CD-3c Review: Calorimeter Breakout
Calorimeter Overview

Stefano Miscetti
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Calorimeter L2 Manager
4/19/16

Mu2e Calorimeter Organization

475.7
Calorimeter
L2: S. Miscetti (LNF)
Deputy: D. Hitlin (Caltech)

475.7.1 Project Management
L3 – S. Miscetti – (LNF)
CAM – D. Hitlin

475.7.2 Crystals
L3 – D. Hitlin (Caltech)
S.Giovannella (LNF)
CAM - D. Hitlin

475.7.3 Mechanics
L3 – F. Happacher (LNF),
F.Raffaelli (Pisa)
CAM – D.Hitlin

475.7.4 Photosensors
L3 –D.Hitlin (Caltech), I. Sarra (LNF)
CAM – D. Hitlin

475.7.5 FEE and Digitizer
L3 – F. Spinella (Pisa)
CAM – D. Hitlin

475.7.6 Calibration
L3 – F. Porter (Caltech),
M.Cordelli (LNF)
CAM – D. Hitlin

475.7.7 Power
L3 – G. Corradi (LNF)
CAM – D.Hitlin

475.7.8 Assembly and Installation
L3 – A.Saputi (LNF)
CAM – D. Hitlin

- **Project Control**: D.Leeb (FNAL) **, QA:** S.Miscetti (LNF)
- **Simulation**: B.Echenard(Caltech), G.Pezzullo(Pisa)**, Calibration:** P.Murat(FNAL)
- **Trigger:** B.Echenard(Caltech), S.DiFalco(Pisa)
- **Integration:** Electronics: I.Sarra(LNF), F.Spinella(Pisa). Mech: F.Happacher(LNF)

Responsibilities

- **INFN**
  - **LNF-INFN:** QA test for crystals and FEE electronics
  - → FEE development and production, Laser calibration system
  - → Calibration, Mechanical support, Assembly
  - **INFN-Pisa**: QA test for Sipm and WFD electronics,
  - → WFD development and production, Trigger and DAQ
  - → Cooling, Assembly
  - **INFN-Lecce**: QA for crystals, Mechanics FEA and assembly
- **Caltech:** QA test for crystals and SIPM, Prototype source,
  - → Radiation hardness for crystals
  - → Source calibration system, Trigger and DAQ
- **JINR:** QA test for crystals and photosensors
- **HZDR:** Radiation hardness for crystals and photosensors

Caltech funded through annual SOWs

Communication

- Weekly Calorimeter meetings
- Weekly Technical Board Meetings
  - S.Miscetti and D.Hitlin
- Bi-Monthly Risk Management Board Meetings
  - S.Miscetti and D.Hitlin
- Monthly Change Control Board Meetings
  - S.Miscetti and D.Hitlin
- Bi-Weekly Mechanical Integration Meetings
  - F.Happacher
- Bi Weekly Electrical Integration Meetings
  - I.Sarra, F.Spinella
- Collaboration Meetings

Physics and Calorimeter Requirements

The Calorimeter requirements are **described in docdb-864**

The 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 the radiation environment of Mu2e
- 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 σ_E/E of O(5 %)

→ Provide timing resolution σ(t) < 500 ps

→ Provide position resolution < 1 cm

→ Provide almost full acceptance **for CE signal @ 100 MeV**

→ Redundancy in FEE and photo-sensors

Solution: A crystal based disk calorimeter

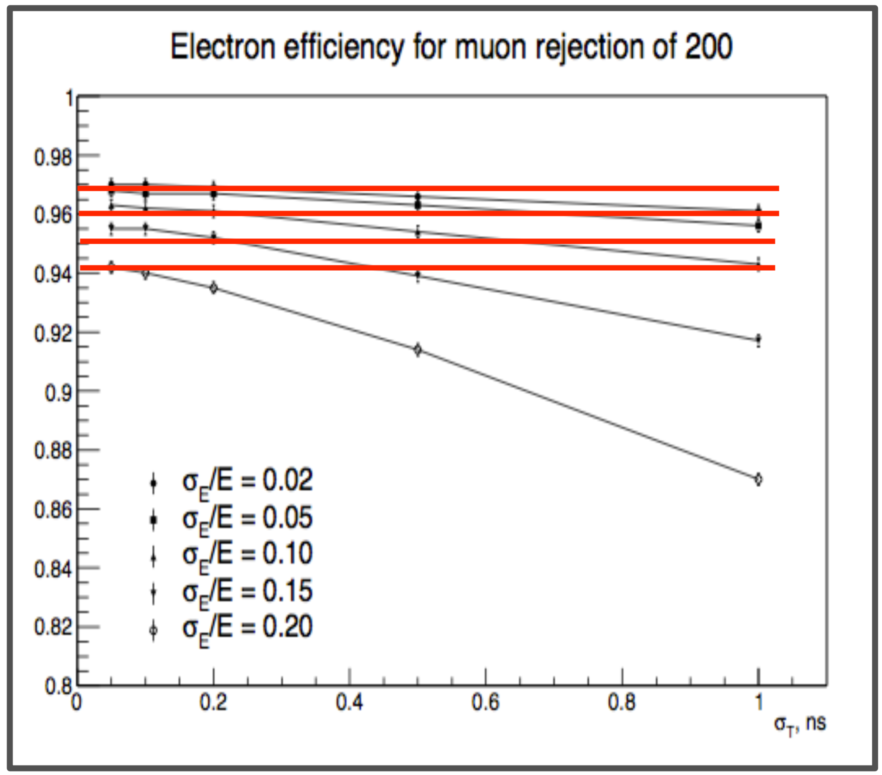
Calorimeter Requirements

TOY MC used to estimate what is the range of calorimeter resolutions that are matching our physics requirements → driven by PID requirement of muon rejection of 200 with high CE efficiency.

→ **Simple gaussian convolution used both for timing and energy**.

ε(pid)	σ/E	σ_T (ps)
97%	2%	250
97%	5%	50
96%	5%	600
96 %	10 %	250
95%	15%	200
95%	10%	800
94%	15%	500
94%	20%	80

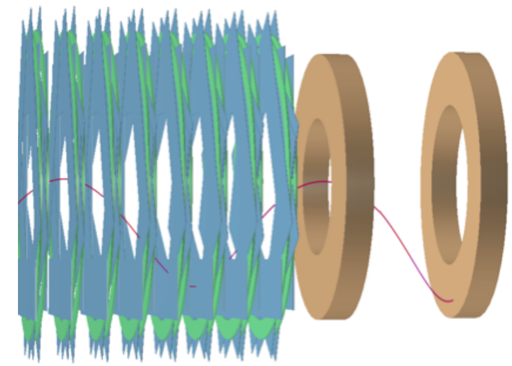
Negligible effect of Pileup Docdb-4256



Fermilab

Derived requirements

High granularity crystal based calorimeter with:



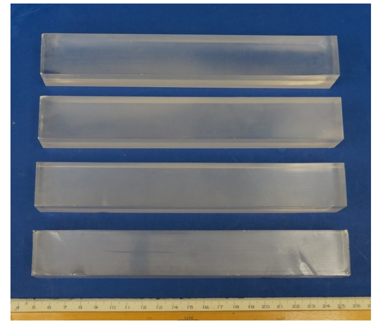
- ❑ 2 Disks (Anuli) geometry to optimize acceptance for spiraling electrons
- ❑ Crystals with high Light Yield for timing/energy resolution → **LY(photosensors) > 20 pe/MeV**
- ❑ **2 photo-sensors/preamps/crystal** for redundancy and reduce MTTF requirement → now set to 1 million hours/SIPM
- ❑ Fast signal for Pileup and Timing resolution **→ τ of emission < 40 ns + Fast preamps**
- ❑ **Fast WFD to disentangle signals in pileup**
- ❑ **Crystal dimension optimized** to stay inside DS envelope → reduce number of photo-sensor, FEE, WFD (cost and bandwidth) while keeping pileup under control and position resolution < 1 cm.
- ❑ Crystals and sensors should work in 1 T B-field and in vacuum of 10^{-4} Torr and:
  → **Crystals survive a dose of 100 krad and a neutron fluency of 10^{12} n/cm^2**
  → **Photo-sensors survive 20 krad a neutron fluency of 3×10^{11} n_1MeV/cm^2**

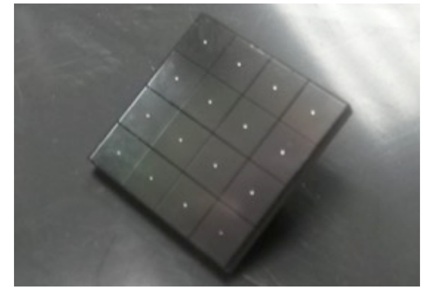
Safety Factor = 3

Fermilab

Introduction and Scope

The Calorimeter consists of two disks with 674 CsI square crystals:



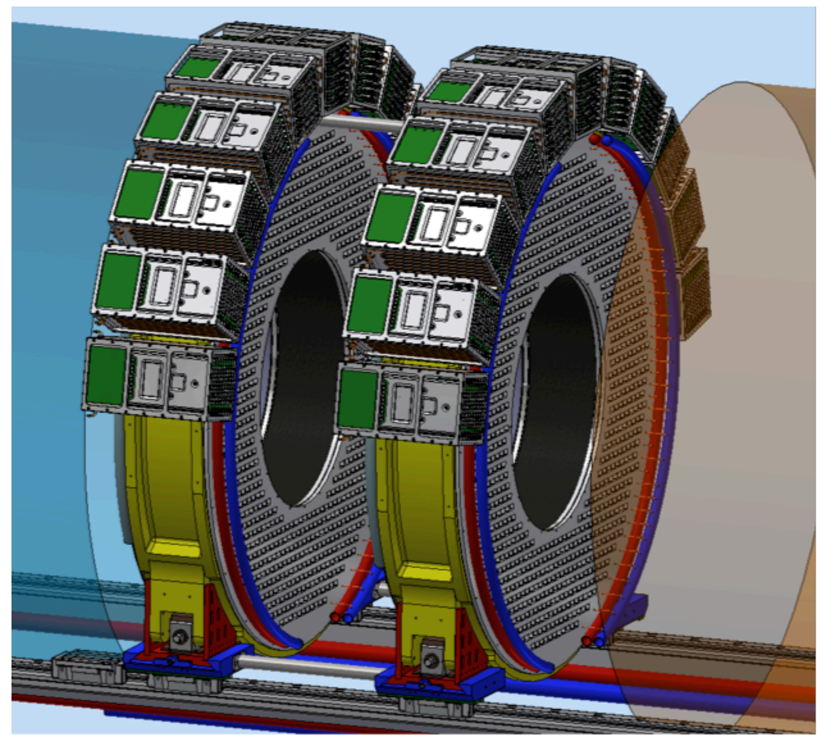


→ R_{inner} = 374 mm, R_{outer}=660 mm, depth = 10 X_0 (200 mm)

→ 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



Independent Design Review

- An independent, external design review of the Calorimeter was held on Feb 16-17, 2016.
- The review Committee consisted of experts in crystals, SiPMs, electronics, mechanical engineering and general calorimetry
  - **Bill Wisniewski – SLAC (Chair)**
  - **Cesar Bini – INFN Roma**
  - **Sergey Los – FNAL**
  - **Giovanni Signorelli – INFN Pisa**
  - **Colin Jessop – Notre Dame**
- Final report is available on the Review web page
  (DocDb 6833)

Design Review Charge Questions

- Does the technical design of the Mu2e calorimeter satisfy the requirements? **Yes**
- Is the technical design of the calorimeter technically sound? Have all the principle issues, including light output, timing, calibration, mechanical integrity, cooling and component reliability been appropriately demonstrated, simulated, and/or calculated? Are all of these issues properly addressed in the design? **Yes**
- **Is the calorimeter procurement, QA, and fabrication plan mature and well documented? Not Yet**
- Have all of the technical risks associated with the calorimeter been accounted for? Have these risks been properly evaluated and mitigated? **Yes**
- Is the technical design of the Calorimeter sufficiently mature to be ready for a DOE CD-3c review by the summer of 2016?

The technical design can be ready in time for summer 2016

Design Review Comments & Recommendations

Calorimeter Design Review

Date: Feb 15-17, 2016

Reviewers: Bill Wisniewski, Cesare Bini, Colin Jessop, Sergey Los, Giovanni Signorelli

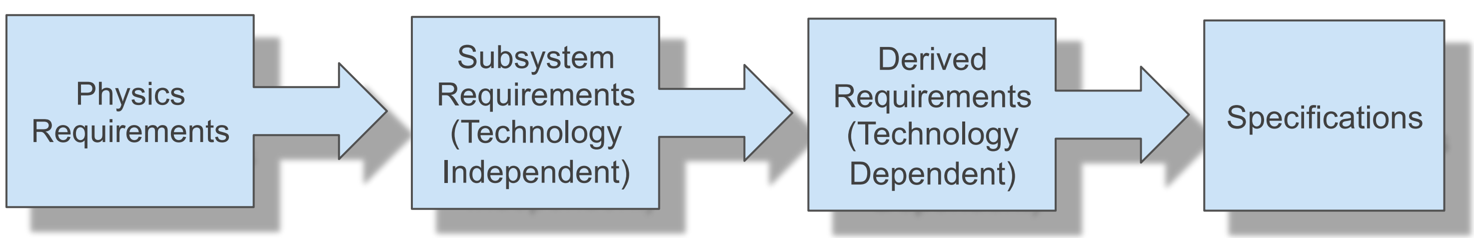
Recommendations

1. Sharpen up presentation of the flow-down of requirements from the experiment's physics goals to the calorimeter parameters.

> Preparation of talk for CD-3 underway. **CLOSED**

Broken down in the following way in the master talk.

Same techniques adopted for each L3's starting from Derived requirements



Design Review Comments & Recommendations

Calorimeter Design Review

Date: Feb 15-17, 2016

Reviewers: Bill Wisniewski, Ceasar Bini, Colin Jessop, Sergey Los, Giovanni Signorelli

Recommendations

2. Update the simulation to include details of CsI and SiPMs. Include in this update all mechanical items that interact with electrons entering the calorimeter.

> This is being done for the digitization part that is taking into consideration the real signal shape observed at the test beam and can be quickly adapted to the final FEE shaping. We are still holding the insertion of the mechanical items in simulation waiting for final dimensions of all parts. **IN PROGRESS**

Design Review Comments & Recommendations

Calorimeter Design Review

Date: Feb 15-17, 2016

Reviewers: Bill Wisniewski, Ceasar Bini, Colin Jessop, Sergey Los, Giovanni Signorelli

Recommendations

3. Complete understanding of the effects of the CsI long lifetime component on the calorimeter performance and translate this understanding into the specification for the crystals. Update the simulation to include details of CsI and SiPMs. Include in this update all mechanical items that interact with electrons entering the calorimeter.

We have already addressed the question via a Toy MC and understood that a F/T down to 80% is acceptable. We are now refining and controlling this in two ways: 1) adding a parametrized slow compoment to the digitized shape in the full simulation to check pileup separation and 2) calculate the effect of noise induced by the Beam-flash. **CLOSED**

Design Review Comments & Recommendations

Calorimeter Design Review

Date: Feb 15-17, 2016

Reviewers: Bill Wisniewski, Ceasar Bini, Colin Jessop, Sergey Los, Giovanni Signorelli

Recommendations

4-5 (6-7) . Prepare the detailed crystal (sensor) specification before the CD-3 review. And prepare the detailed QA plan for acceptance for crystals (sensors).

- The specifications have been completed. Their draft is 7051 (7052) for crystals (photosensors). For crystals we are proceeding in these days with The preparation of the bid for pre-production → **CLOSED**

- For the QA, detailed QA plans have been already prepared (DocDb 7053) for crystals and photosensors. Details will be provided during the breakdown talks from the L3s → **CLOSED**

Design Review Comments & Recommendations

Calorimeter Design Review

Date: Feb 15-17, 2016

Reviewers: Bill Wisniewski, Ceasar Bini, Colin Jessop, Sergey Los, Giovanni Signorelli

Recommendations

8 . Hold a design review of the mechanical systems at Fermilab. The review team should include Fermilab engineers. This review should be held before placement of the crystal production order. There are two goals for this review: 1. Fresh eyes may see ways to improve the design; 2. Consistency with Fermilab requirements can be verified.

This is being organized. Proposal is to have it in October around the CM date in order to have: 1) Cooling station design completed. 2) integration of source done, 3) installation plan prepared. Proposed date is 2 days in October 2016 close to the CM meeting. Agenda is being discussed → **CLOSED**

Design Review Comments & Recommendations

Calorimeter Design Review

Date: Feb 15-17, 2016

Reviewers: Bill Wisniewski, Ceasar Bini, Colin Jessop, Sergey Los, Giovanni Signorelli

Recommendations

9 . Consider performing irradiation of the calorimeter components at a reactor to test the effects of thermal neutrons on the calorimeter.

In order to understand the effect of thermal neutrons, we are following two roads: (a) Estimate by simulation the expected rate, (b) Measure the radiation induced current crystals with 10^3 thermal n/cm^2/sec at ENEA thermal neutron generator HOTNES (Tn few meV) → **IN PROGRESS**

Design Review Comments & Recommendations

Calorimeter Design Review

Date: Feb 15-17, 2016

Reviewers: Bill Wisniewski, Ceasar Bini, Colin Jessop, Sergey Los, Giovanni Signorelli

Recommendations

10. Particular attention should be paid to matching the signal dynamic range from the crystals all the way down to the digitizers, so there is no saturation or loss of resolution due to partial use of the digitizer input dynamic range

This is being carefully calculated. We will measure the signals for a MIP with the final SIPM packaging and determine the maximum amplitude at 100 MeV adding a factor of 40% safety. **CLOSED**

Design Review Comments & Recommendations

Calorimeter Design Review

Date: Feb 15-17, 2016

Reviewers: Bill Wisniewski, Ceasar Bini, Colin Jessop, Sergey Los, Giovanni Signorelli

Recommendations

11. Electronics power distribution and grounding solutions should be coordinated with the FNAL electrical safety rules.

This is already done. DocDb under preparation. **CLOSED**

12. The Module 0 test should evolve into a full system test, and include as many final components as is possible.

This is our plan. The idea is to test all final crystals and photosensor with a pre-release of FEE and WFD. Test beam is being planned. Radiation hardness test are being discussed. **CLOSED**

Design Review Comments & Recommendations

Calorimeter Design Review

Date: Feb 15-17, 2016

Reviewers: Bill Wisniewski, Ceasar Bini, Colin Jessop, Sergey Los, Giovanni Signorelli

Recommendations

13. Explore the potential of the use of pi+ decays for the calorimeter calibration.

We estimated the time required for pi^+ --> e nu calibration in the calorimeter as follows:
1. For a calibration of the global scale, where the E/P distribution summed over all crystals is used, the time required is minor (see discussion below). Note that for this purpose we rely on the crystal inter-calibration determined from other means.
2. For a crystal-by-crystal calibration, sufficient statistics of positrons hitting each crystal is required. It takes of order 100 events to calibrate a crystal to 1% at this energy.

→ Assuming 100 events/crystal and uniform disk illumination, **we talk about 200k events** (requiring 100 events/crystal in the second disk, which corresponds to ~200 events/crystal in the first disk) The current estimate for the number of events in the pi+ --> e+ nu peak was 20k events/day (docDB 5998). **Thus, to accumulate sufficient statistics for the crystal-to-crystal calibration with pi+'s, translates into 10 days of data taking.**

The global calibration could easily be done in 1 day . Doing the crystal-by-crystal calibration at the level of 1% is more significant, another reason why this calibration method will not be frequent (ie, months, not weeks) → **CLOSED**

Design Maturity

docdb 6972.

Calorimeter Subsystem	Design Completion	Remaining Work/Risks
Crystals	90%	Specification of CsI slow component - Low risk.
Photosensors	85%	SiPM packaging. Have one packaged SiPM from Hamamatsu but want to qualify other vendors - Low risk.
Mechanical Infrastructure	65%	Finalize cooling design. Optimizing tradeoffs between noise, radiation damage and operating temperature. x2 headroom - Low Risk
Front End Electronics And Digitizer (WFD)	60%	• New pre-amp design for CsI/SiPM - Low Risk. • 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. – Low Risk
Overall Design	**80%**	

Design Maturity and Path to Completion

- **The risks associated with the remaining design work is small**
  - More detail in talks from L3 Managers (we have 3 new risks 1 cooling (Mechanics), 2 WFD (20 channels/board, Rings organization). They will be described in their reports.

- **The primary work remaining to complete the design includes:**

→ Finalize cooling design

→ Produce 20 ch board prototype for WFD

→ Test final SIPM package + FEE with cooling prototype

Construction Readiness Review (s)

- **The Calorimeter plans on two Construction Readiness Reviews (CRRs) :**
  (1) for crystals and sensors, CCR_CS and (2) for the whole system, CCR_all

- We have implemented a better logic for the schedule that is being updated in BCR-30:
  (a) we have corrected the baseline for CsI+SIPM and add contributions for the cooling station

  (b) inserted these two new reviews:
  → CRR_CS
  After QA evaluation of pre-production crystals and SIPMs in order to speed up procurement for the whole production
  → CRR_all
  After having fully evaluated a preproduction prototype (module-0) in a test beam @ Frascati and completed Mechanical Design Review and mockup:
  - **Final CsI crystals + QA**
  - **Final SiPMs + QA**
  - **Final FEE including Mezzanine Board and WFD**
  - **DAQ Pilot System readout**

Procurement Plans

Crystals → Procurement plan in DocDb 7051

5+ possible vendors: Siccas (China), St.Gobain (France), Hilger (UK), Filar Optomaterials (Italy), ISMA (Ukraine).

- QA tests in FNAL/Caltech. Test with a Na^{22} source + irradiation tests.
- Bid for pre-production and firm quality ranking is starting ("competitive bid") @ FNAL

SiPMs → Procurement plan in DocDb# 7052

3+ possible vendors: Hamamatsu (Japan), FBK/Advansid (Italy),Sensl (Ireland).

- QA tests in Caltech/Pisa. Test with a UV Led + irradiation tests. MTTF test.
- Bid for pre-production similar to crystals one being prepared by INFN

Mechanical Infrastructure

- INFN in kind contribution. Mech. Structure Fantini S.R.L., Inner Ring
- FEE+WFD also an INFN in kind contribution.

  Procurement, QA and burn-in plans explained in L3 report.

Calibration source

- Procurement and QA plans explained in L3 report

Quality

- Calorimeter Quality plans included in Mu2e Quality Planning Document. Will be discussed in L3 talks.

	D	E	F	G	H	I
1	Deliverable	QA or QC Step?	QA or QC Process Documentation (DocDB #)	Inspection or Acceptance Criteria/Plan	Verification	Records (DocDB# or Database Reference)
3	Crystals	QA: Dimensional control of the procured Crystals	in progress	A CMM (Coordinate Measurement Machine) at FNAL will be used to determine the dimension of the crystals in 20 points along the axis for each face. This will corresponds to a determination of 100 points in 10' for crystal. This includes also the time to position and remove the crystal from the CMM machine. Criteria will be to accept only crystals with < 50 mum on the tollerances.	The CMM machine is operated by Fermilab that it will ensure it works following specifications. The measurement is carried out by specialized personnel that ensure the measurement is accurate.	Results of this measurement will be documented in a "Traveler" and in a Crystal DB both in excel file and in another format.
5	Crystals	QA: Resolution	DocDb 7053	The same data used for <LY> and LRU will be also used to characterize the energy resolution at 511 keV	As above	The energy resolution data are recorded for each crystal in 8 points along the crystal axis. . The crystal unde test is identified by its own production number. The data are directly entered into an Excel file, in a traveler and in a DB.

Assembly and Installation

- The calorimeter assembly will proceed in rows of crystals piled up in the mechanical support after QA will be completed on a sufficient number of crystals and photosensors.

- During stacking, a survey of the geometry of the growing stack will be performed.

- The cabling will proceed while stacking, since Mezzanine boards and WFD are organized by increasing radius this will not interfere too much with the assembly.

- Simple channel functionality, noise and gain estimates with cabling of temporary services will be possible.

- Two fully cabled disks will be then brought, with a special
  tool by a dedicated transportation and then inserted over the rails.

Commissioning Plan

We will commission the calorimeter in 3 steps:

- After assembling a disk, we will carry out a standalone data taking with CR trigger in the assembly area, with temporary services, as well as a laser run to control all channels are alive and well performing. Noise will also be measured. No SIPM cooling for this test (i.e. 25 and not 0 °C).

- Operation will be repeated (with temporary services and similar procedure) once the detector is in MU2E building pit. A joined CR run with tracking and CRV will be performed to check DAQ and reconstruction issues. A temporary fixture will also allow to connect the source and make dedicated runs in the assembly area (with enclosed space requirement enforced).

- Once inside DS + with vacuum established + final services + B ON, we will test:
  - → The cooling system, bringing all SIPMs to 0 °C. With a Laser run, we will check if our SiPMs pre-calibration follows the correct T-dependence on Vop.
  - → The calorimeter equalization by means of the Fluorinert Source
  - → A cosmic ray run with B ON

Cost and Schedule Performance

Mu2e Project
February 29, 2016
Currency in: $K

Control Account	Current Period							Cumulative to Date								
	Budget	Earned	Actuals	SV ($)	SV (%)	CV ($)	CV (%)	Budget	Earned	Actuals	SV ($)	SV (%)	CV ($)	CV (%)	SPI	CPI
475.07.01 Calorimeter Project Management	2	5	5	3	109%	(0)	-7%	162	162	156	0	0%	6	4%	1.00	1.04
475.07.02 Crystals	(1)	17	8	18	-2865%	9	54%	93	87	162	(6)	-7%	(74)	-85%	0.93	0.54
475.07.03.02 Radiation & Temperature Monitoring	0	0	0	0	0%	0	0%	0	0	0	0	0%	0	0%	-	-
475.07.04 Photodetectors	0	9	0	9	-	9	100%	196	172	210	(24)	-12%	(38)	-22%	0.88	0.82
475.07.05 Electronics	0	0	0	0	0%	0	0%	109	109	112	0	0%	(3)	-2%	1.00	0.98
475.07.06 Calibration System	7	0	0	(7)	-100%	0	0%	124	133	228	9	7%	(95)	-71%	1.07	0.58
475.07.07 Calorimeter Power	0	0	0	0	0%	0	0%	0	0	0	0	0%	0	0%	-	-
475.07.08 Calorimeter Installation	0	0	0	0	0%	0	0%	0	0	0	0	0%	0	0%	-	-
Total	**9**	**32**	**13**	**23**	**(29)**	**18**	**1**	**685**	**664**	**868**	**(21)**	**(0)**	**(204)**	**(2)**	**0.97**	**0.76**

Control Account	At Complete				
	BAC	EAC	VAC	% Spent	% Complete
475.07.01 Calorimeter Project Management	271	265	6	59%	60%
475.07.02 Crystals	2,571	2,633	(63)	6%	3%
475.07.03.02 Radiation & Temperature Monitoring	162	162	0	0%	0%
475.07.04 Photodetectors	777	815	(38)	26%	22%
475.07.05 Electronics	109	112	(3)	100%	100%
475.07.06 Calibration System	567	695	(128)	33%	23%
475.07.07 Calorimeter Power	3	3	0	0%	0%
475.07.08 Calorimeter Installation	306	304	1	0%	0%
Total	**4,766**	**4,991**	**(224)**	**17%**	**14%**

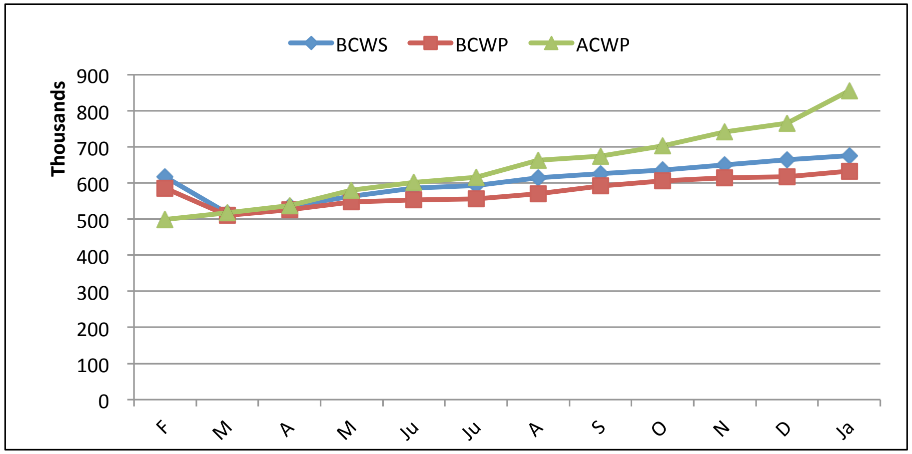
SPI= Schedule Performance

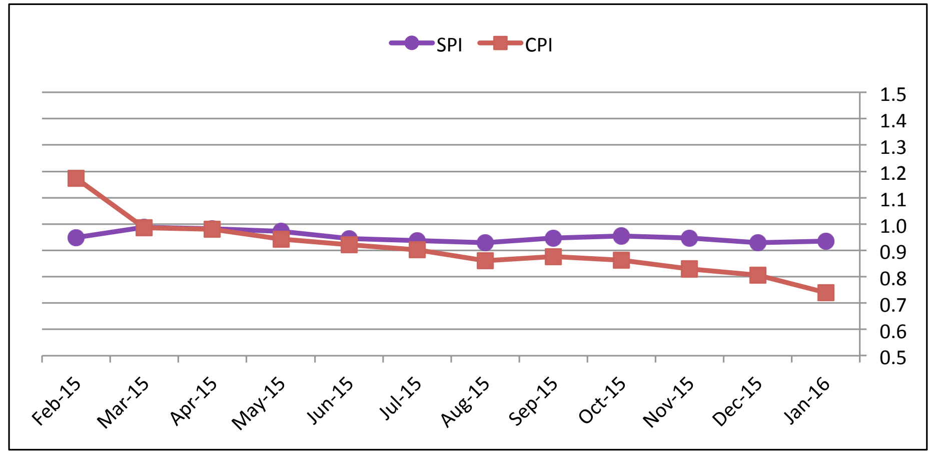
CPI = Cost Performance Index

BAC = Budget at Completion = 4,766 M$
EAC = Estimate at Completion = 4,991 M$
ETC = Estimate to Complete
ETC refresh supported by BOEs completed in March

Cost and Schedule Performance

475.07 Calorimeter





Evaluated up to the end of February:

→ Low performance of CPI index is due to:

1) Crystals , where actuals where increased due to the long R&D phase to down-select btw BaF2 and CsI (+70 k$)
2) Source, where we needed to refurbish items for the calibration source such as pressure vessel, flanges and the main pump.

More details in the L3 breakdown talks.

Calorimeter Cost (DOE only)

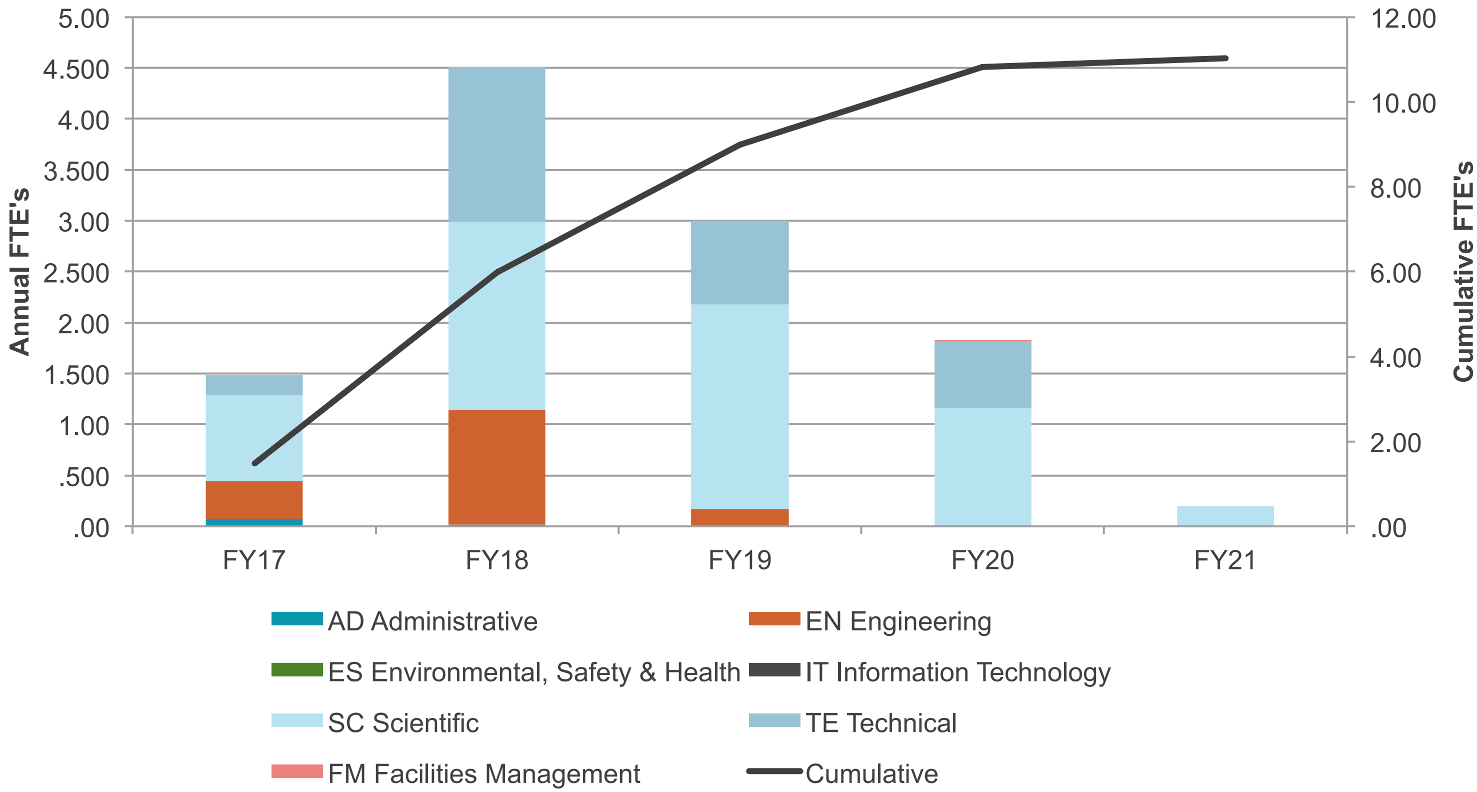
(AY K$)	Budget at Completion			Forecast (Estimate at Completion)		
	M&S *	Labor	Total	Estimate Uncertainty (on remaining work)	% Contingency (on remaining work)	Estimate at Completion
475.07 Calorimeter						
475.07.01 Calorimeter Project Management	261	10	271	22	20%	265
475.07.02 Crystals	2.520	50	2.571	388	16%	2.633
475.07.03 Mechanical Support	162		162	32	20%	162
475.07.04 Photosensors	777		777	256	42%	815
475.07.05 Digitizer and FE Electronics	109		109			112
475.07.06 Calibration Systems	504	64	567	137	29%	695
475.07.07 Calorimeter Power		3	3	1	30%	3
475.07.08 Calorimeter Installation	48	258	306	106	35%	304
Grand Total	4.381	385	4.766	942	23%	4.991

- M&S includes University Labour
- Bottoms up ETC completed in March is about $70k more than base cost at CD-2
- Contingency is $ 300k less than baseline value
- BOEs posted on web page
- **DOE-INFN cost/manpower sharing being prepared by means of a MOA (INFN-MU2E)**

Crystals (DOE 2/3, INFN 1/3), SIPM (DOE-INFN 50:50), Source (DOE), Laser(INFN)
FEE/WFD – INFN in-kind. Mechanics: INFN-in-kind but 50-50 for cooling station and T/Radfets
INFN contribution for M&S around 3-3.3 M$.

Fermilab

DOE Labor Resources

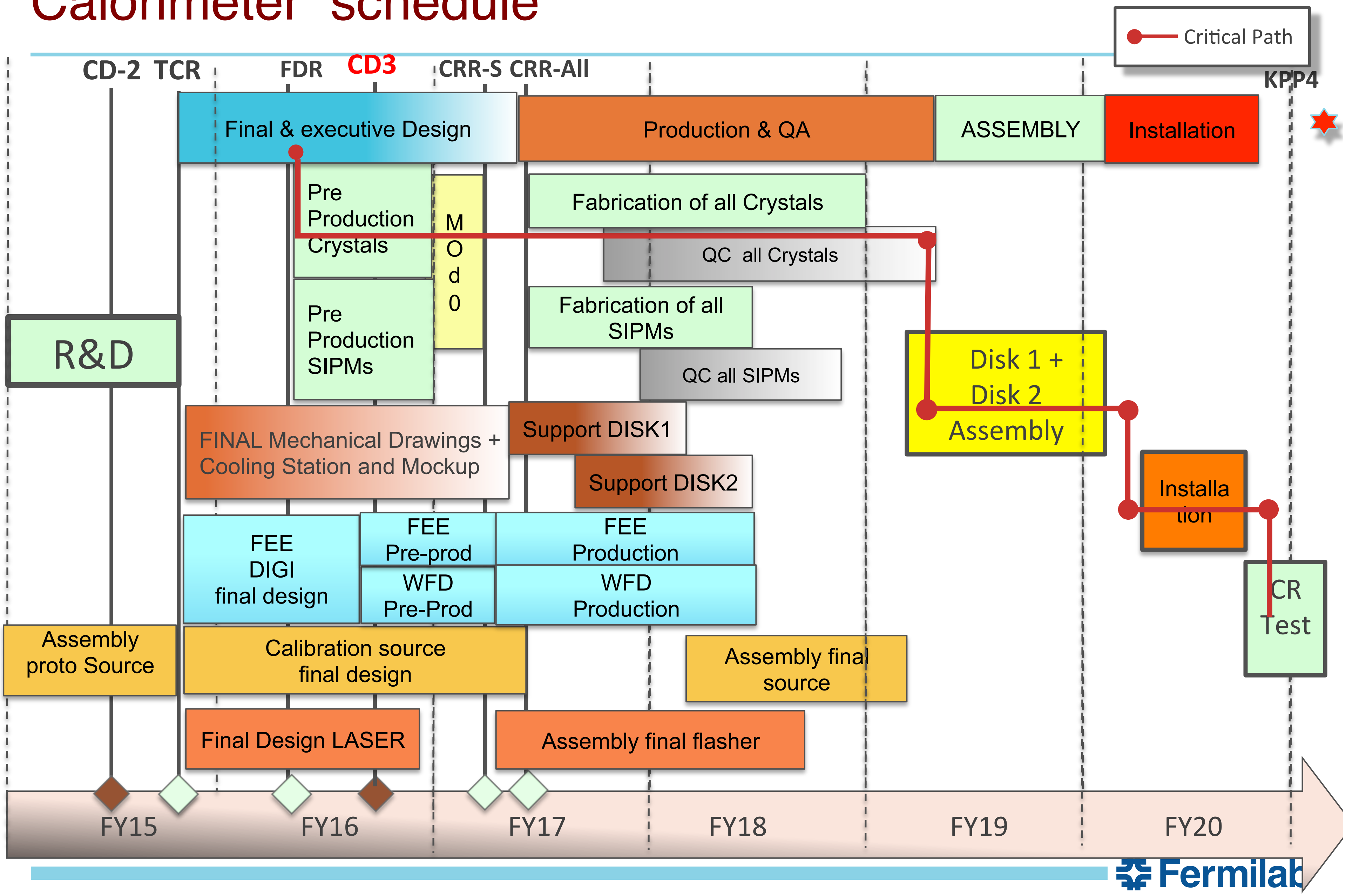


- Agreements in place with Fermilab for FY16.
- Confident that resources in the out years will be available.
- INFN manpower of > 10 FTE will be available for the next 4 years.

Major Calorimeter Milestones

1. 47507.2.001986	**PO issued for production crystals**	**March 2017**
2. 47507.4.000700	**PO issued for production photo-sensors**	**April 2017**
3. 47507.6.001510	**PO issued for source system material**	**Nov 2017**
4. 47507.4.000790	**QC of all photo-sensors complete**	**August 2018**
5. 47507.5.001522	**INFN delivers FEE electronics**	**May 2018**
6. 47507.2.092161	**Survey of production crystals complete**	**March 2019**
7. 47507.2 8.002181	**Disk 1 completed**	**May 2019**
8. 47507.2 8.002279	**Disk 2 completed**	**Oct 2019**
9 . 47507.8.002410	**Ready for cosmic ray system test**	**August 2020**

Calorimeter schedule



Summary

- The Calorimeter design is 80% complete. The risks associated with the remaining design are understood and small. Clear path to a final design.
  - Recommendations from Independent design review addressed
  - Interfaces, risks, ES&H issues identified and under control
  - QA/QC plans in place
  - Procurement plans in place
- The Calorimeter cost and schedule remain consistent with the baseline schedule approved in March 2015.
- Construction Readiness Review scheduled for April 2017
- The Calorimeter is ready for CD-3 approval