The Instrumented Flux Return Detector of the SuperB project: R&D studies and first results of the Fermilab Beam Test

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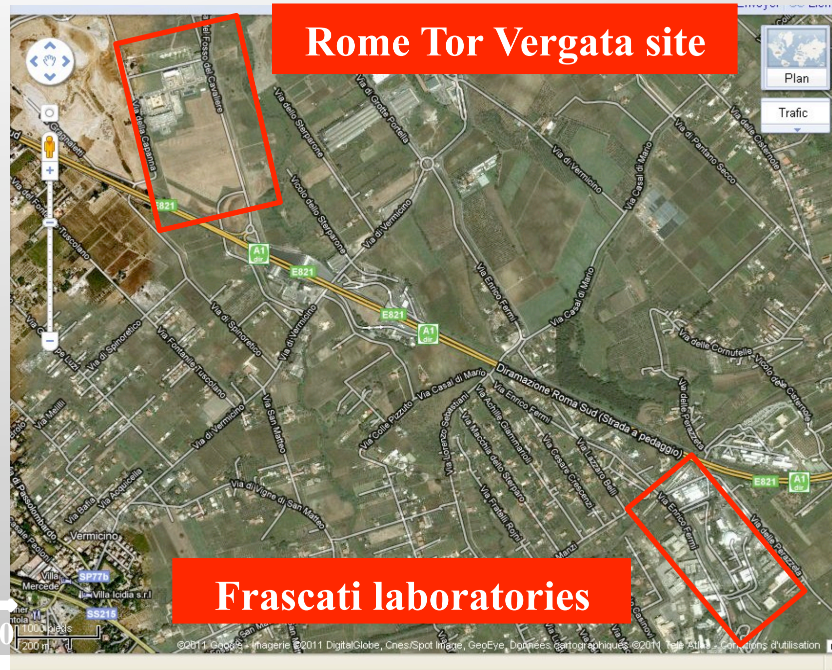
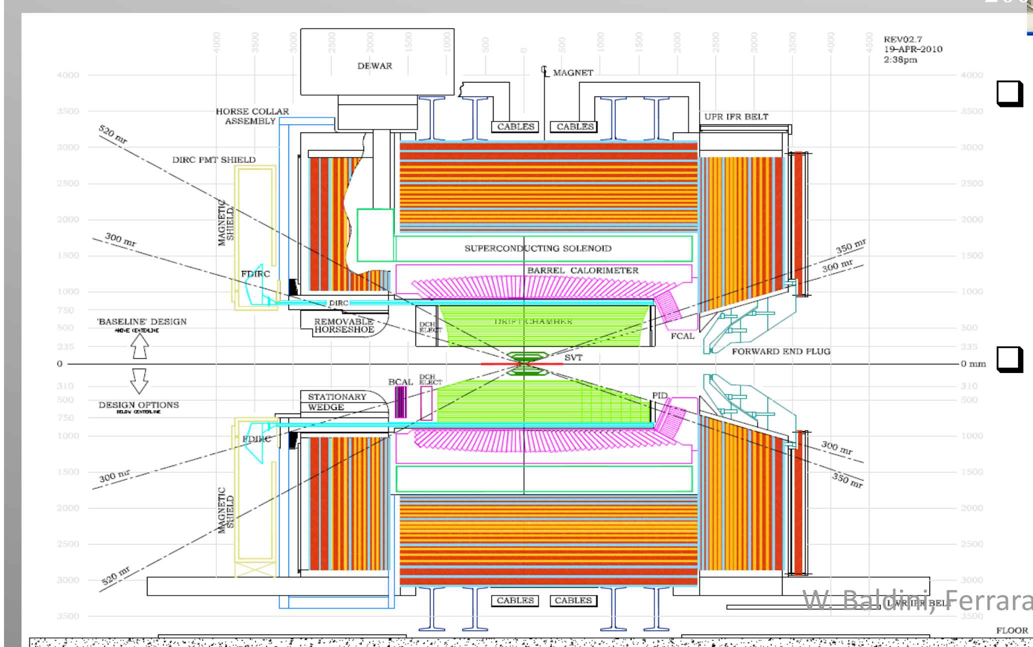
Overview

- The SuperB project
- The Instrumented Flux Return Detector
- First R & D studies
- Design and construction of the Prototype
- The Fermilab Beam test
  - Detector Performances
  - Muon Identification
- Conclusions

The SuperB Project

- Super Flavour factory with an expected luminosity of 2×10^{36} $cm^{-2}s^{-1}$ polarized e^- (6.7GeV) on e^+ (4.2GeV)
- High intensity Asimmetric $e^+ e^-$ collider to be built in Italy (near Rome) with a strong International involvement
- Complimentary to the LHC experiments: high precision studies, rare decays, search for NP





- The Detector plan to reuse parts of the BaBar spectrometer modified to cope with 100 time higher luminosity
- Recently approved by Italian Government and classified as one of the flagship project of the Italian Research Program

The Instrumented Flux Return Detector

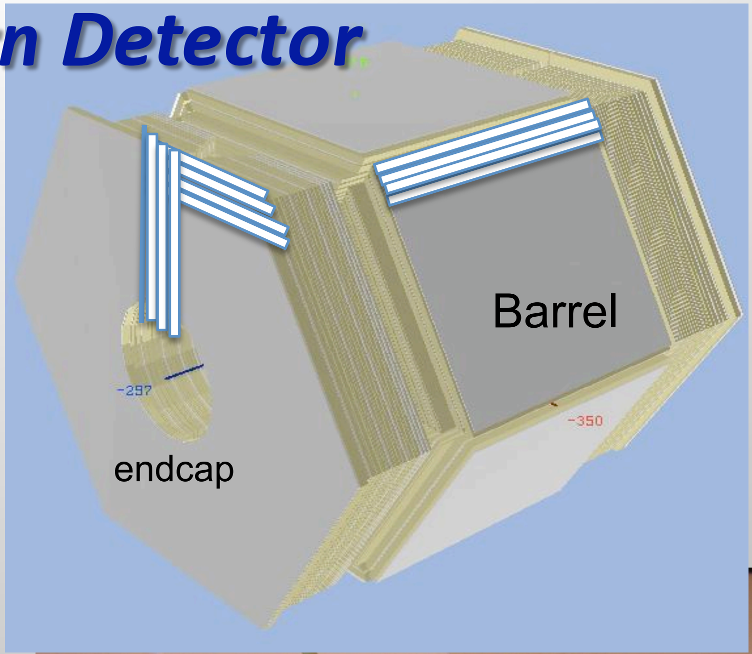
- Part of the Superb apparatus is the **Instrumented Flux Return**: the most external detector used to identify **muons** and **neutral hadrons**

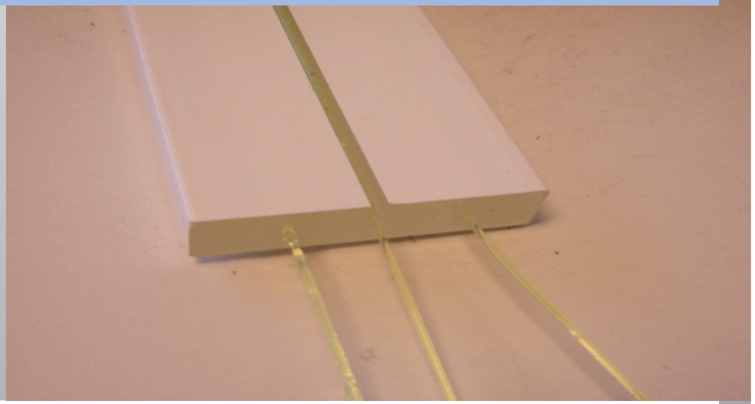
- Superconducting **solenoid iron yoke instrumented with fast scintillators** to cope with high flux of particles (≈ 200 kHz/cm^2)

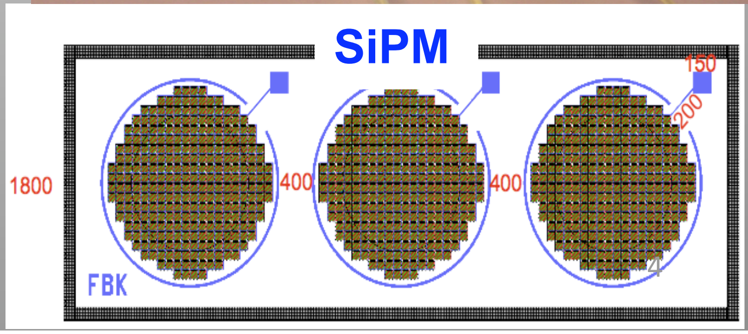
- 92cm of Iron interleaved by **9 active layers** of highly segmented scintillators

- 4cm scintillator bars readout through **3 WLS fibers** and **Silicon Photo-Multipliers (SiPM)**

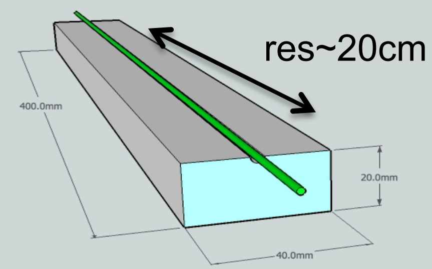
- Two readout options under study:
  - Time readout **(TDC-RO) for the barrel**
  - Binary readout **(BI-RO) for the endcaps**





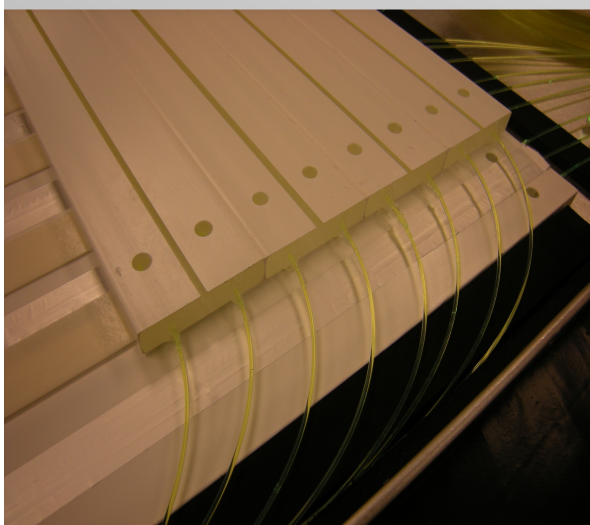


Readout Options



Time readout Option (TDC-RO): the hit bar gives the first coordinate while the signal arrival time provides the second

- measure the 2 coordinate at the same time
- 1ns time resolution → ~ 20cm
- need TDC readout for each channel
- relatively simple to be constructed



Binary readout Option: (BI-RO): the two coordinates are given by two planes of orthogonal scintillator bars:

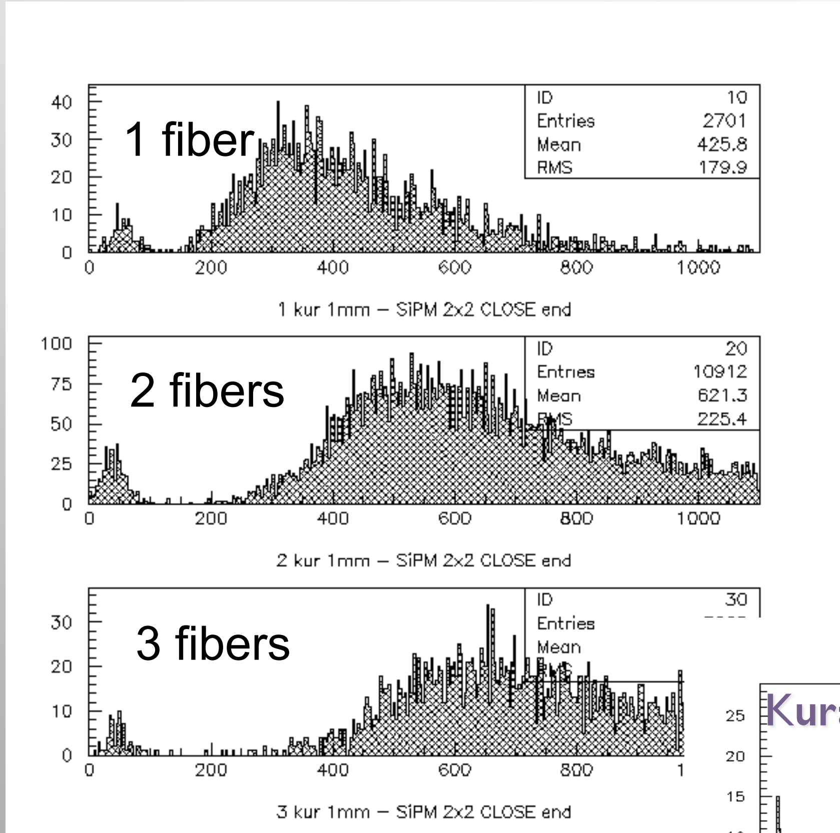
- high combinatorial
- simpler (and cheaper) electronics
- more complex construction

Both option are being tested on beam thanks to a full depth prototype

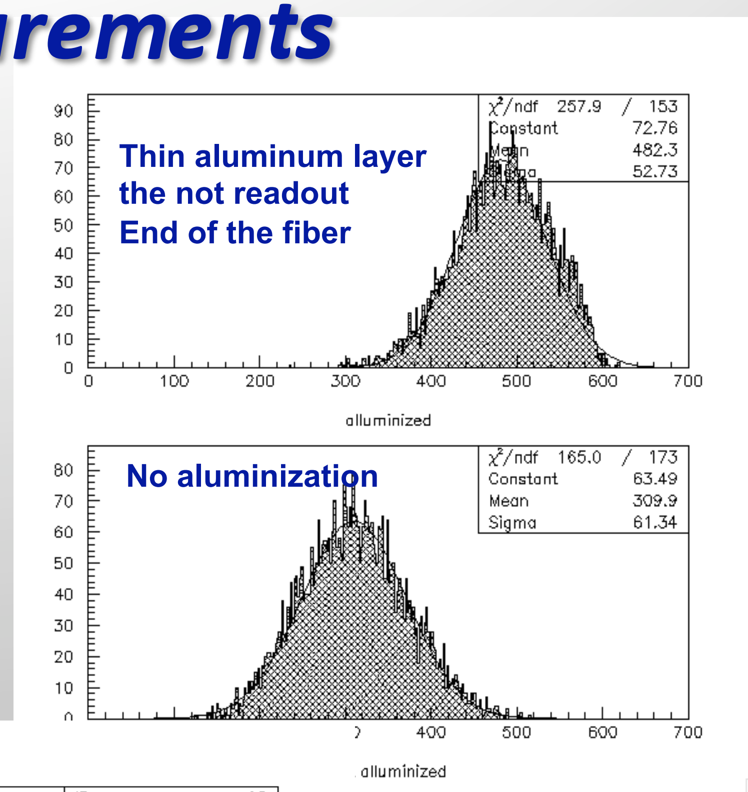
First R&D studies

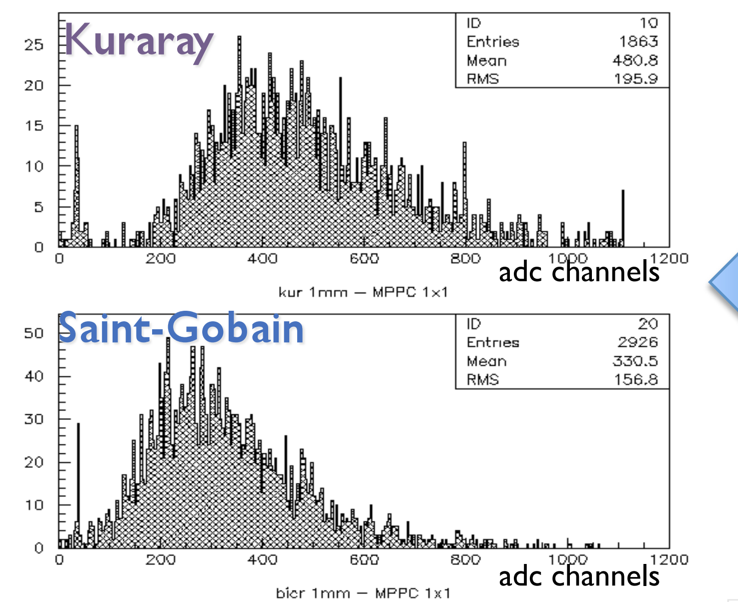
- **This baseline detection technique is the result of many R&D studies :**
  - **Fibers:**
    - **How many fibers/scintillator bar-→ 1,2,3 fibers**
    - **Possibility to use clear fibers to bring the signal to the SiPMs**
    - **Which fibers and which diameter (Kuraray Y11 vs Saint-Gobain BCF92 , 1.0-1.2mm)**
  - **Photodetectors:**
    - **SiPM from FBK (Fondazione Bruno Kessler, Trento - Italy) vs Hamamatsu (Japan)**
    - **Dimensions: 1x1mm^2 , 2x2mm^2, + few custom geometries**
  - **Scintillators:**
    - **Fiber housed in a surface grove or in an embedded hole on the scintillator bars**
    - **Optical glue vs optical grease**
  - **Quality of the polishing of the fiber surfaces**
  - **…… not enough time to show all the details**

…just some measurements



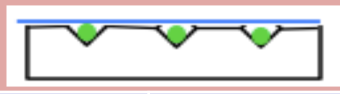
Light Yield of a 4cm wide scintillator readout through 1,2,3 fibers: 3 is the most cost effective number

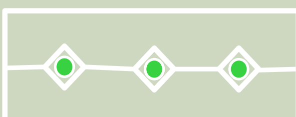




Light Yield of a 2m long fiber: comparison Kuraray Y11 and Saint-Gobain BCF-92

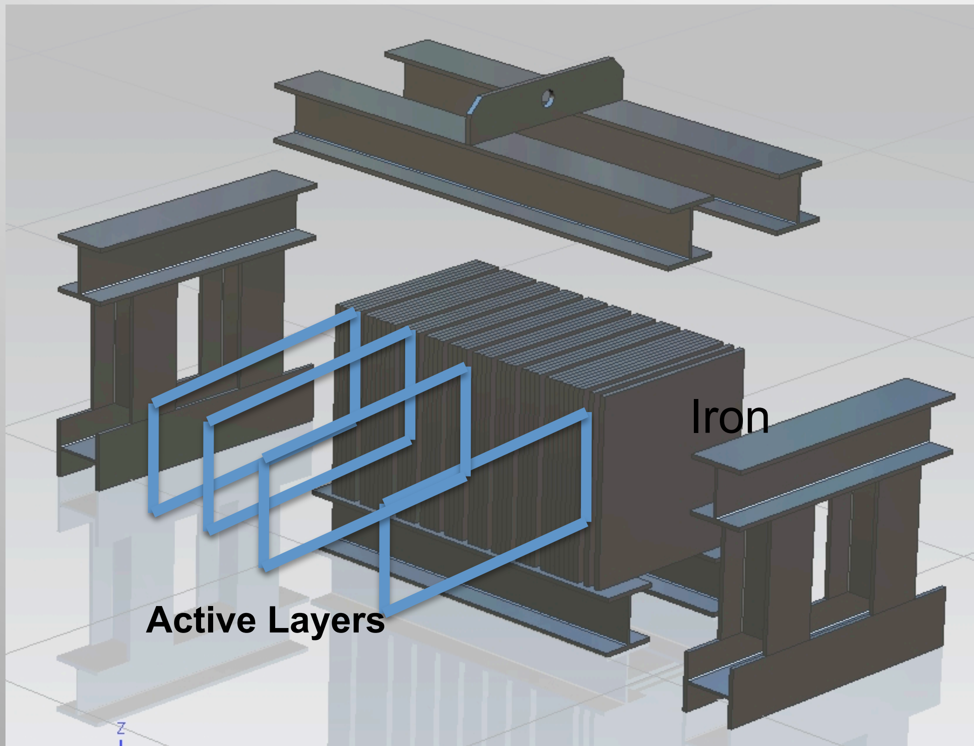
Summary of R&D measurements

Binary readout 		Time resolution			Efficiency		
		1.5pe	2.5pe	3.5pe	1.5pe	2.5pe	3.5pe
2 fibers	2.4m grease	1.87	2.16	2.14	98.8%	97.4%	91.6%
	2.4m NO grease	2.30	2.49	2.64	97.2%	94.9%	85.7%
3 fibers	2.4 m grease	1.41	1.51	1.85	99.0%	99.4%	97.7%
	2.4m NO grease	1.73	1.88	2.15	98.8%	97.8%	89.2%

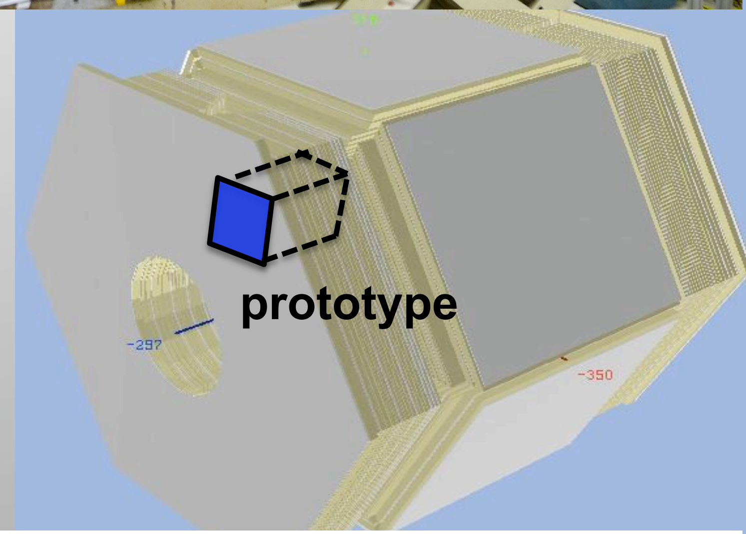
Time readout 		Time resolution			Efficiency		
		1.5 pe	2.5pe	3.5pe	1.5pe	2.5pe	3.5pe
3 Fib.	2.2m with grease	1.16	1.17	1.26	95.9	99.1	99.1
	2.2m (no grease)	1.32	1.37	1.26	96.1%	97.4%	94.4%

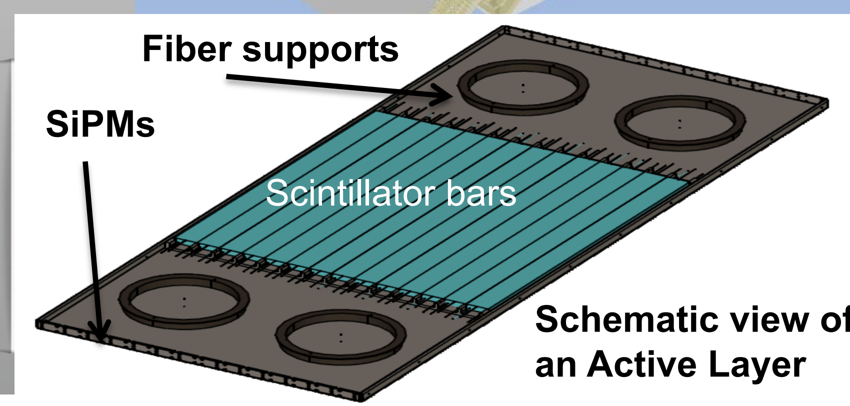
Once the baseline technique has been established a full depth prototype has been designed and built

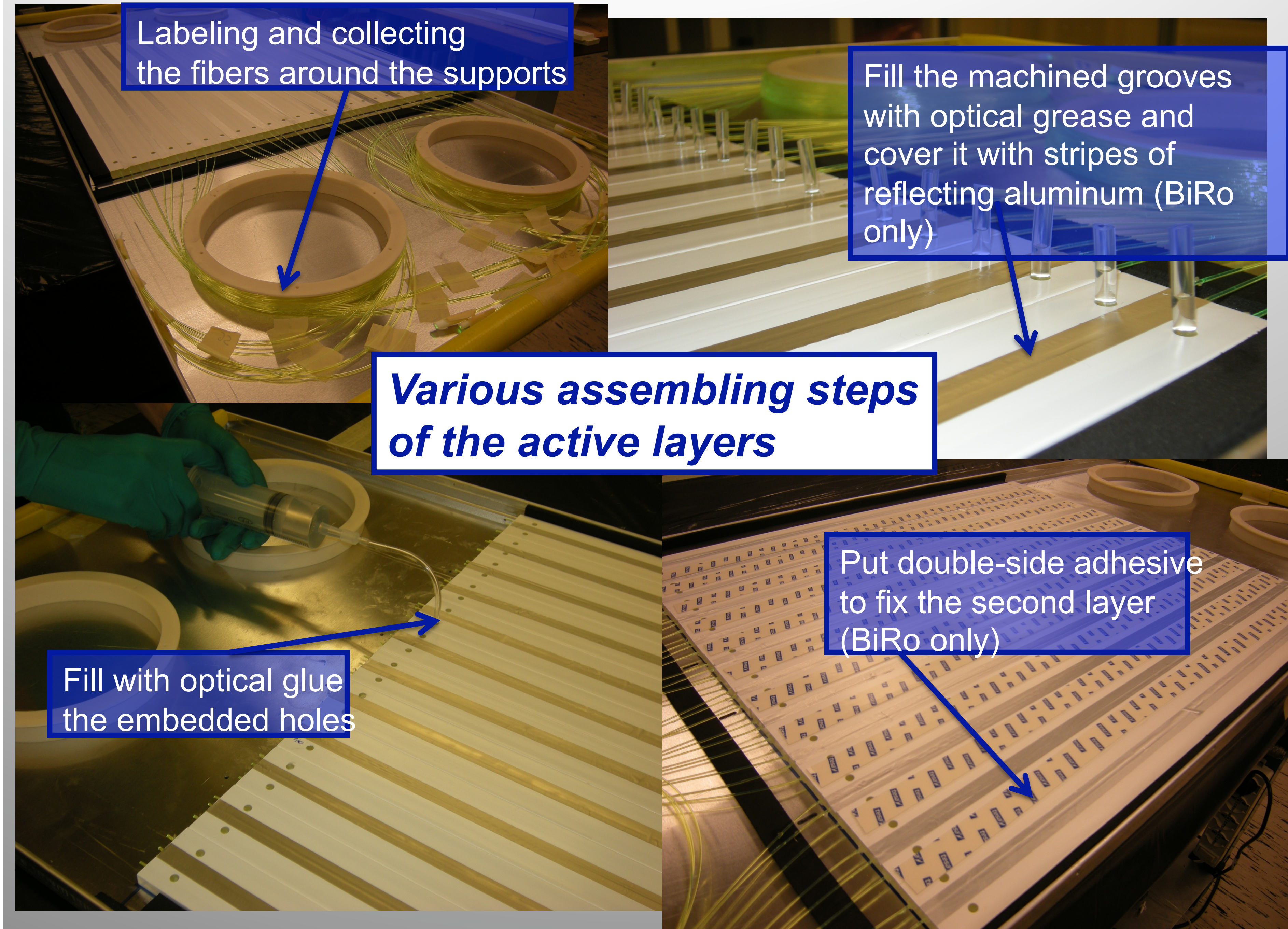
The Prototype: design and construction



- ❑ Iron: ***60x60x92 cm³*** 9+ slots to house the active layers with different segmentations
- ❑ up to ***9 active layers*** readout together
- ❑ ***4 Time Readout*** (TDC-RO) "standard "
- ❑ ***4 Binary Readout*** (BiRo) "standard"
- ❑ ***4 special modules*** to study different
- ❑ fibers or SiPM geometry

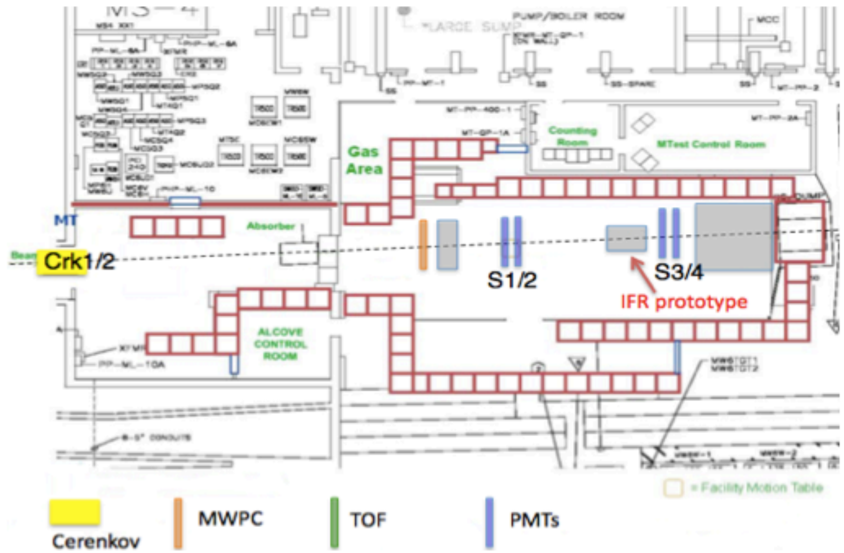




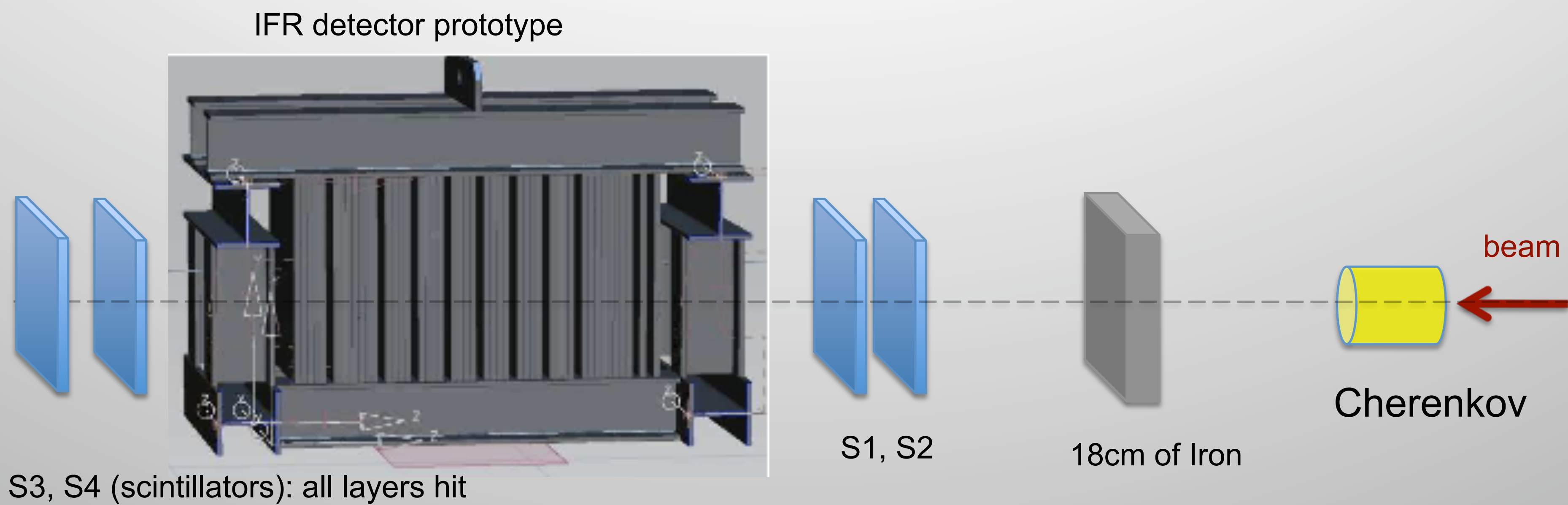

Labeling and collecting the fibers around the supports
Fill the machined grooves with optical grease and cover it with stripes of reflecting aluminum (BiRo only)
Various assembling steps of the active layers
Fill with optical glue the embedded holes
Put double-side adhesive to fix the second layer (BiRo only)

The beam test at Fermilab

The Fermilab Test Beam Facility



Testbeam Setup

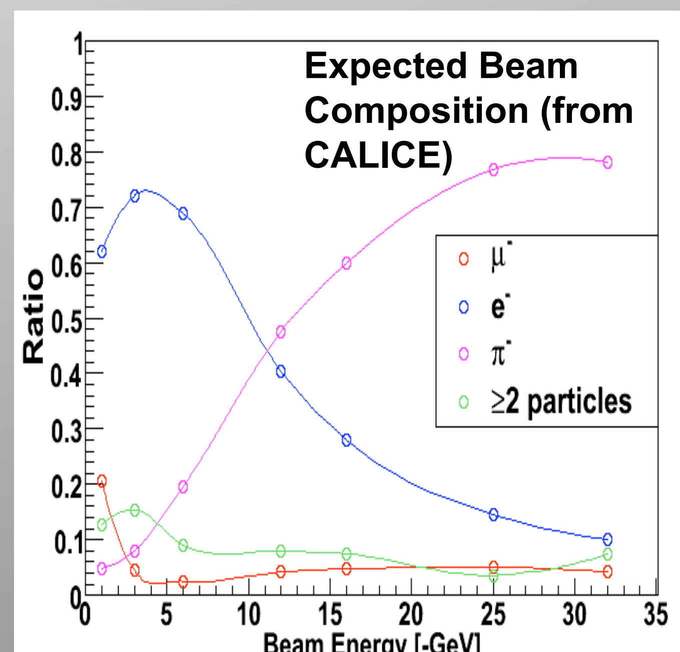


Triggers:

Muon tracks ➡ $S_1 \times S_2 \times \overline{C_e} \times C_\mu$

Pion tracks ➡ $S_1 \times S_2 \times \overline{C_e} \times \overline{C_\mu}$

Mu + Pi tracks ➡ $S_1 \times S_2 \times \overline{C_e}$



First Beam Test Results

- We took data at 8,6,5,4 GeV in 7 days of data taking

- The main goal of this beam test was the measurements of the detector performances (mainly detection efficiency and time resolution) and possibly muon identification

- We took data mainly at high momentum range with N_2 as Cherenkov gas (not efficient at low momentum)

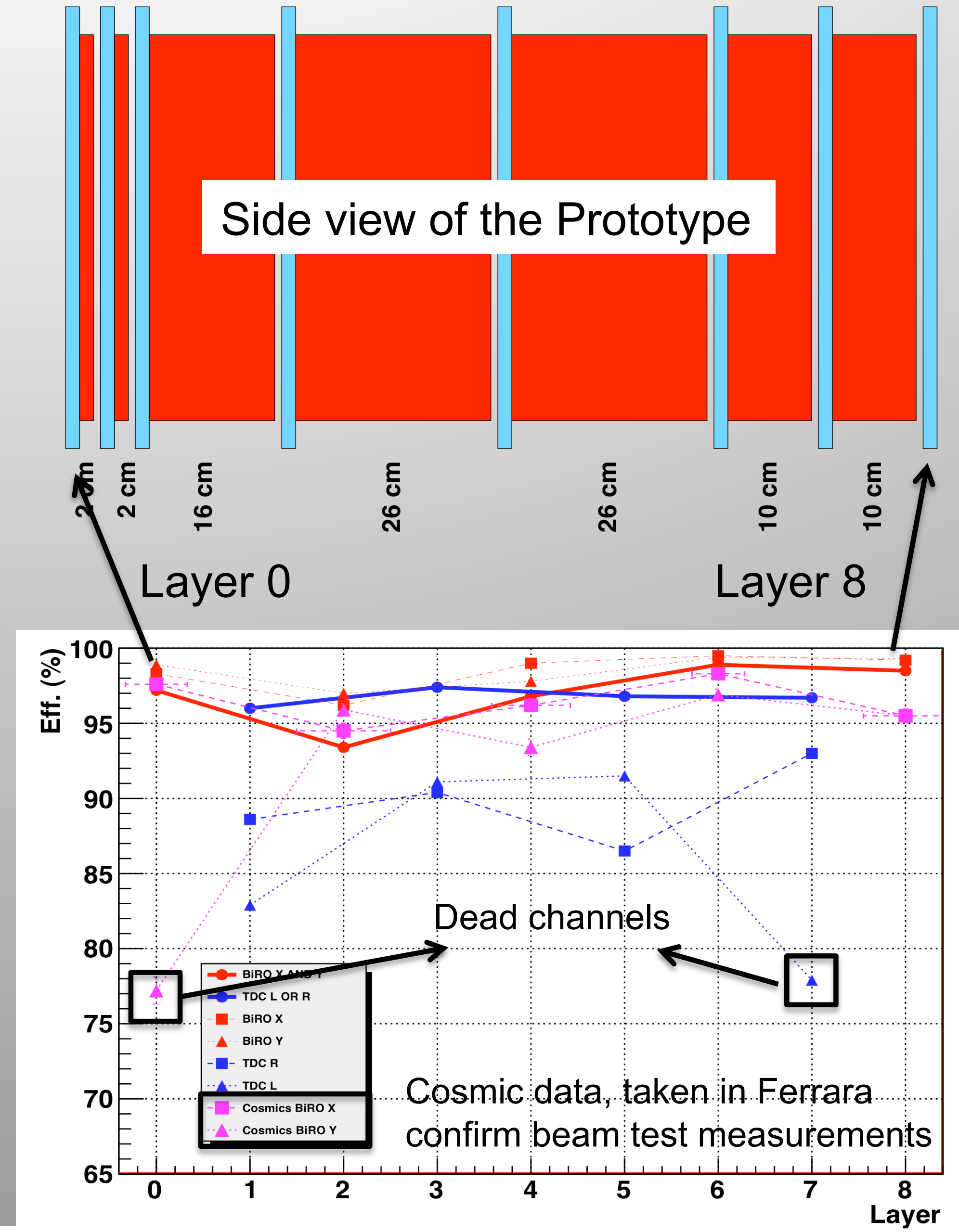
- Triggers: track defined as S1xS2 and selecting muons, pions, muon +pions thanks to the Cherenkov counter

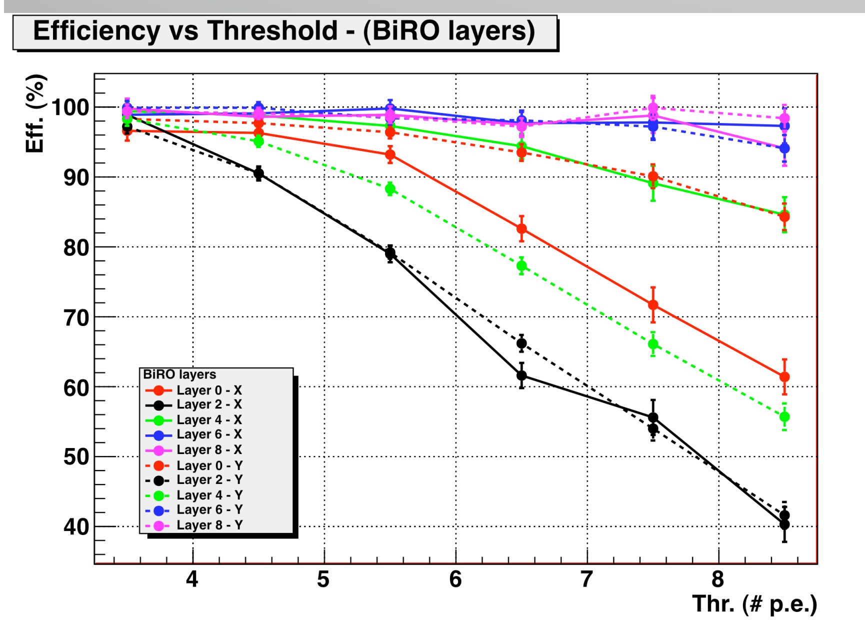
- We have scheduled a new data taking from July 20 to Aug. 03 to cover the lower momentum region (1 - 5 GeV) with C_4F8 O as Cherenkov gas

- We plan to use also the TOF system

Detector Performances: Efficiency

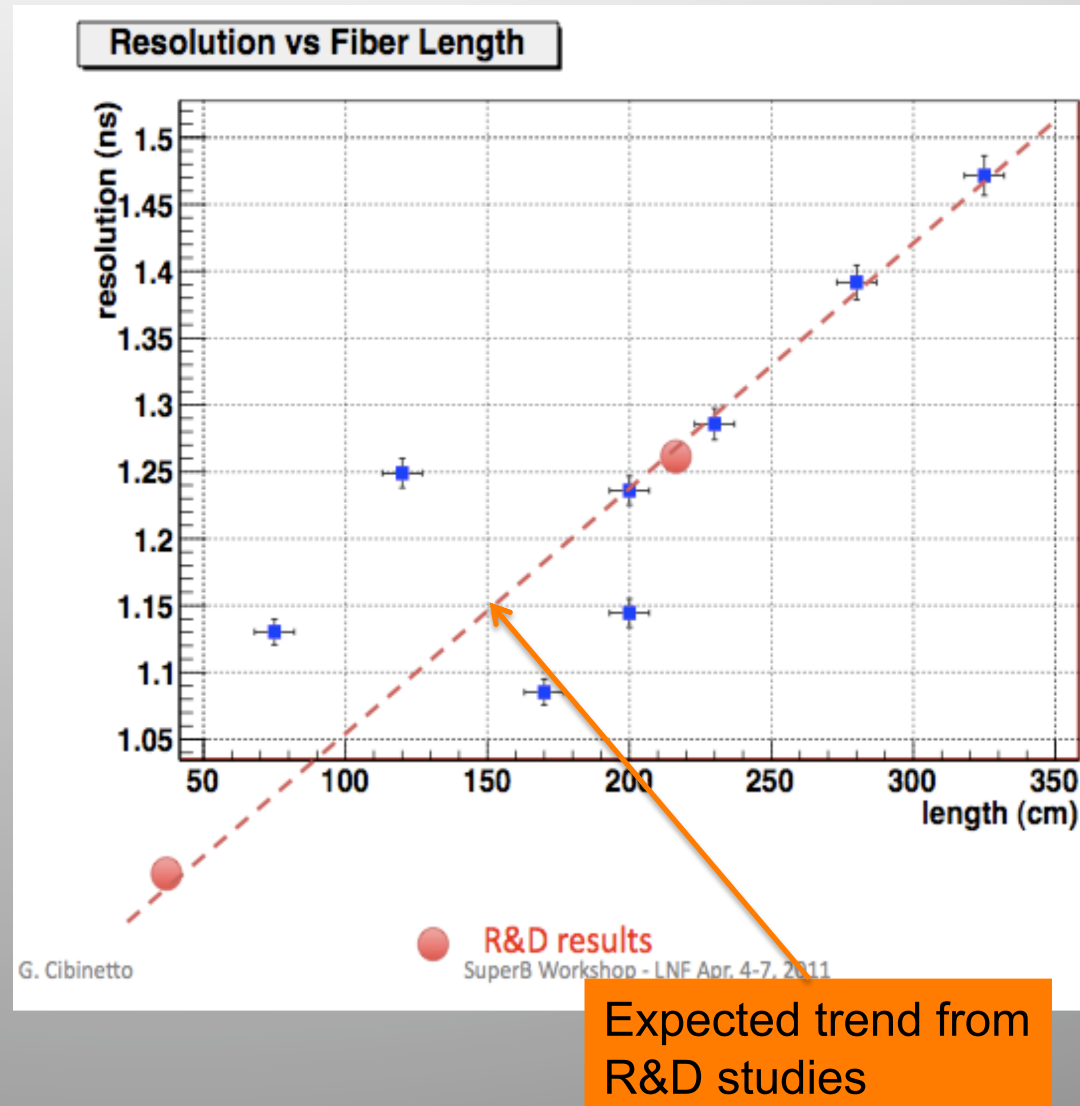
- ❑ Layers 0,2,4,6,8 Binary Readout, various fibers length (from 110cm to 370 cm)
- ❑ Layers 1,3,5,7 Time Readout SiPM on both ends of the scintillator, fibers length: all 400cm
- ❑ Standard thresholds: 3.5 p.e.
- ❑ Very good efficiencies: ≈ 95%





Detector Performances: Time Resolution

- ❑ Layers 1,3,5,7 time readout
- ❑ The beam test results are in good agreement with the R&D data
- ❑ Few points are out of the expected trend due to different SiPM bias voltage
- ❑ More measurements at the next beam test



Muon Identification: Hit Multiplicity

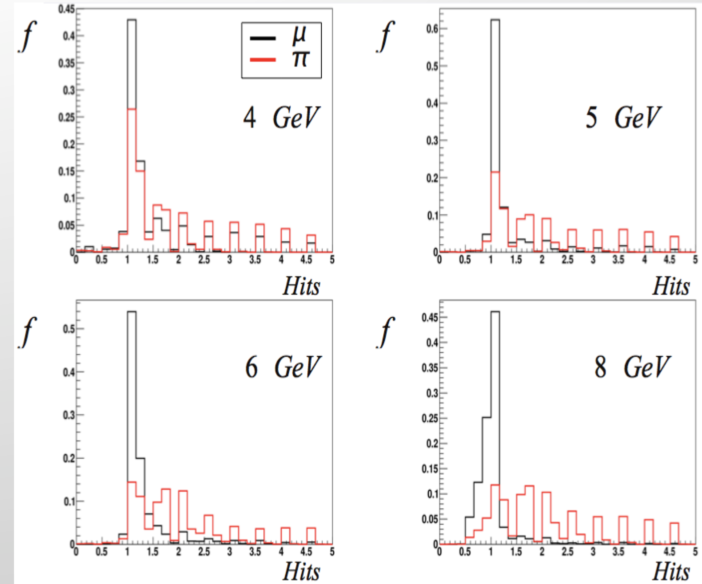
❑ Particle identification based on: hit multiplicity, shower shape, track length

❑ These informations will be used as input for a PID algorithm

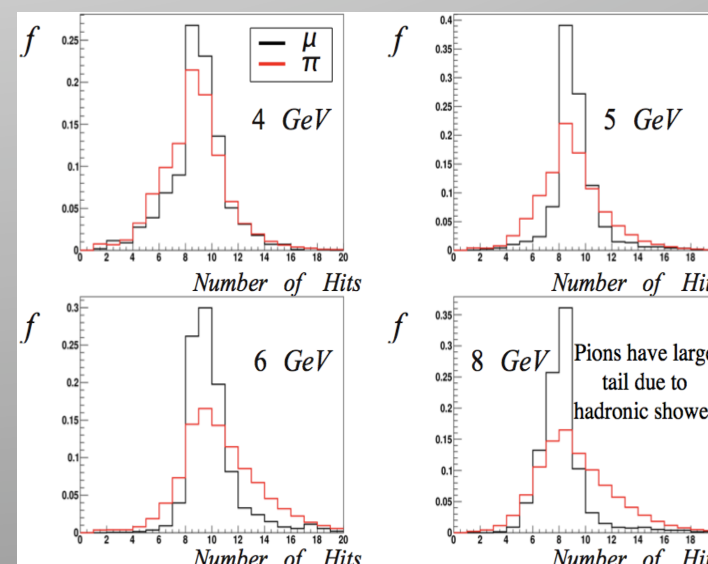
❑ At 4-5 GeV momentum the Cherenkov detector with N_2 gas is not very efficient

❑ Muon-pion mis-identification very high at low momentum

Hit multiplicity plots



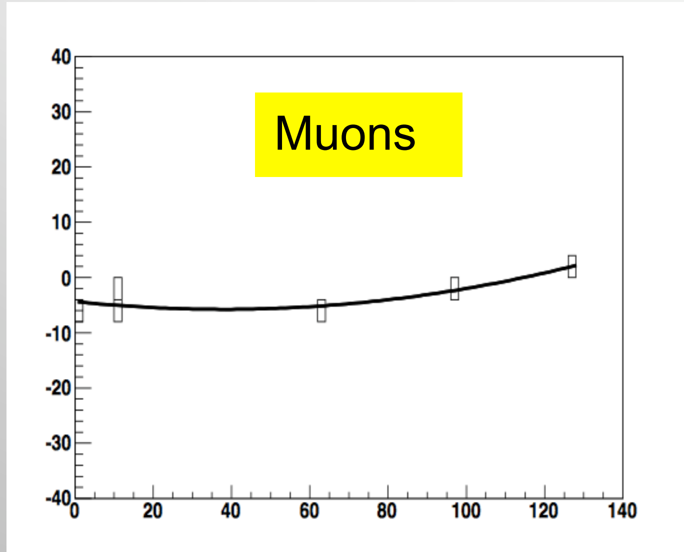
Hit multiplicity distribution per Layer



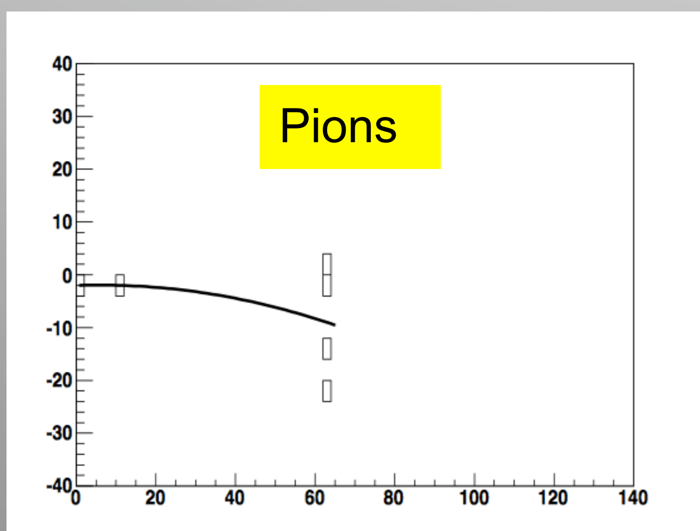
Hit multiplicity distribution per event

Muon Identification: shape of the shower

Track Length:

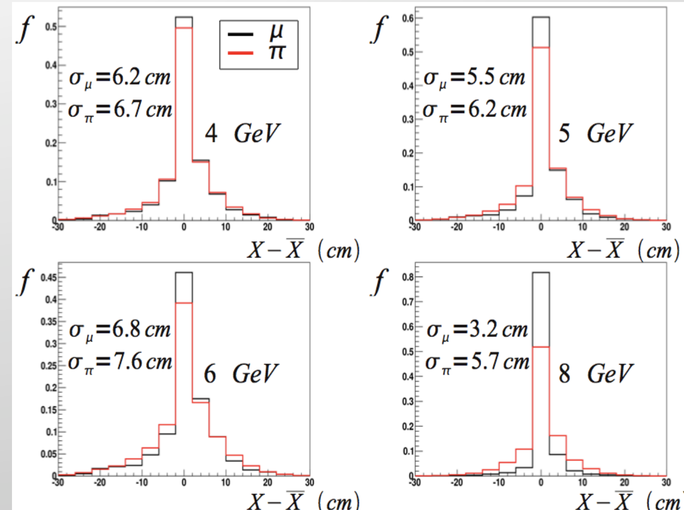


Track Length (cm)

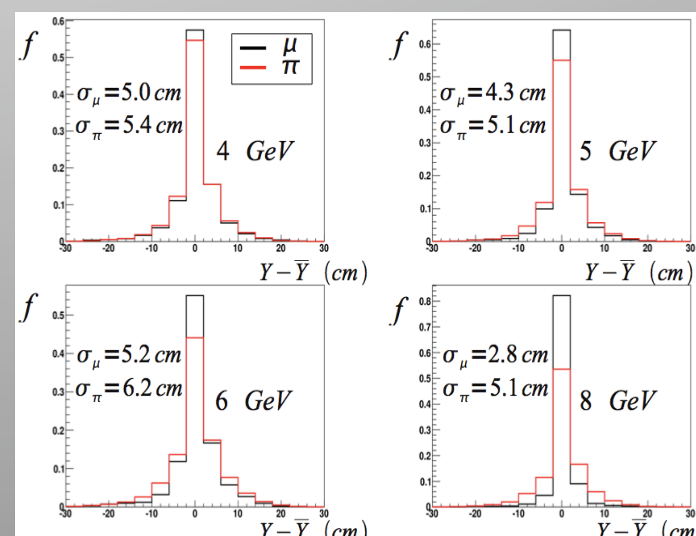


Track Length (cm)

Transverse shape of the shower:



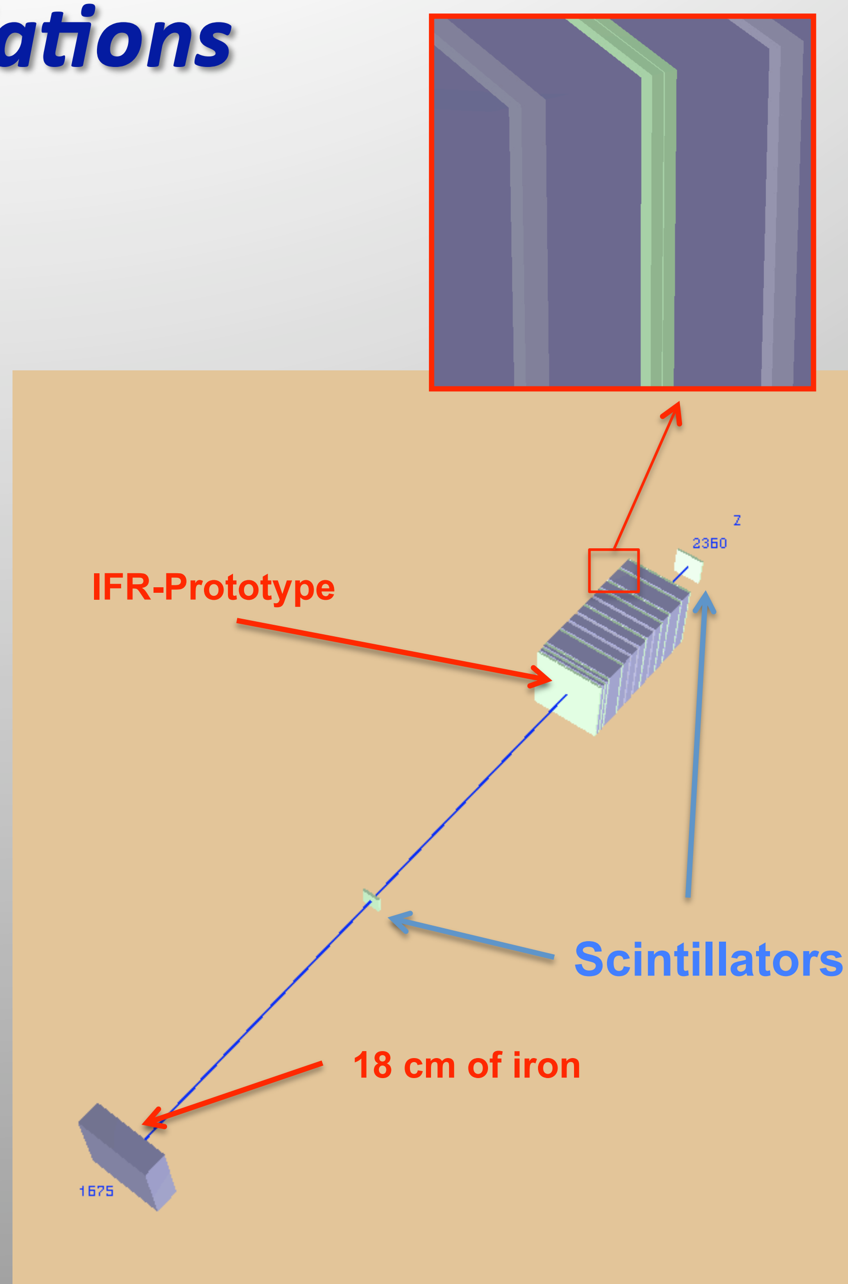
X coordinate



Y coordinate

Monte Carlo Simulations

- In order to fully understand the data it's very important to have a reliable simulation of the apparatus
- A full GEANT4 simulation of the whole testbeam setup has been developed
- Calibrate the Monte Carlo with real data and then use MC to understand the detector and beam contamination (e.g. pions decaying in flight…)



Conclusions

- **Many past and ongoing activities on the SuperB IFR detector:**
  - R&D studies to define a baseline detection technique
  - the design, construction and test on beam of a prototype to measure the performances on realistic working conditions
  - The related data analysis and MC simulations to fully understand the beam test data
- **The beam test data confirm the good results of the first R&D studies: detection efficiency ≈95% and time resolution ≈ 1.2nsec and good muon/pion identification at high momentum**
- **A new testbeam is foreseen in July-Aug to extend the studies to lower momentum 1-5 GeV**