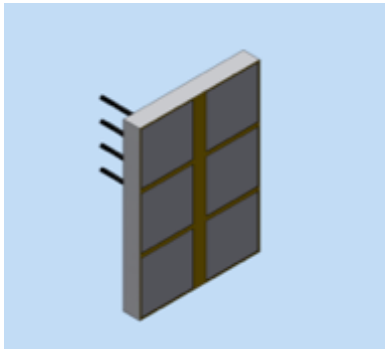
→ Redundancy in FEE and photo-sensors

## Solution: A crystal based disk calorimeter

# The Mu2e calorimeter

**The Calorimeter consists of two disks with 674 34x34x200 mm$^3$ CsI square crystals:**



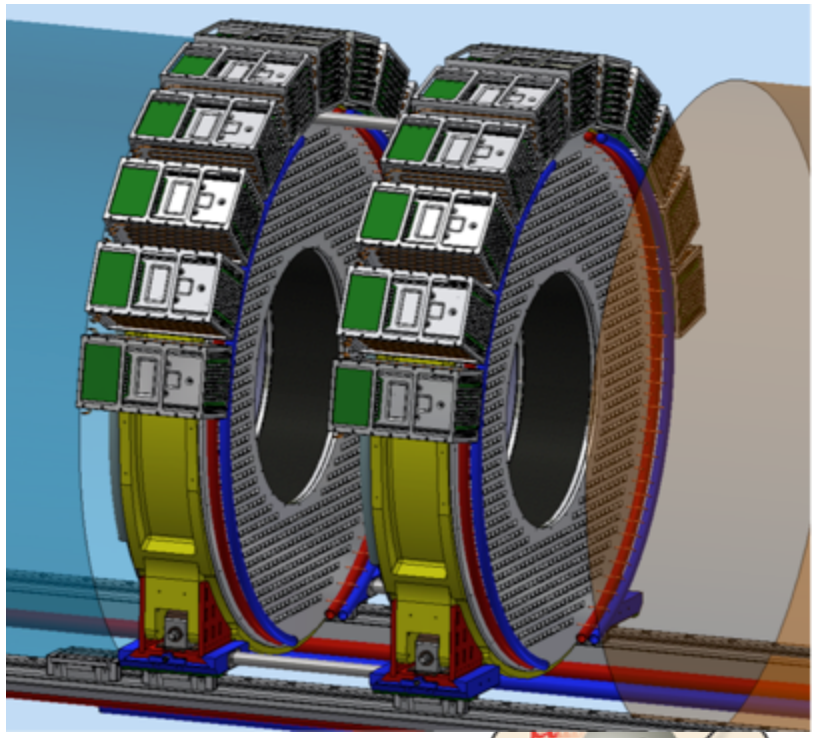


→ $R_{inner}$ = 374 mm, $R_{outer}$=660 mm, depth = 10 $X_0$ (200 mm)

→ Each crystal is readout by two large area UV extended SIPM's (14x20 mm$^2$)

→ Analog FEE is on the SiPM and digital electronics located in near-by electronics crates

→ Radioactive source and laser system provide absolute calibration and monitoring capability



# Long list of reviews on 2015-2016

- TCR technology choice review, July 2015
- Technical Choice → December 2015 → CsI+SiPM
- FDR Final Design Review → Feb 2016
- DR for CD3c , Director review for CD3-C → April 2016
- CD3c → June 2016
- **CD3c approval , July 2016**

**A lot of work in the last 2 years, but we finally arrived to a final decision:**

- We are freezing the design and proceeding with pre-production, Module-0 and final engineering.
- We will then proceed for slice test and construction period.

**Only comments/recommendations from CD-3c:**

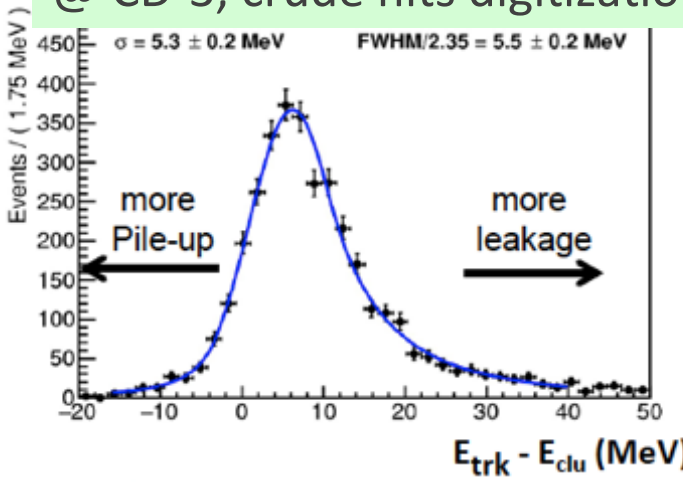
→ Test the "custom-SIPM" layout
→ Proceed with agreement btw Mu2e-INFN
→ Conduct a Vertical Slice test
→ Prepare detailed assembly and installation procedures

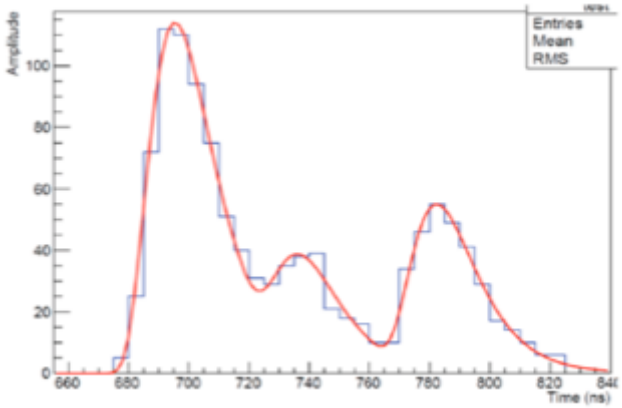
# EMC Simulation

**Great improvement in simulation with full digitization included.**

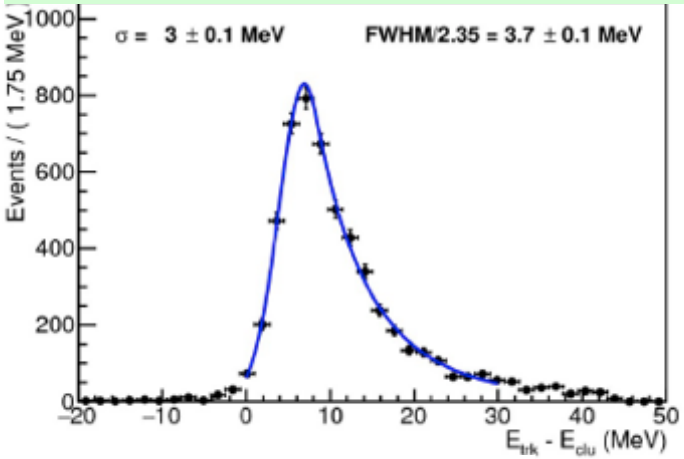
- As expected: CsI + SiPM is a good candidate also for Energy resolution!
- A lot of work also on trigger and on in-situ calibration.

## @ CD-3, crude hits digitization

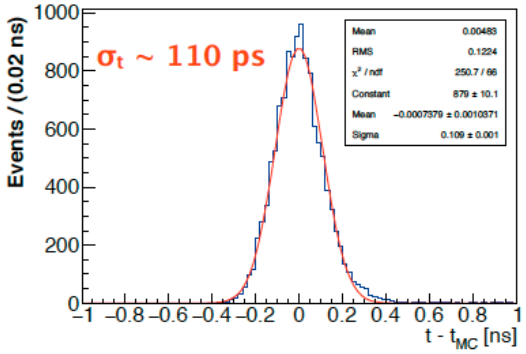



## Today: with realistic hits digitization




CE time resolution



# Calorimeter: Design Status Updated 9/16

| Calorimeter Subsystem | Design Completion | Remaining Work/Risks |
|---|---|---|
| Crystals | 100% | CsI slow component specified. |
| Photosensors | **90%** | **SiPM packaging.** Have one packaged SiPM from Hamamatsu but want to qualify other vendors |
| Mechanical Infrastructure | **80%** | Finalize cooling design. Optimizing tradeoffs between noise, radiation damage and operating temperature. x2 headroom |
| Front End Electronics And Digitizer (WFD) | **80%** | • **New pre-amp design for CsI/SiPM**<br>• WFD board design with 20 channels. Moderate risk that we may have to back off to 18 channel boards. Adds a small amount of complexity. |
| Calibration | 90% | Integration of source pipes. Finalize laser optics. |
| **Overall Design** | **88%** | |

# Long list of "upcoming" reviews

- Mechanical Review → end of 2016- beginning 2017
- Construction Readiness Review 1 (sensors, crystals) → March 2017
- CRR for all calorimeter system ( mech, FEE, installation) Summer 2017

**A clear priority path exists:**

- Conclude engineering
- Proceed with Module-0, vertical slice test
- Prepare Bids for large procurement
- Prepare QA / assembly site @ FNAL
- Make all tests under vacuum
- Complete Irradiation program

# Detailed work report @ MUSE GM

| | |
|---|---|
| 15:20 - 15:40 | Calorimeter crystals *20'*<br>Speaker: Raffaella Donghia (LNF) |
| 15:40 - 16:00 | Calorimeter photosensors *20'*<br>Speaker: Ivano Sarra (LNF) |
| 16:00 - 16:30 | Coffee break |
| 16:30 - 16:50 | Mu2e calorimeter mechanics *20'*<br>Speaker: Fabio Happacher (LNF) |
| 16:50 - 17:10 | Plans for module 0 *20'*<br>Speaker: Dr. Matteo Martini (LNF) |
| 17:10 - 17:30 | Calorimeter waveform digitizer *20'*<br>Speaker: Elena Pedreschi (PI) |
| 17:30 - 17:50 | Calorimeter trigger *20'*<br>Speaker: Stefano Di Falco (PI) |

# Irradiation plans & implication for Muse

- Crystals tested up to 100 krad, $10^{12}$ n @ 14 MeV, slow neutron high rate
- SIPMs tested up to 20 krad, $4x10^{11}$ n_1MeV eq/cm$^2$
- WD (FPGA OK) ADC+DCDC tested up to 20 krad, $6x10^{11}$ n_1 MeV eq/cm$^2$

Safety factors of 3 used so far

- Electronics integration group Increased safety factors value from 3 to 12 while asking for 10 year lifetime.
- So increases for FEE/WD are 10 for TID, 2 for neutrons.
- Calculation for SIPM underway

| Inside Bore (Tracker, Calorimeter) | Radiation Type | Simulation Safety Factor | Low Dose Rate Safety Factor | Lot Variation Safety Factor | Total Safety Factor |
|---|---|---|---|---|---|
| | TID | 3 | 2 | 2 | 12 |
| | NIEL | 3 | 1 | 2 | 6 |
| | SEE | 3 | 1 | 2 | 6 |

| Region | Z (mm) | RLO (mm) | RHI (mm) | TID Grays | NIEL 1 MeV Equiv n/cm$^2$ | SEE > 30 MeV Equiv Had/cm$^2$ |
|---|---|---|---|---|---|---|
| Tracker | 8681 | 712.5 | 797.0 | 1.08E+04 | 1.25E+13 | 6.84E+10 |
| Calorimeter | 11855.0 | 679.6 | 764.7 | 1.8E+03 | 2.79E+12 | 2.21E+10 |

We should see how to maximize these tests @ HZDR

# Status of “large” bids (1)

- The 2 largest bids are the ones for Crystals and photosensors
- Same technique of “competitive bid” used for both bids:
  - → **Use pre-production to rank the vendors**
  - → **Final selection with 40% cost, 60% technical**

For crystals, the bid has been based @ FNAL:

- 6 vendors participated St.Gobain, Siccas, Amcrys, OptoMaterial, Hilger, Khineng.
- **3 vendors selected for preproduction**

  **St. Gobain, Siccas, Amcrys**
- We have required them to provide 24 pieces/each for module-0.
- We will receive additional 50 crystals from Amcrys as JINR (Dubna) contribution bringing to 122 crystals the amount we will use for pre-production tests and module-0.

→ **Expect delivery end of October.**

→ **3 months delay w.r.t. our expected schedule.**

# Status of “large” bids (2)

**For photosensors, the bid has been done @ INFN:**

- 3 vendors participated
- 3 vendors selected for preproduction of the Custom SIPM
  **Hamamatsu, SensL, FBK. Each of them will produce 50 pieces.**
- Expected delivery middle of October
  → We will take < 4 months for the evaluation.
  → Shorter time for QA (< 2 months)
  → Longer time for Irradiation and MTTF

- We will reward them with a fixed prize of 22 kEuro/each
  (with VAT,Shipping excluded).
- **Also for the sensors we accumulated 2 months delay w.r.t. schedule.**
  A lot of tests done in the last months with “home-made” custom SIPM
  so that **preparation of QA Station in Pisa is proceeding well**

# Calorimeter: next steps

→ **Statement of Work between DOE and INFN in preparation.**
This document will list the work we will commit to do

→ **Engineering should continue in view of 3 reviews at end of 2016 and in 2017:**
→ Mechanical review
→ Construction Readiness Reviews (Crystal and sensors + all the rest)

→ Pre-production + QA + Rad Hard test for crystals … in progress

→ Pre-production + QA + Rad Hard test + MTTF for SiPMs .. In progress

→ Pre-production FEE+WFD … in progress

→ Mockup of Mechanics for FULL SIZE support, CF structure and rear cooling disk .. In progress

→ **Module-0 construction + tests of Rad-Hard and under vacuum (2017)**

→ **Construction Readiness Reviews : SPRING/SUMMER 2017**

→ **Larger bids in 2017 for 2017-2018 procurement crystals, SiPMs, mechanics**

→ **2018 construction of FEE+ electronics + installation toolings**

→ **2019 calorimeter assembly + 2020 installation/commissioning**

# Calorimeter: MUSE network contribution

**Two relevant MUSE network contributions during this first 9 months:**

- **1) Irradiation of Large Area UV extended Hamamatsu SiPM @ HZDR**

  → preparation of facility
  → successful test of 1 Hamamatsu SiPM
  → planning under discussion for next steps

- **2) Improvement of QA for crystals interacting with PRISMA people seconded at LNF**

  → More “Industrial” standard proposed for QA.
  **Dedicated document in writing**
  → Mysql DB + WEB interface for a first version of CRYSTAL TRAVELER → new DB version under discussion with FNAL DB group.

# Calorimeter: MUSE deliverable

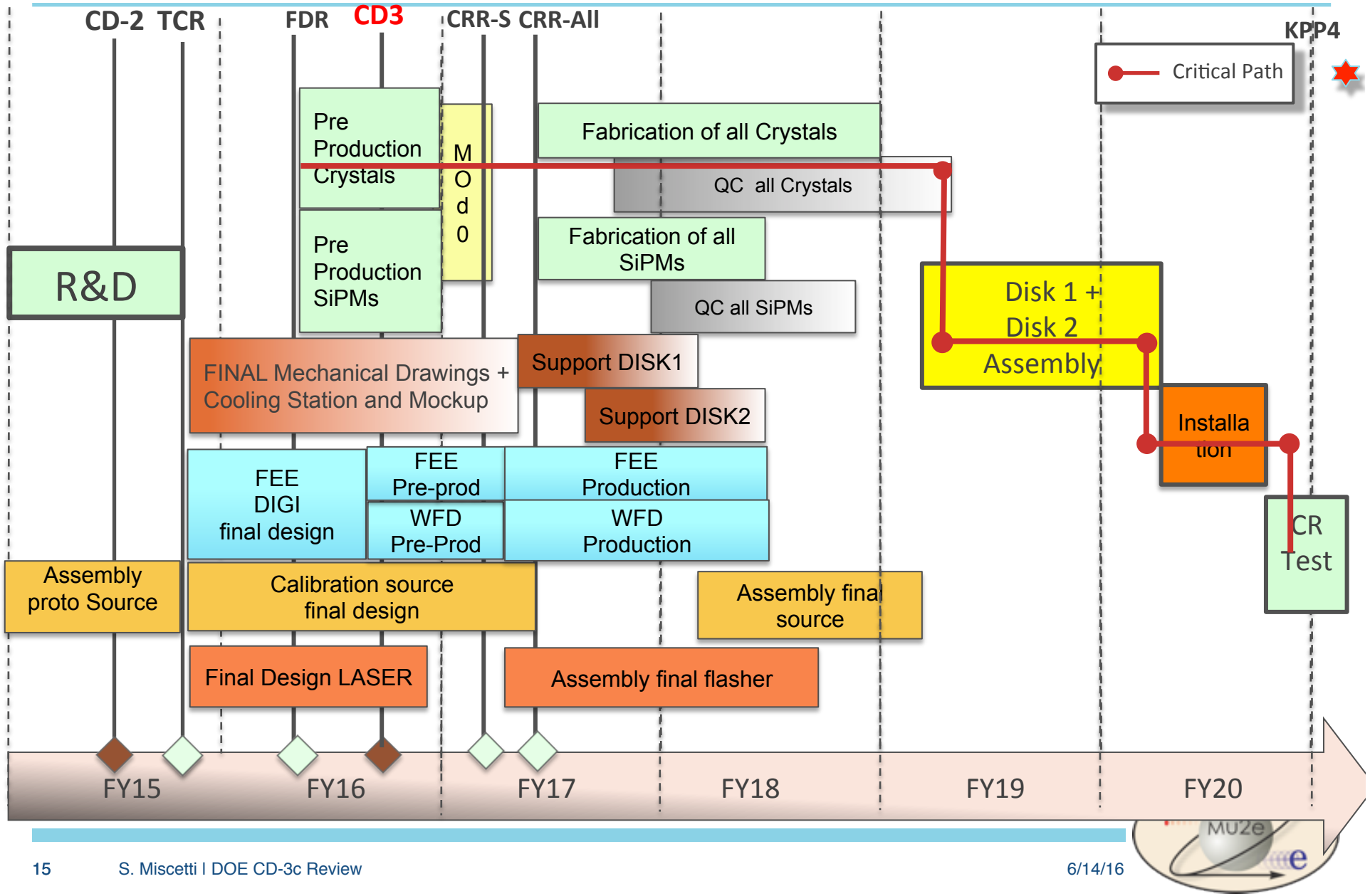
**The first deliverable we have as working group on the Mu2e detector is due to the end of the year:**

**Calorimeter Technical Design report**

- Since we have a lot of change/improvements and a lot of engineering done since the 2015 Mu2e TDR
  → we will write a dedicated "Calorimeter TDR" with emphasis on engineering
- I will discuss this with the TM and the spokes
- We will organize the writing in chapters provided by the L3 groups
- We will submit the final TEDR on ArXiv and as FNAL publication

ADDITIONAL MATERIAL

# Calorimeter schedule



# Outcome of CD-3c, recommendations


U.S. DEPARTMENT OF ENERGY

**2.3 Detector Systems**
**Full Committee**

OFFICE OF SCIENCE

- **Recommendations**
  - Conduct a full system test for each subsystem prior to the respective procurement readiness review.
  - Complete a comprehensive system test of the first plane to provide input for the straw assembly CRR, currently scheduled in August, 2017 (WBS 475.6, Tracker).
  - Develop plans to monitor and control gas temperature and pressure in the tracker (WBS 475.6, Tracker).
  - Ensure that the documents for detailed assembly and installation procedures are complete by the final mechanical design review. (WBS 475.7, Calorimeter).
  - Proceed to CD-3.