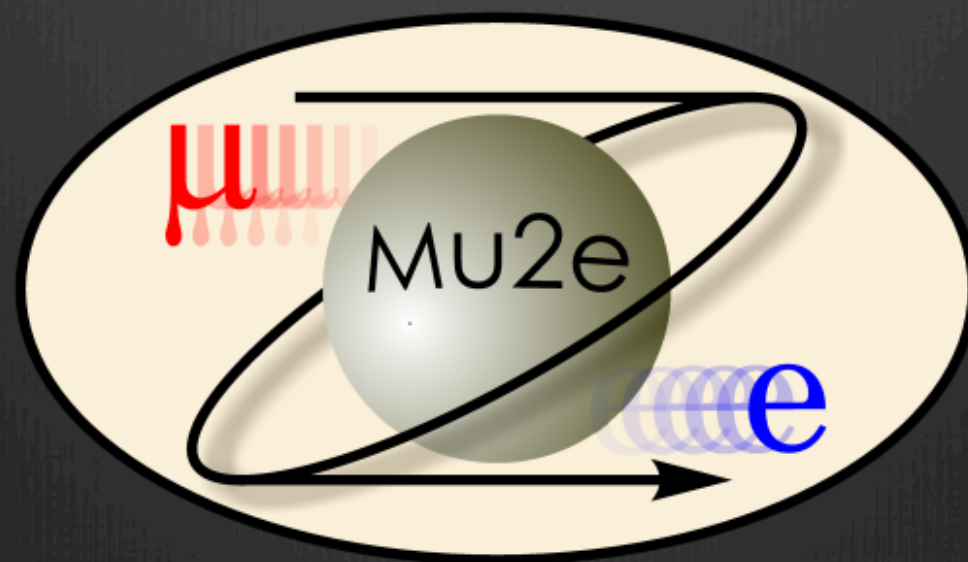




Mu2e @ Fermilab

F. Grancagnolo



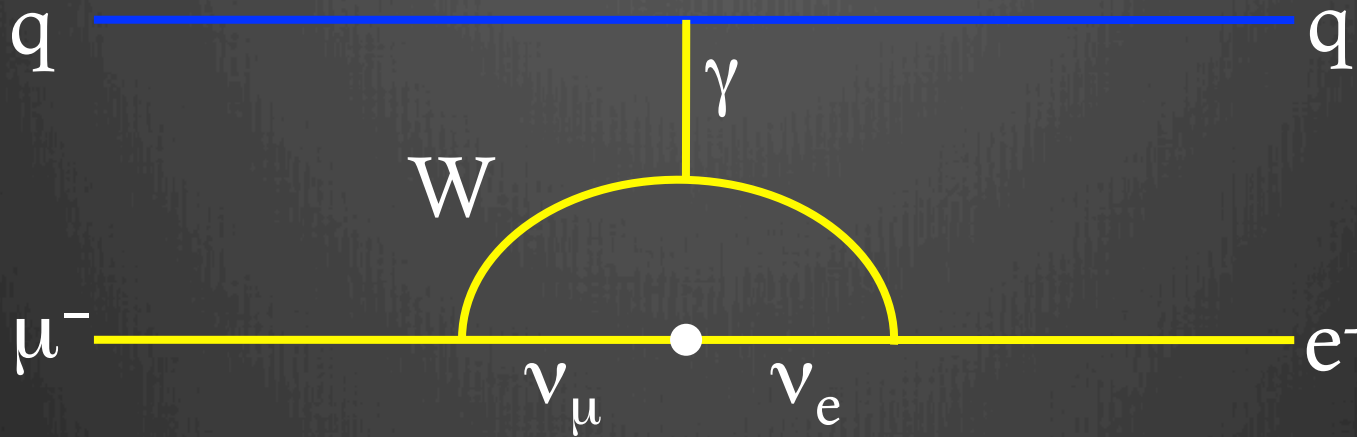
What is Mu2e?

- ⊗ A search for Charged-Lepton Flavor Violation via

$$\mu^- N \rightarrow e^- N$$

- ⊗ It will use the new *Fermilab Muon Campus* and modest modifications to the current accelerator complex to reach a sensitivity 10 000 better than world's best
- ⊗ It will have *discovery* sensitivity over a wide range of New Physics parameter space

CLFV in the Standard Model



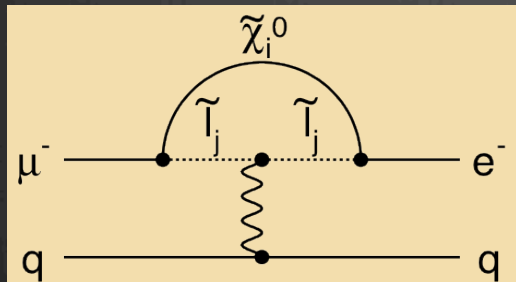
- ⊗ Strictly speaking, forbidden in the SM
- ⊗ Even in ν -SM, extremely suppressed

$$(\text{rate} \sim (\Delta m_\nu^2 / M_W^2)^2 < 10^{-50})$$

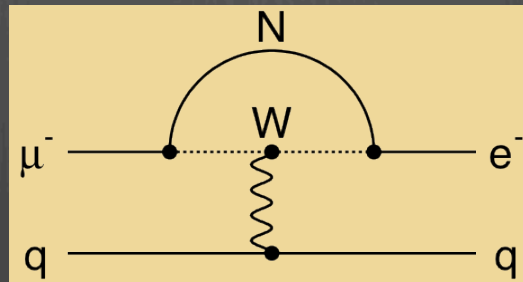
- ⊗ However, most all NP models predict rates observable at this generation CLFV experiments

New Physics Contributions to $\mu N \rightarrow e N$

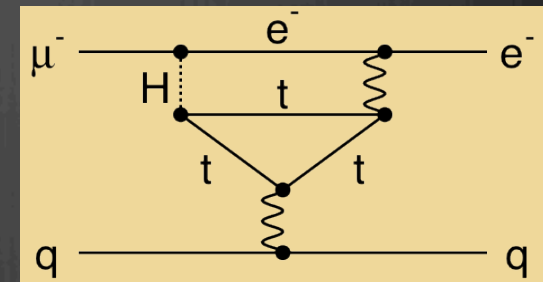
Loops



Supersymmetry

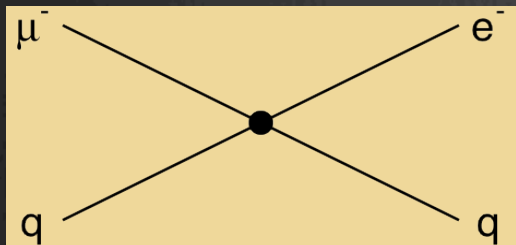


Heavy Neutrinos

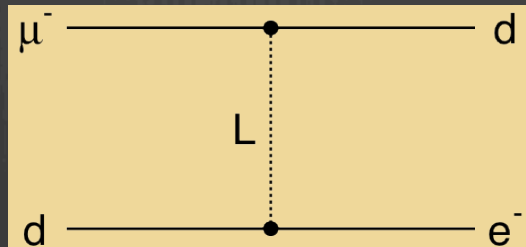


Two Higgs Doublets

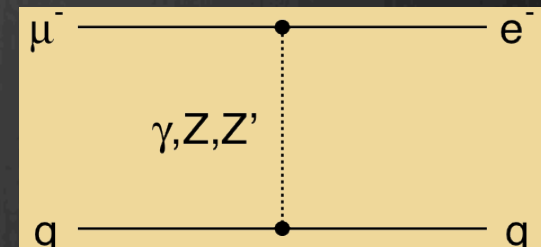
Contact Terms



Compositeness



Leptoquarks

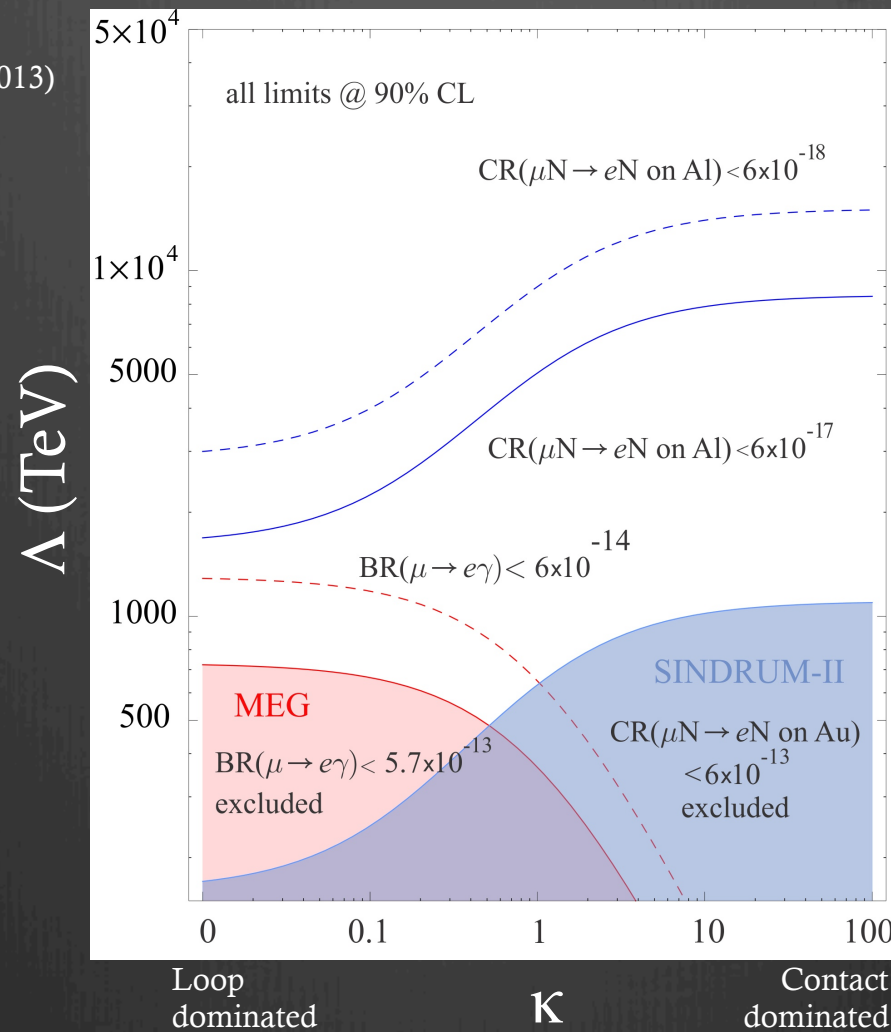


New Heavy Bosons /
Anomalous Couplings

$\mu N \rightarrow e N$ sensitive to wide array of New Physics models

Mu2e Sensitivity

A. de Gouvêa and P. Vogel,
Prog. Part. Nucl. Phys. 71, 75 (2013)



Courtesy A. de Gouvêa, B. Bernstein, D. Hitlin

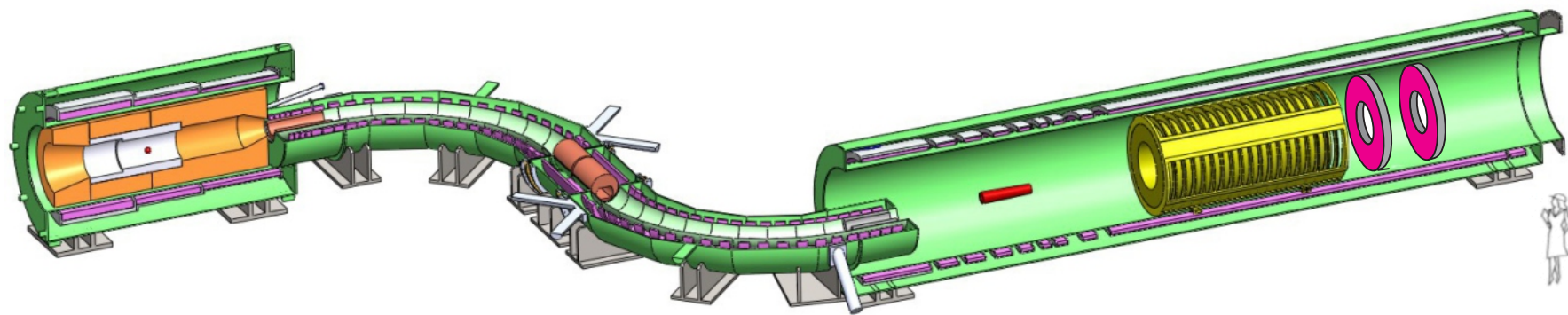
Mu2e Sensitivity best in all scenarios

Mu2e Experimental Apparatus

Production
Solenoid

Transport
Solenoid

Detector
Solenoid



about 25 meters end-to-end

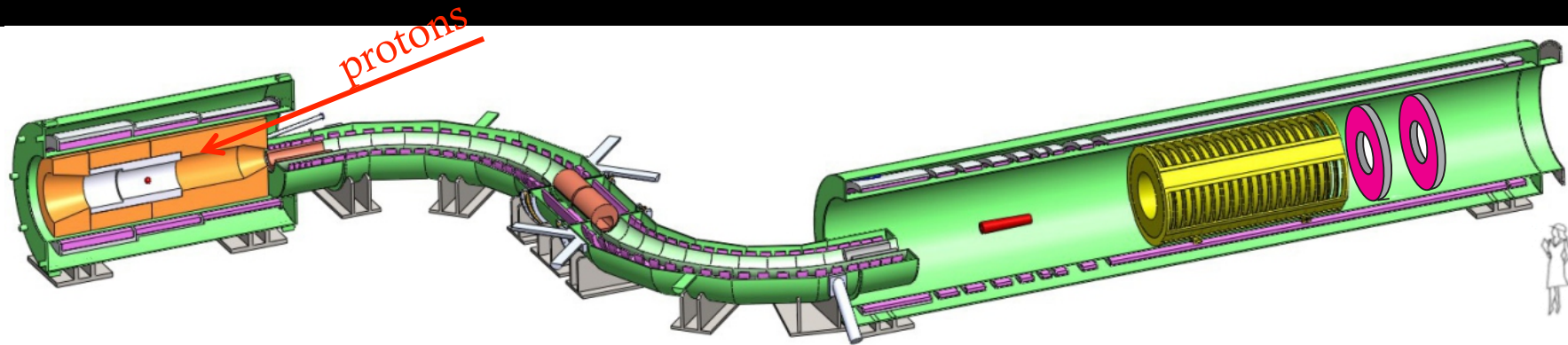
- Consists of 3 solenoid systems

Mu2e Experimental Apparatus

Production
Solenoid

Transport
Solenoid

Detector
Solenoid



Production Solenoid:
8 GeV protons interact with a tungsten target to produce μ^- (from π^- decay)

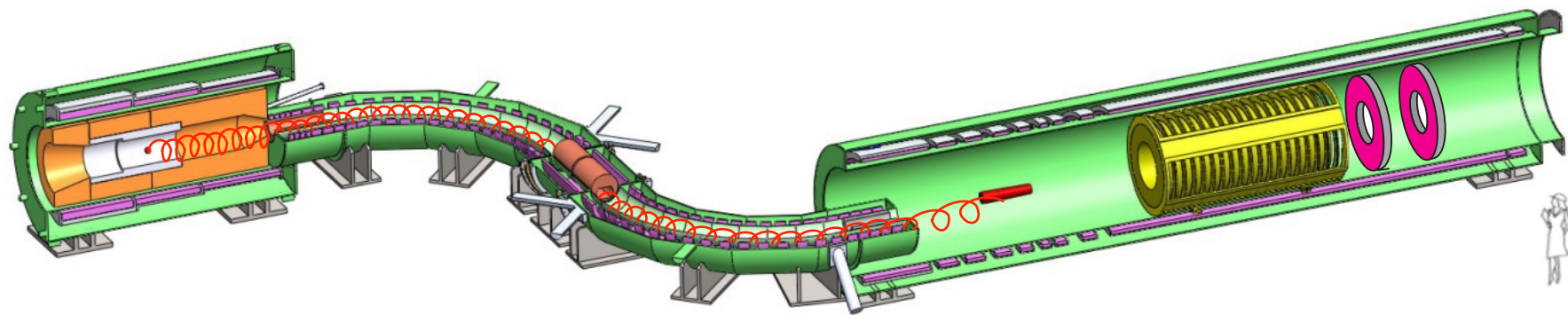
- Consists of 3 solenoid systems

Mu2e Experimental Apparatus

Production
Solenoid

Transport
Solenoid

Detector
Solenoid



Transport Solenoid:
Captures π^- and subsequent μ^- ; momentum- and sign-selects beam

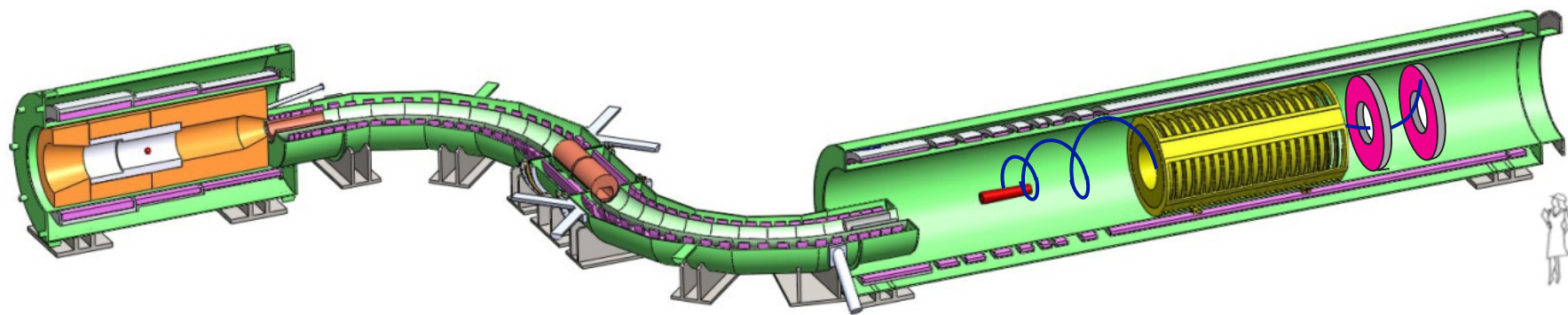
- Consists of 3 solenoid systems

Mu2e Experimental Apparatus

Production
Solenoid

Transport
Solenoid

Detector
Solenoid



Detector Solenoid:

Upstream – Al. stopping target, Downstream – tracker, calorimeter
(not shown – cosmic ray veto system, extinction monitor, target monitor)

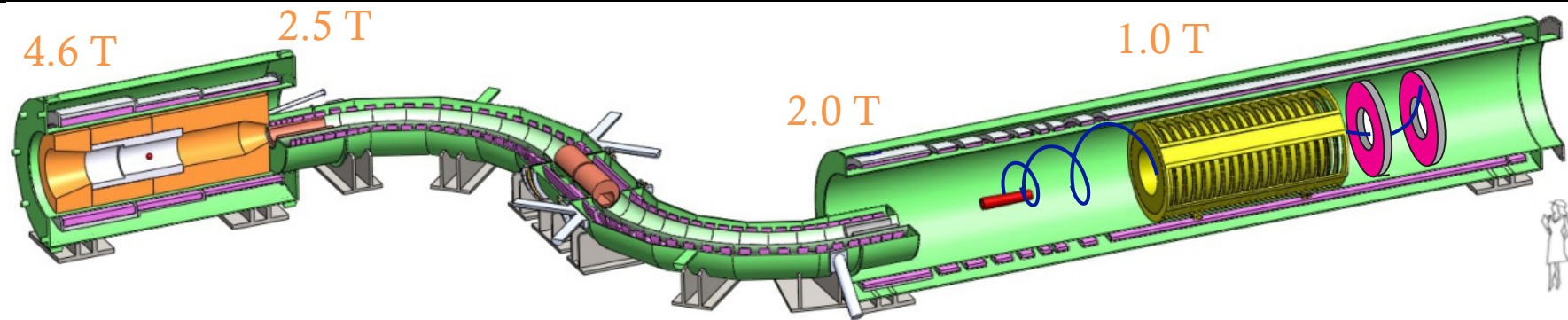
- Consists of 3 solenoid systems

Mu2e Experimental Apparatus

Production
Solenoid

Transport
Solenoid

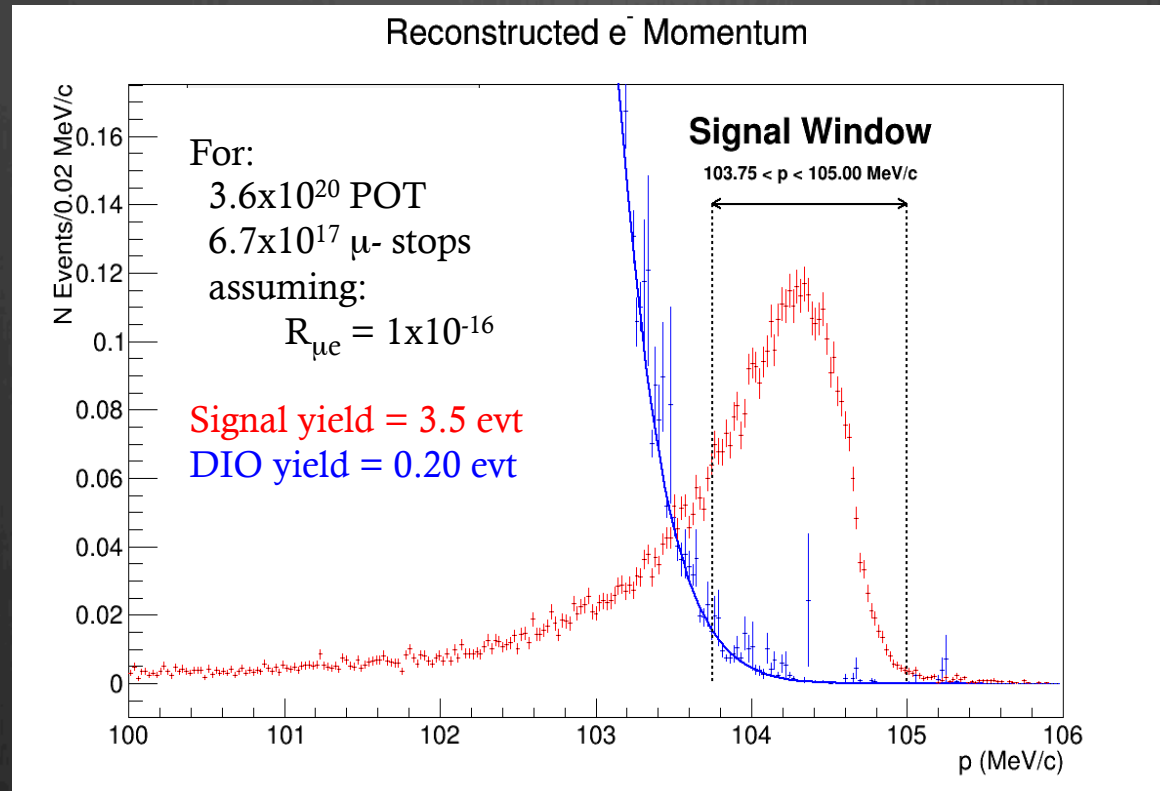
Detector
Solenoid



Graded fields important to suppress backgrounds, to increase muon yield, and to improve geometric acceptance for signal electrons

- Consists of 3 solenoid systems

Expected Result



Single-Event-Sensitivity = 2.9×10^{-17}

Total background < 0.5 events

Mu2e Status and Plans

- CD2 for detectors (baseline/TDR) obtained on the 5th of March 2015
- CD3b for Civil Construction and start for TS Bid obtained on same date.
- **Final signatures from DOE done:**
 - Procurement of Superconducting cables in progress
 - Bid for DS/PS assigned to General Atomics
 - Bid for TS completed. Expected output on May 2015 → July 2015?
 - Civil Construction started: **Ground Breaking Cerimony Apr. 18.**
- CD3 for detectors planned for March 2016
- **Overall DOE budget secured, 280 M\$.**



Mu2e INFN Approval Phase

◆ 2 rounds of CSN1 review process done in the last 3 months:

- Approval of large money range (April 2015)
 - > 2 MEuro
- Approval of financial envelope on (4 June 2015)
 - test of radiation hardness OK
 - ... 2.7 vs 3 Meuro (Csl vs BaF2)
 - ... BaF2 budget has been partially cut ..

◆ CTS review has been delayed to next November

- CSN1 introduction letter will be written on September to CD
- CD/GE will decide if sending us to CTS
- new CTS Chair will be G.Battistoni
- A lot of material has to be loaded in INFN DB
- **both the TCR and the TS Bid SHOULD be completed**

Calorimeter Costs to INFN

INFN Total Cost CORE

It reflects changes on Euro/\$
exchange rate from 1.35 to
1.09. Plus reduction of scope

v2.0 by S.Miscetti

01/04/15

Cost Of Baseline	Work Package	Cost	Cont	Total
	Crystals (1/3 of Total)	€1.100.000,00	€165.000,00	€1.265.000,00
	Photosensors (1/2 of Total)	€505.000,00	€101.000,00	€606.000,00
	Mechanics (100 %)	€280.000,00	€56.000,00	€336.000,00
	FEE (100 %)	€267.000,00	€53.400,00	€320.400,00
	WaveForm Digitizer (100%)	€410.000,00	€41.000,00	€451.000,00
	Laser System (100%)	€147.000,00	€28.600,00	€175.600,00
	Source (0%)	0	0	0
	Total apparati - crys-ps	€1.104.000,00	€179.000,00	€1.283.000,00
	TOTAL	€2.709.000,00	€445.000,00	€3.154.000,00
			0,164267257	€3.154.000,00
Fract of (elec+mech+cal)/(Crys+APD)		0,406785035		
Contingency over all system		0,164267257		
Contingency over (elec+mech+cal)		0,162137681		
Cost if Option Csl + MPPC (same share)				
	Crystals (0.5/cc x 0.5/0.33) = 0.75	€655.000,00	€288.200,00	€943.200,00
	mppc UV extended (0.83)	€444.000,00	€88.800,00	€532.800,00
	TOTAL	€2.689.095,00	€556.000,00	€2.759.000,00

Note: keep high contingency on crystals to take Optomaterial into consideration ... evaluating also option for ADVANSID

INFN Referee's Proposal

- Poiché esiste una **ragionevole aspettativa di riuscire a ottenere i goal di progetto con CsI** siamo dell'avviso di basare la valutazione del contributo INFN sulla stima dei costi corrispondenti a questa soluzione:
 - **2.76 M€**
- Nel caso la technology review confermi viceversa (con compelling evidence!) la scelta BaF_2 , il contributo potrebbe eventualmente aumentare, ma comunque non eccedere i 3.0 M€
- Riteniamo importante esprimere un **caveat sulla distribuzione temporale dell'impegno**, che deve prevedere il grosso degli impegni core concentrati negli **anni 2017-2018**
- Per il 2016: disponibilità limitata per un ramp up
- Dal 2019: conflitto con la partenza di altri progetti

The Mu2e Calorimeter

Role of calorimeter

- particle id.
- CR rejection

Crystal calorimeter

- Compact
- Radiation hard
- Good timing (1 ns) and energy resolution (5%)

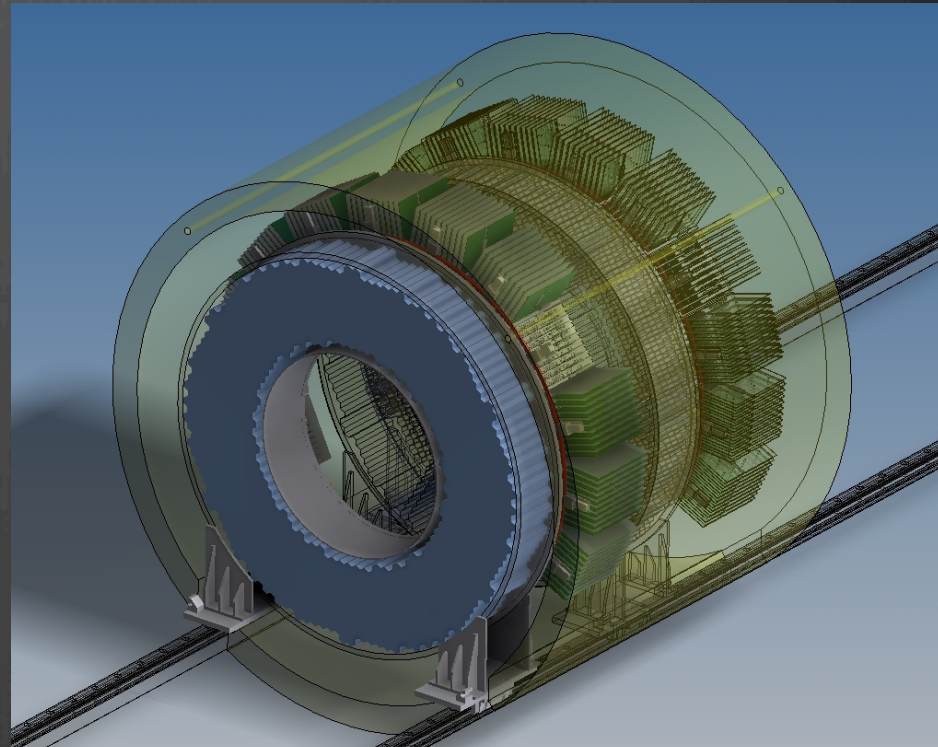
Will employ 2 disks

(radius = 36-70 cm)

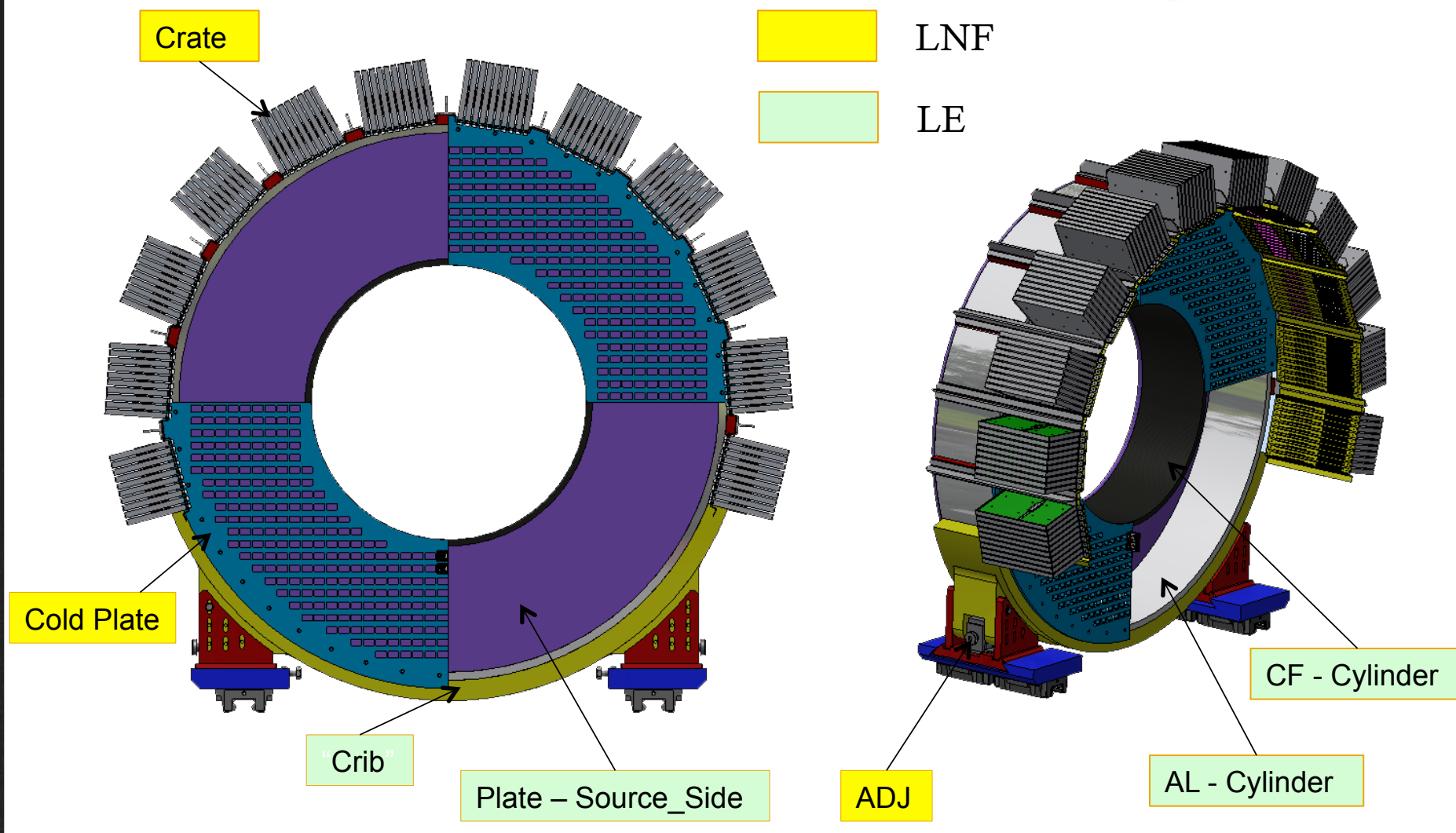
~2000 BaF₂ or CsI crystals with

square cross-section ~3 cm side, ~20 cm long ($10X_0$)

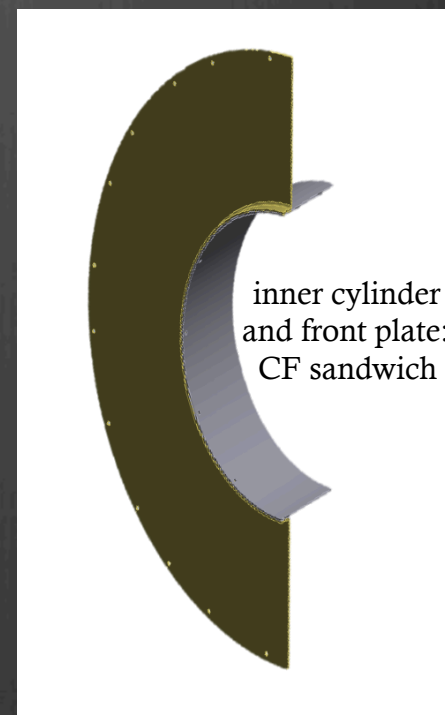
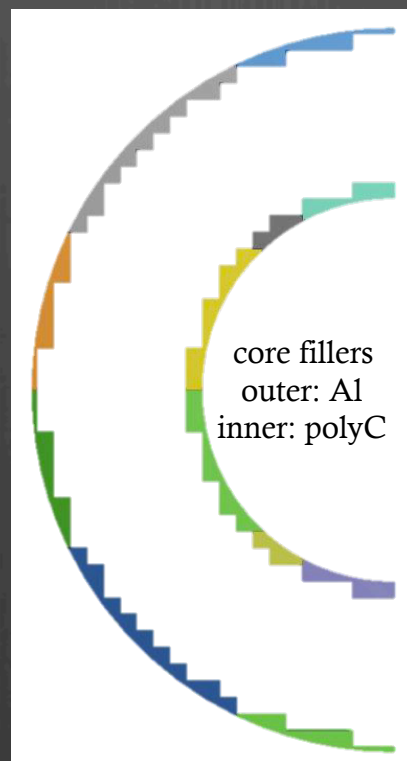
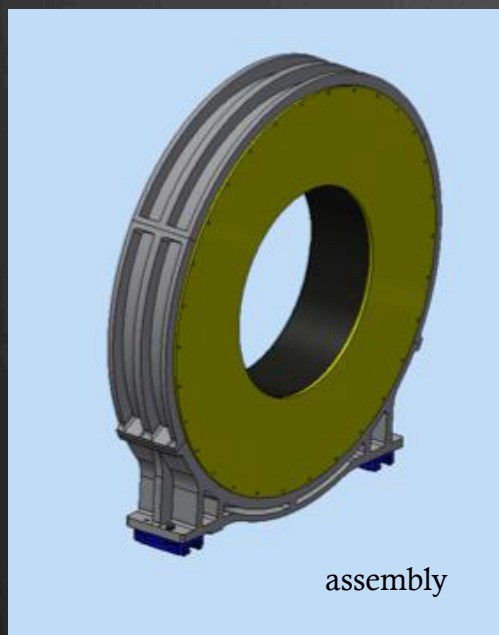
Two photo-sensors/crystal on back (APDs or SiPMs)



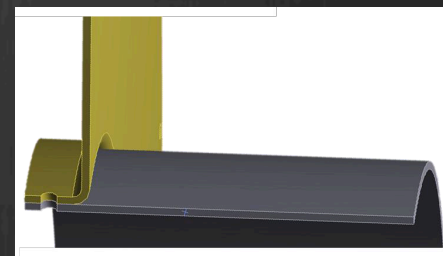
Calorimeter Assembly



INFN Lecce Responsibilities



Al outer
cylinder



2016 Tasks

⊗ **Module 0 – final (BaF_2 or CsI) configuration 7x7 crystals**

- wrapping tests (4 layers of 25 μm Teflon)
- glue / grease / nothing
- APD / SiPM readout
- front-end + cooling + cabling
- digitizers
- mechanics + piling up strategies

⊗ **Prototypes cores/fillings**

⊗ **Wrapping tests under vacuum and under full load**

⊗ **CF lamination tests inner cylinder and front plate**

⊗ **Outer cylinder and crib feasibility studies**

2016 Richieste INFN-LE

⦿ Anagrafica

2.3 FTE

• F. Grancagnolo	DR	30%	(70% MEG + Firb)
• A. Maffezzoli	PO	20%	
• A. Manocchio	Dott	100%	
• G. Piacentino	PA	50%	(50% g-2/Dot1)
• G. Tassielli	RU	0%	(100% MEG + Firb)
• G. Zavarise	PO	30%	

⦿ Missioni

26.0 K€ + 2.5 K€ sj

• interne	1.0 K€/FTE + beam tests (2w x 2fisici)	2.3 K€ + 2.5 K€ sj
• estere	1.2 m.u. x 4.8 K€/m.u./FTE x 2.0 FTE	11.5 K€
	Executive Board (FG) 1.5 mu	7.2 K€
	+ 20% (rivalutazione \$)	5.0 K€

⦿ Consumo

16.0 K€

• meccanica Modulo 0	5.0 K€
• test wrapping	3.0 K€
• prototipi cores/fillings	2.0 K€
• laminazioni inner cylinder and front plate	4.0 K€
• auto al Fermilab	2.0 K€

⦿ Costruzioni Apparati

20.0 K€

⦿ Licenze software

10.0 K€