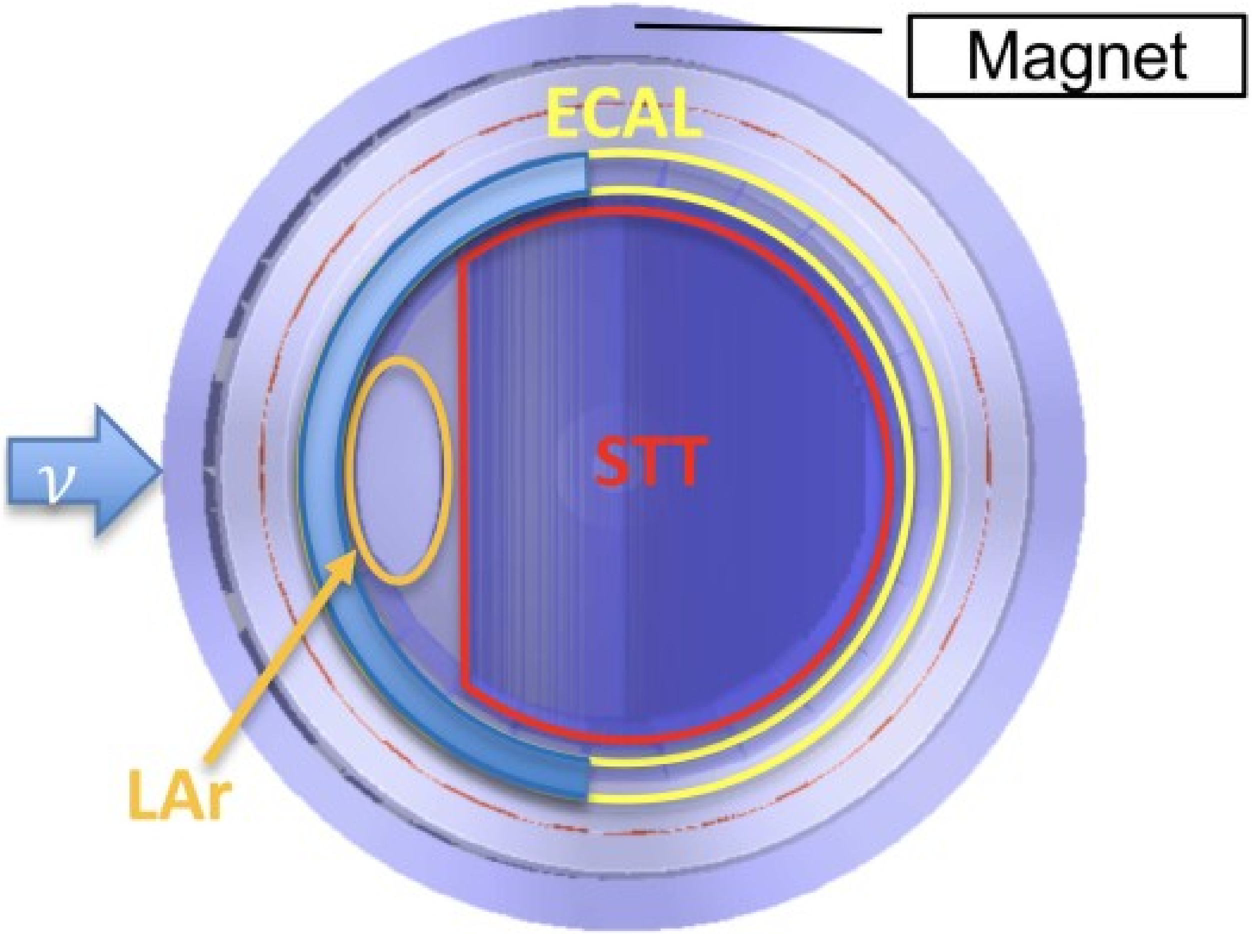


Introduction to SAND Tracker discussion

S. Di Falco and G. Sirri

Meeting Collaborazione Italiana DUNE

November 6, 2023

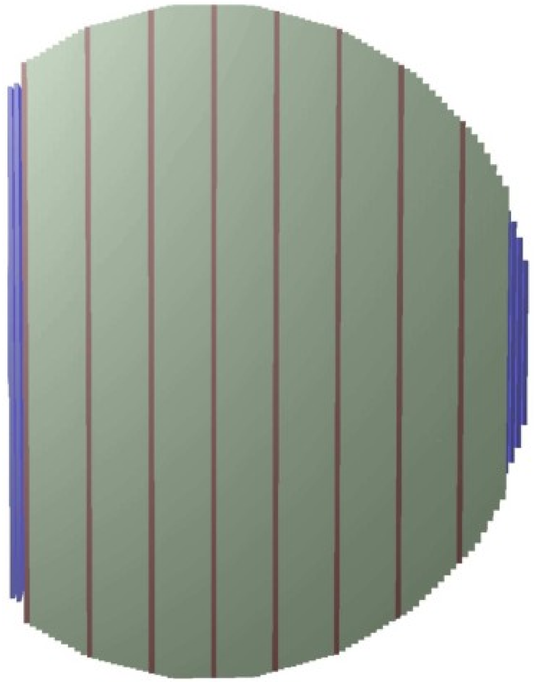
Introduzione

Questa breve introduzione vuole essere un aggiornamento di quanto mostrato a Settembre ai referees, che si può trovare su https://agenda.infn.it/event/37384/

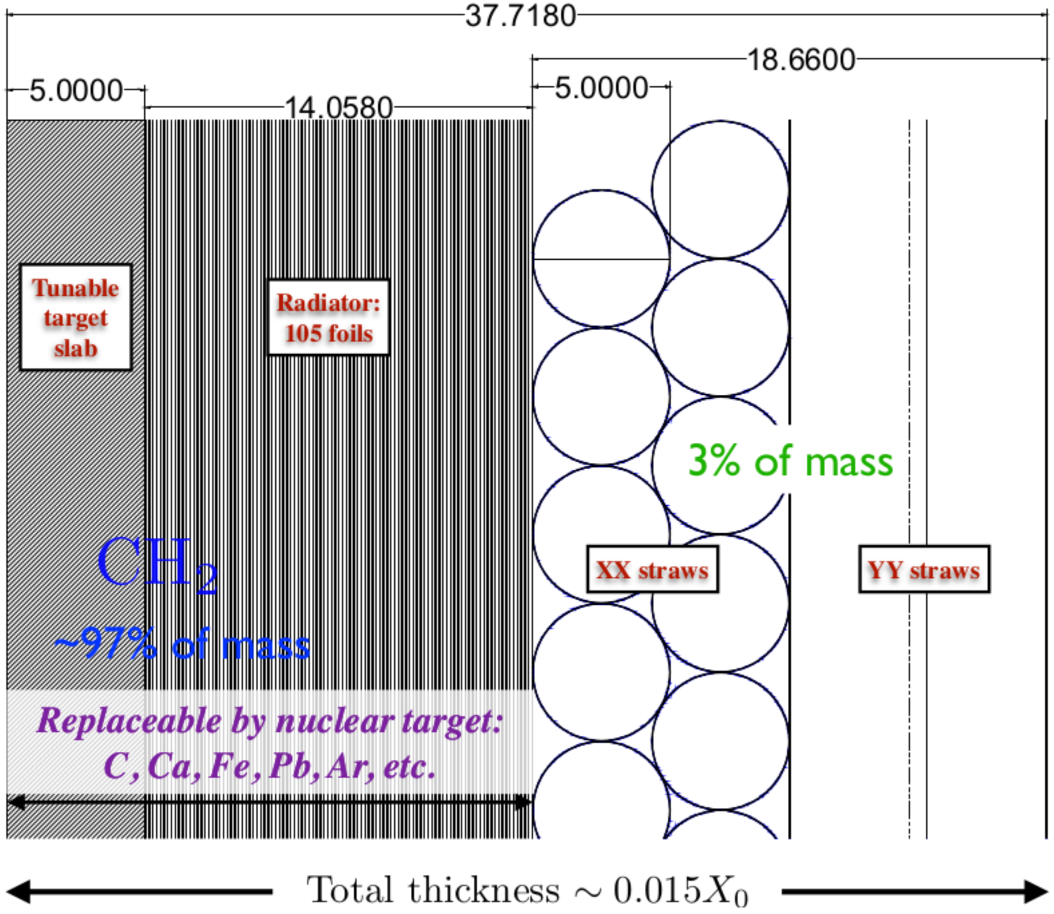
Cerchiamo di coprire ciò che non verrà coperto dalle presentazioni della sessione e che riguardano lo stato di avanzamento degli studi sulle due possibili soluzioni:

- Straw Tube Target Tracker
- Drift Chamber Tracker

SAND Straw Tube Target Tracker (STT)



Green: CH_2 *Brown: C*

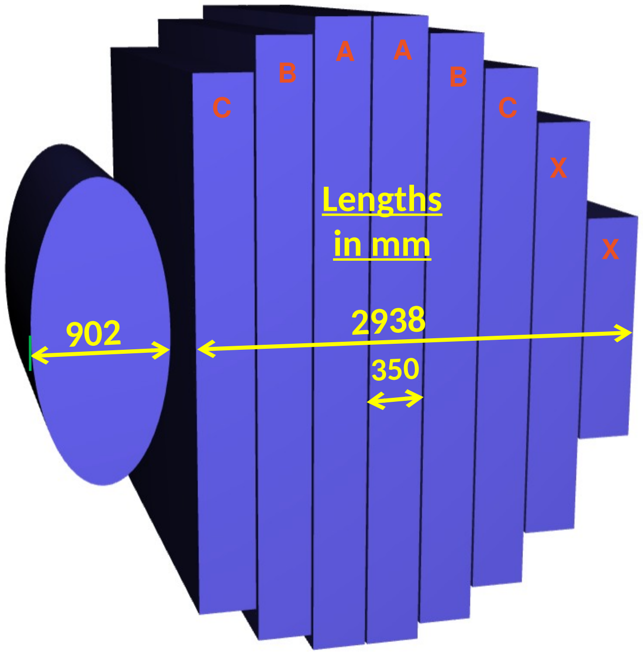


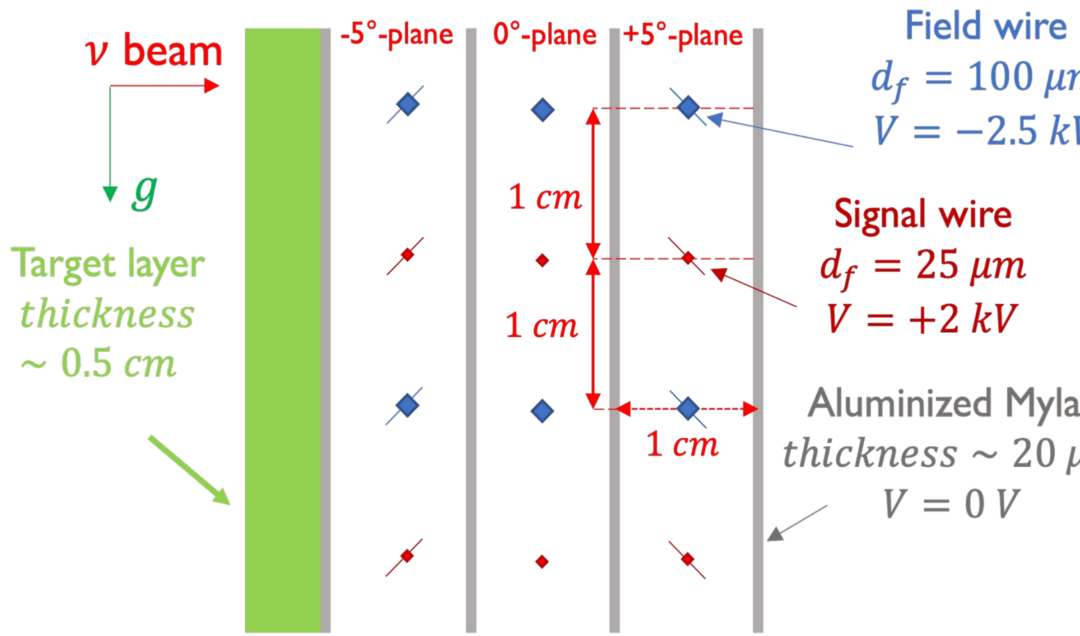
78 CH_2 modules → Solid H target!
8 C modules

Main goals:
- $\nu_\mu, \bar{\nu}_\mu, \nu_e$ and $\bar{\nu}_e$ fluxes vs E
- inclusive and exclusive ν-H and $\bar{\nu}$-H CC (systematics on reconstructed E)
- inclusive and exclusive ν-A and ν-A CC on other nuclear targets

1 module is made of:
- 1 target slab
- (optional) radiator for TR
- 2 XX straw layers
- 2 YY straw layers

SAND Drift Chamber Tracker





Alternativa per il Sistema di Tracciamento in SAND

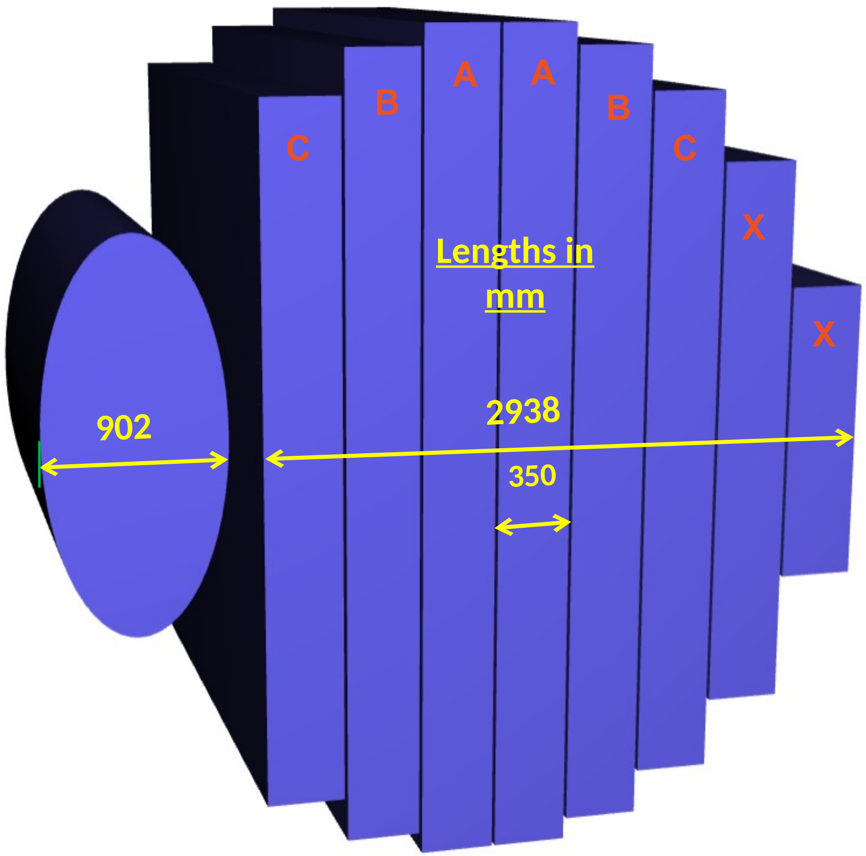
E' iniziato uno sviluppo per utilizzare piani di camere a deriva multifili come tracciatore in SAND.

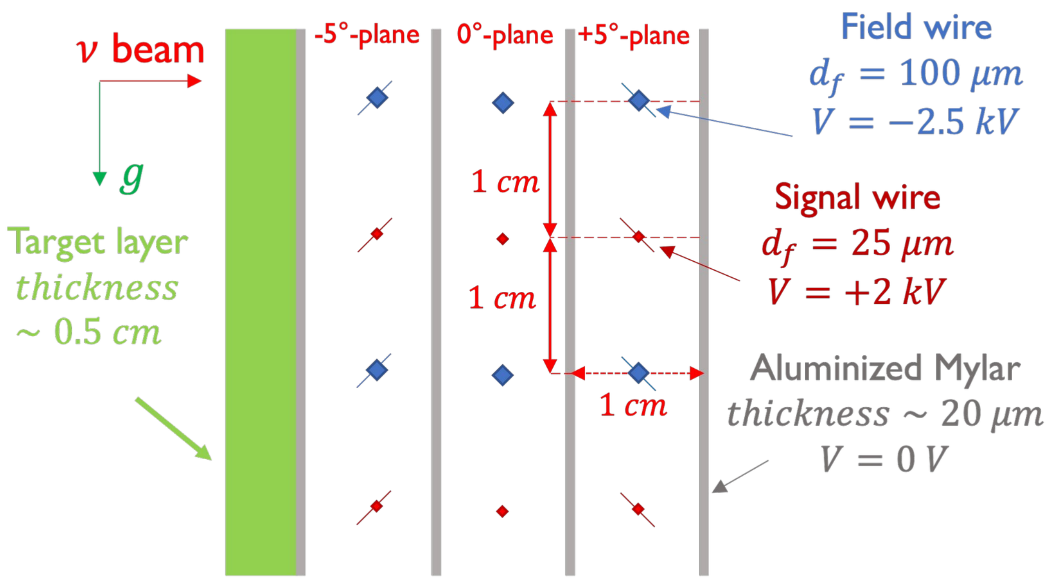
L'obiettivo è quello di ridurre la complessità meccanica del tracciatore mantenendo prestazioni comparabili a quelle degli STT.

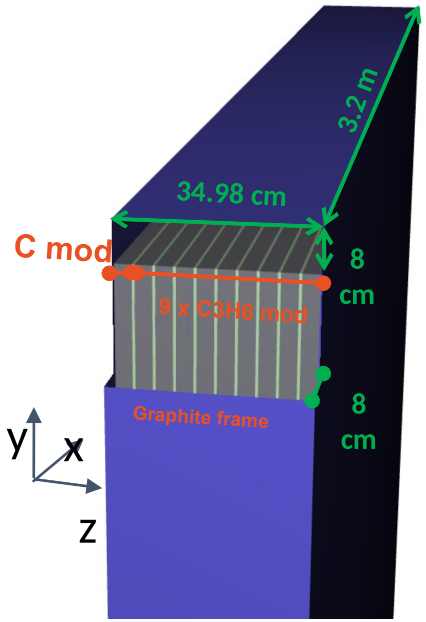
Fra i possibili vantaggi, c'è anche la riduzione del numero di canali.

Sviluppi in corso e Obiettivi a breve termine :
- sono state valutate varie configurazioni di cella e simulato il campo elettrico
- è in produzione la costruzione di un modulo prototipo di 30x30 cm.
- si sta progettando un prototipo di 120x80 cm per la convalida del design.

SAND Drift Chamber Tracker







Ipotesi di layout dei moduli del tracker: 3 piani di camera con fili a -5°, 0° +5° rispetto all’orizzontale

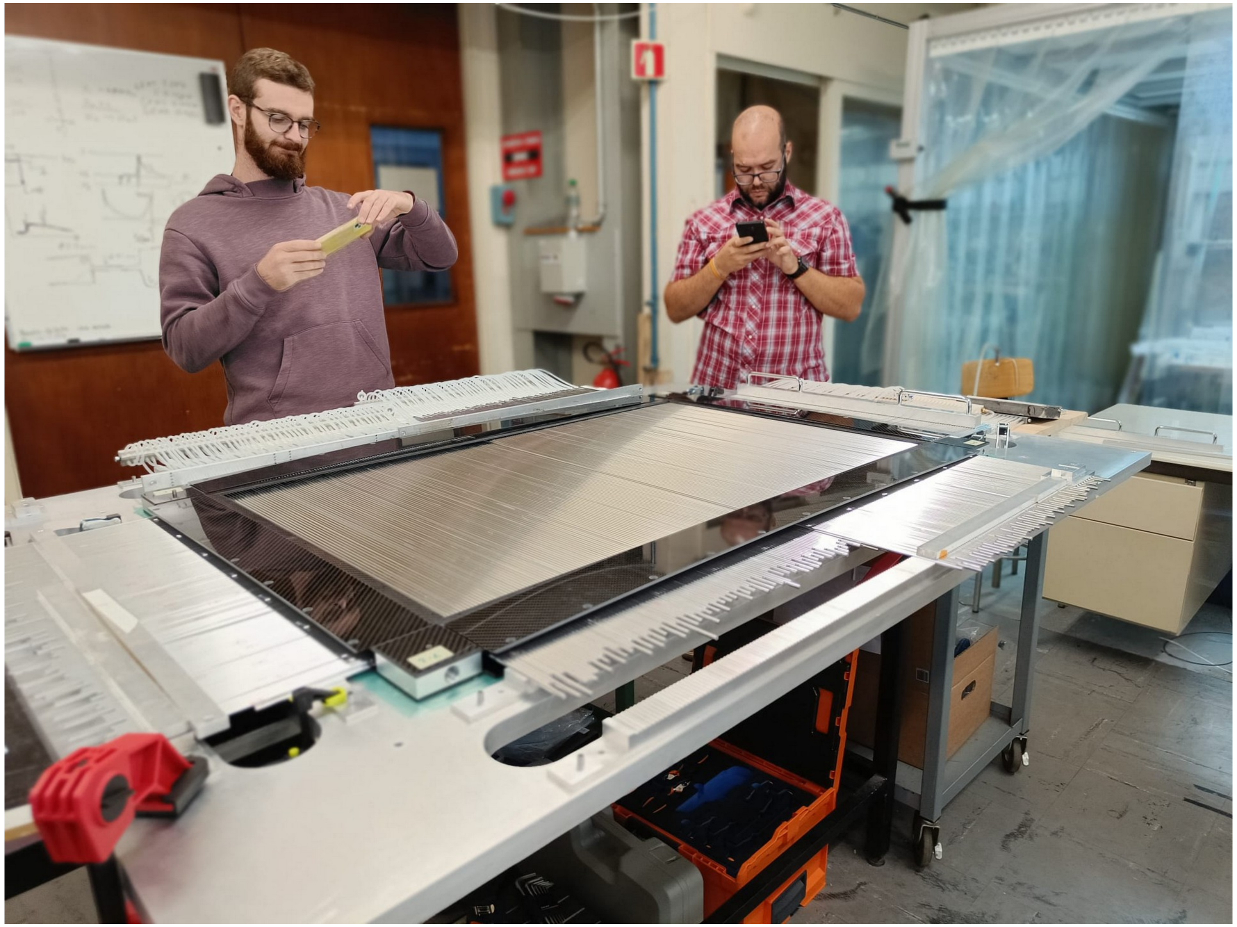
Main goals:
- ν_μ, $\bar{\nu}_\mu$, ν_e and $\bar{\nu}_e$ fluxes vs E
- inclusive and exclusive ν-H and $\bar{\nu}$-H CC (systematics on reconstructed E)
- inclusive and exclusive ν-A and ν-A CC on other nuclear targets

Milestones 2024

31 dic 2024 SAND/STT: test beam of the straw tube target tracker prototype
31 dic 2024 SAND/Tracker : test beam of the drift chamber tracker prototype

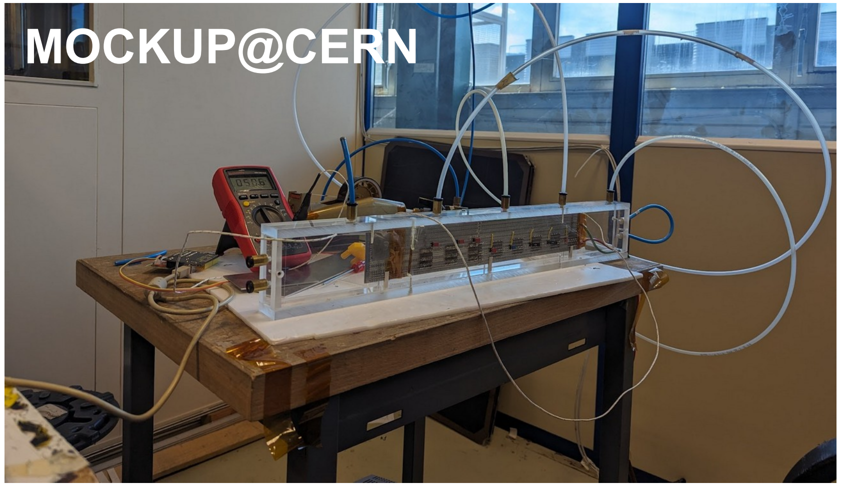
Per quanto riguarda STT un prototipo 80x120 cm verrà assemblato al CERN nei prossimi 10 giorni insieme ai nostri collaboratori russi che hanno finora costruito il mockup e i prototipi 20x20 cm.

Un test di montaggio a secco è stato già effettuato nel mese di Ottobre unendo le forze da JINR/INP (Mosca), INFN (Pisa e Roma1), GTU (Tbilisi), NISER (India)

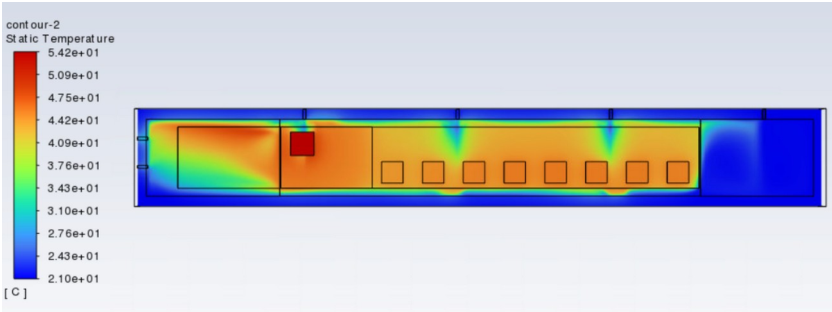


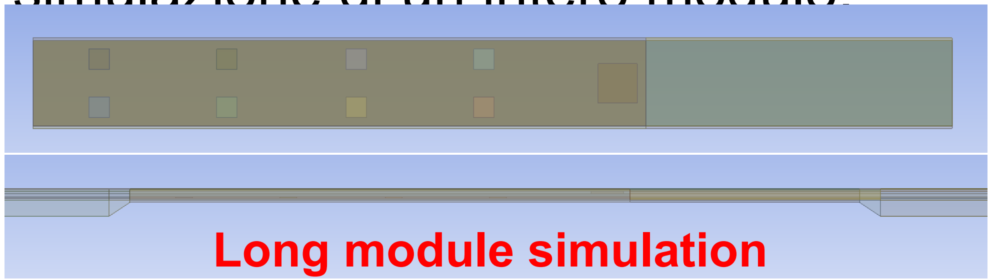
Un secondo prototipo STT 80x120 cm verrà assemblato a Pisa all'inizio del 2024 traendo frutto dell'esperienza del montaggio al CERN.

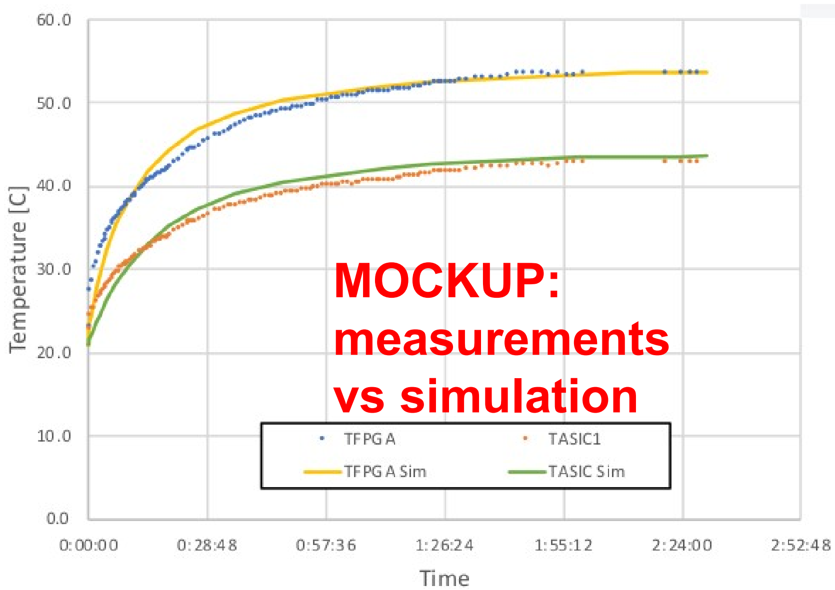
Validazione della simulazione termica con mockup

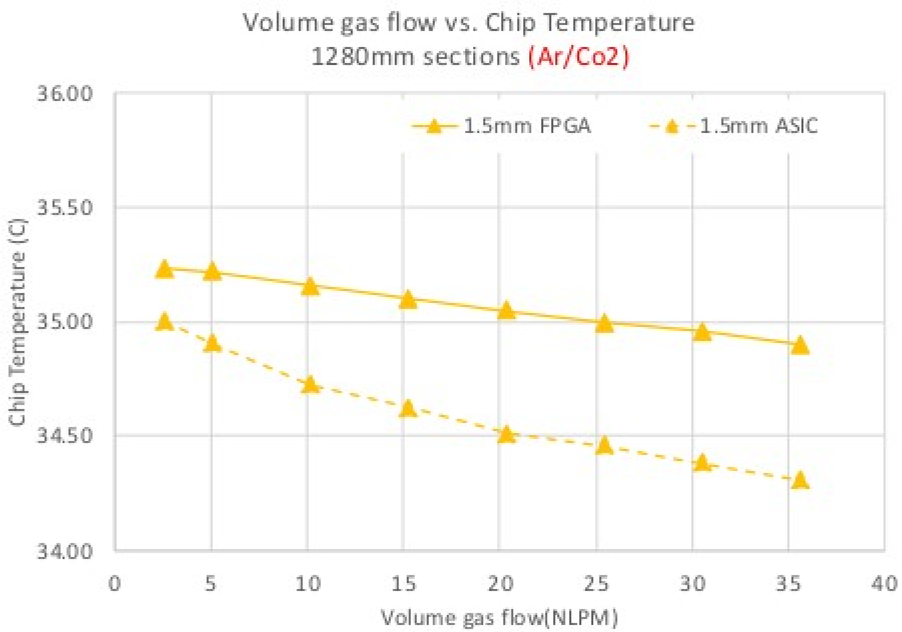


Un simulatore della dissipazione termica prevista dall'elettronica posta all'interno dei moduli STT è stato usato per verificare i risultati della simulazione.
L'accordo è molto buono e convalida il risultato della simulazione di un intero modulo.

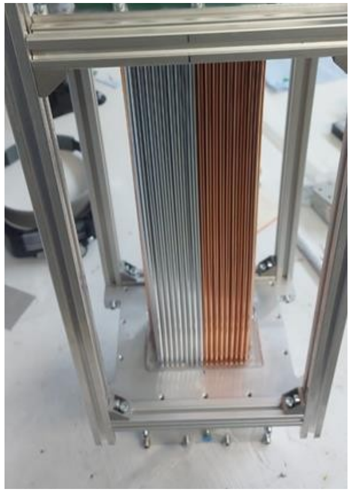


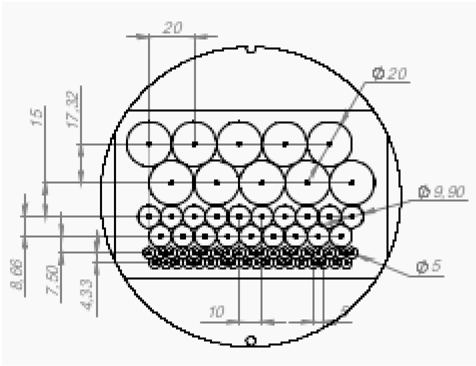




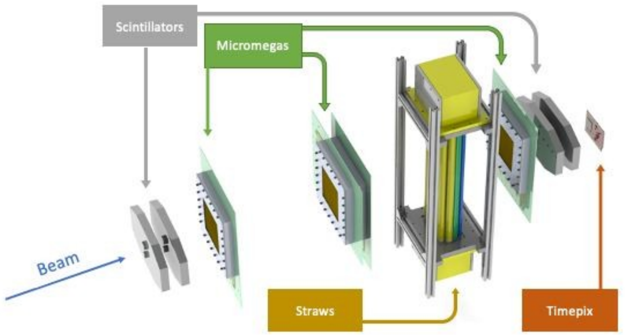


Ultimi risultati dai test su prototipi di straw al Cern

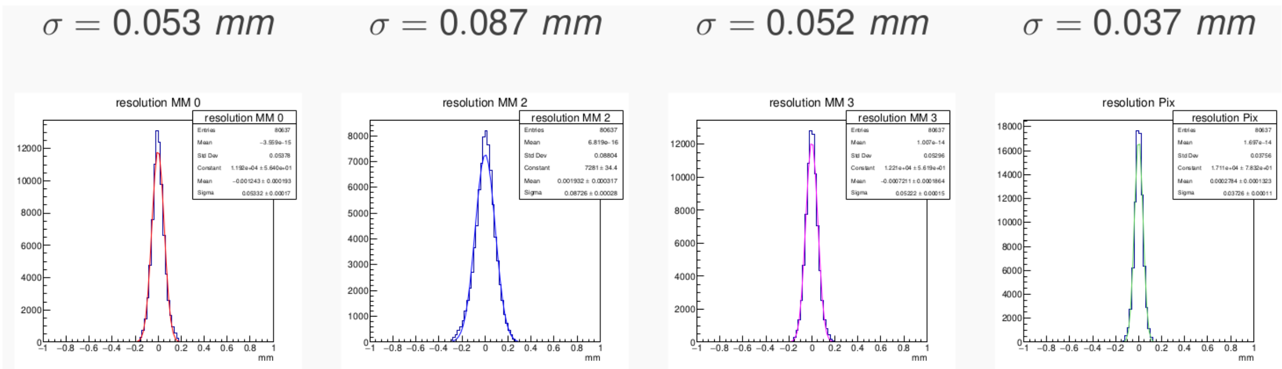




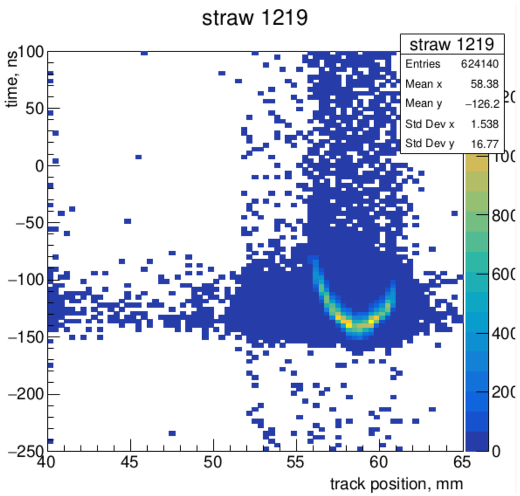
Il gruppo di Dubna sta continuando l’attività di test sui prototipi (collegata anche a altri esperimenti: SHIP, HIKE, NA62, SPD, COMET) presso la North Area del CERN (H4 beam line).

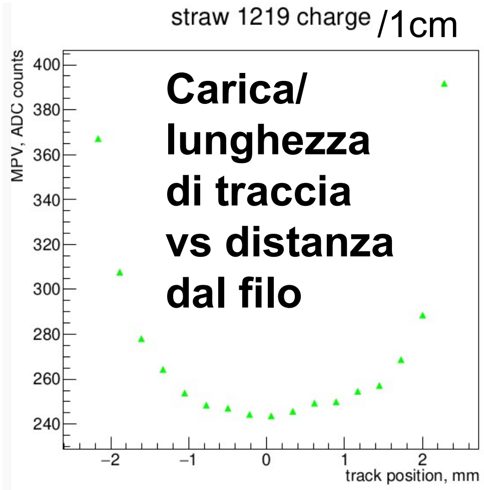


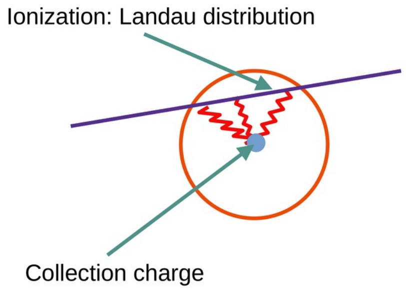
Sistema di tracciatura: 3 MicroMegas + 1 Pixel detector:



Relazione tempo-distanza di drift

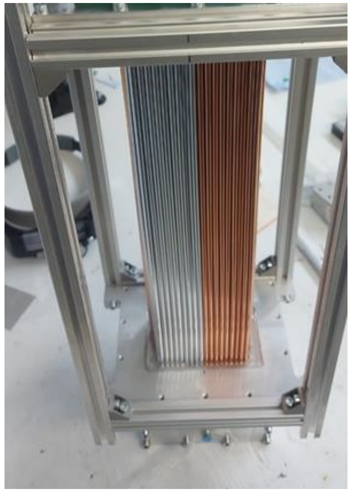


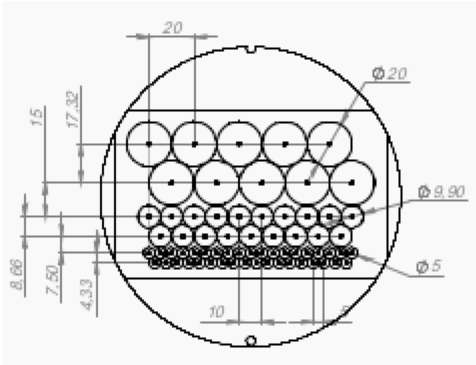


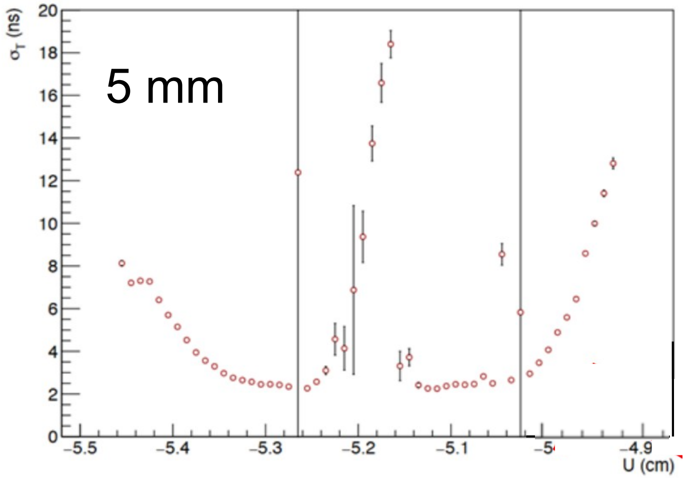


Chip usato per leggere gli straw: VMM3

Ultimi risultati dai test su prototipi di straw al Cern



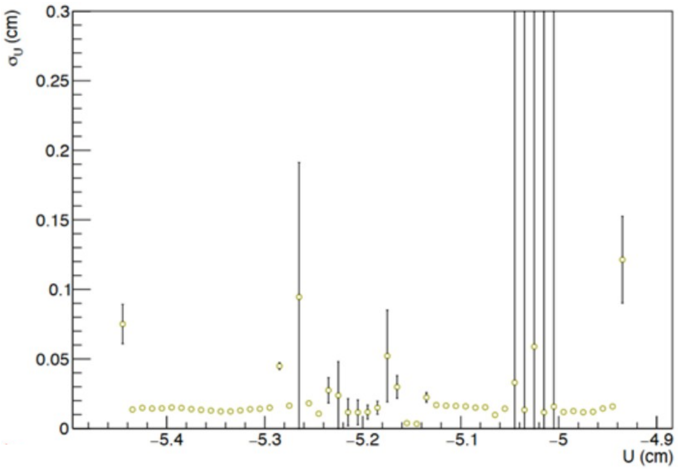




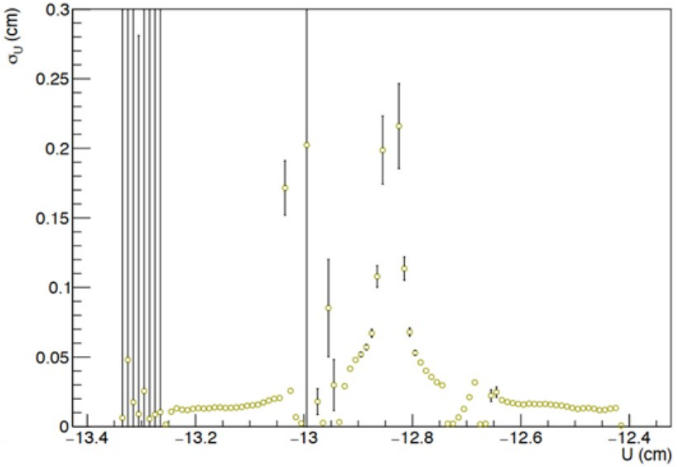
Migliore risoluzione in tempo: 2 ns

Risultati PRELIMINARI

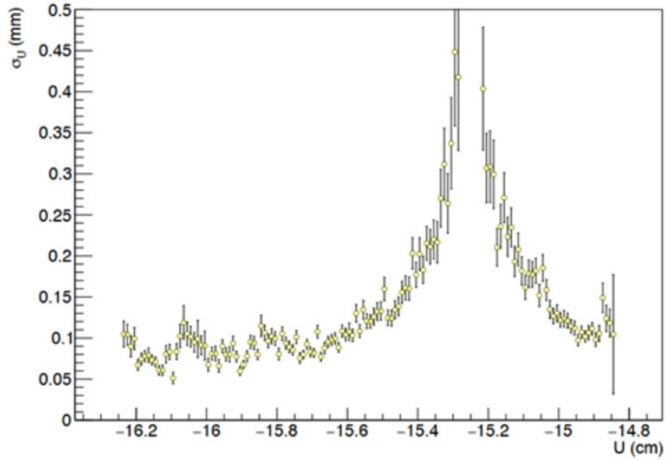
5 mm



10 mm



10 mm SHIP TB 2017



	5 mm	10 mm	10 mm SHIP TB 2017
Migliore risoluzione in tempo:	2 ns	4 ns	3ns
Risoluzione media pesata in posizione:	136 μm	150 μm	100 μm

Questioni aperte: Simulazione

- L’attuale simulazione si basa su uno smearing gaussiano della posizione del deposito di energia basata su esperimenti precedenti. Occorre aggiornarla con i risultati dei test sui prototipi avendo anche un’idea più chiara della fase di digitalizzazione.

- La scelta del diametro di 5 mm per gli straw è stata fatta riducendo il diametro di 10 mm finché non si smetteva di guadagnare in risoluzione in impulso. Occorre studiare l’effetto sulla fisica (misura del flusso dei ν) di straw di dimensioni maggiori (6, 8 o 10 mm).

- La costruzione dei prototipi necessita di sapere quali sono i requisiti sull’allineamento e sulla sagitta dei fili: richieste di precisione troppo spinta possono risultare molto più costose se non addirittura infattibili se proiettate sulle dimensioni di 4 m.

- Occorre studiare la dipendenza dall’angolo di inclinazione delle tracce della risoluzione in impulso e le implicazioni sulle misure di fisica di nostro interesse

Questioni aperte: Meccanica

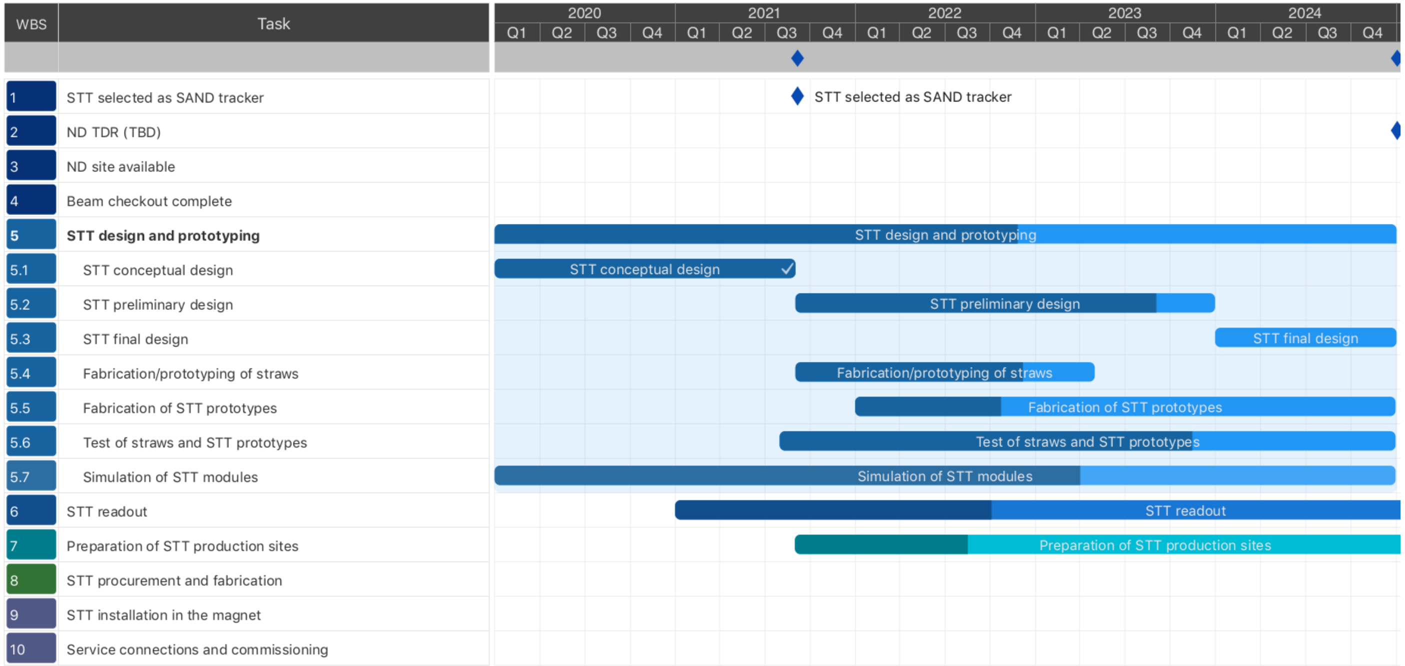
- I test sui prototipi 80x120 sono solo il primo passo: occorre studiare e verificare sperimentalmente la fattibilità dei moduli più lunghi.
- I pin per il fissaggio dei fili usati in passato risultano non più disponibili a prezzi accettabili. Vanno studiate e provate soluzioni alternative
- Il sistema di gas può essere commissionato al CERN ma occorre stabilirne i parametri
- Il sistema di raffreddamento deve essere testato su un modulo reale: possibili difficoltà possono provenire dall'ostruzione del flusso da parte di residui di colla o dei distanziatori previsti per tenere centrato il filo.
- La modularità del flussaggio di gas potrebbe essere aumentata per garantire minor danno in caso di rottura di un singolo straw
- Chi, dove e quando realizzerà il modulo di 4 metri?

Questioni aperte: Elettronica

- Nei test al CERN dei prototipi si stanno testando usando due chip esistenti: VMM3 (che ha un baco nella misura in energia per piccoli segnali) e TIGER (che satura per le energie più alte). Entrambi hanno bisogno di una revisione che deve essere commissionata in tempi brevi. Chi ne copre il costo?

- Qualunque sia la scelta tecnologica sulla lettura dei fili occorre sicuramente coinvolgere più persone cui assegnare compiti e responsabilità precise e assicurarsi che i tempi di realizzazione tornino con quelli previsti per l’istallazione

Questioni aperte: Tempi e Costi



- La time schedule mostrata per la realizzazione di STT è molto aggressiva: non si arriverà ad avere un prototipo di lunghezza 4 m, richiesto per congelare il diegno finale, per la fine del 2024.

- La stima dei costi per STT va aggiornata sulla base delle soluzioni costruttive indicate dalla produzione dei prototipi

- Esiste una time and cost schedule per la soluzione a drift chambers?

- Poche persone realmente attive al momento. E' importante coinvolgere più persone e tenerci stretti gli attuali collaboratori internazionali

BACKUP

STT working group summary of activities

Biweekly meetings mainly chaired by R. Petti, USC (https://indico.fnal.gov/category/1402)

Items covered:

- test beam of small scale prototypes (ASIC selection)

- New ASIC requirements and contacts with ASIC developers

- Straw tubes characterization

- Staw endplugs and wire Pins

- Design and construction of a 1200x800 mm^2 module

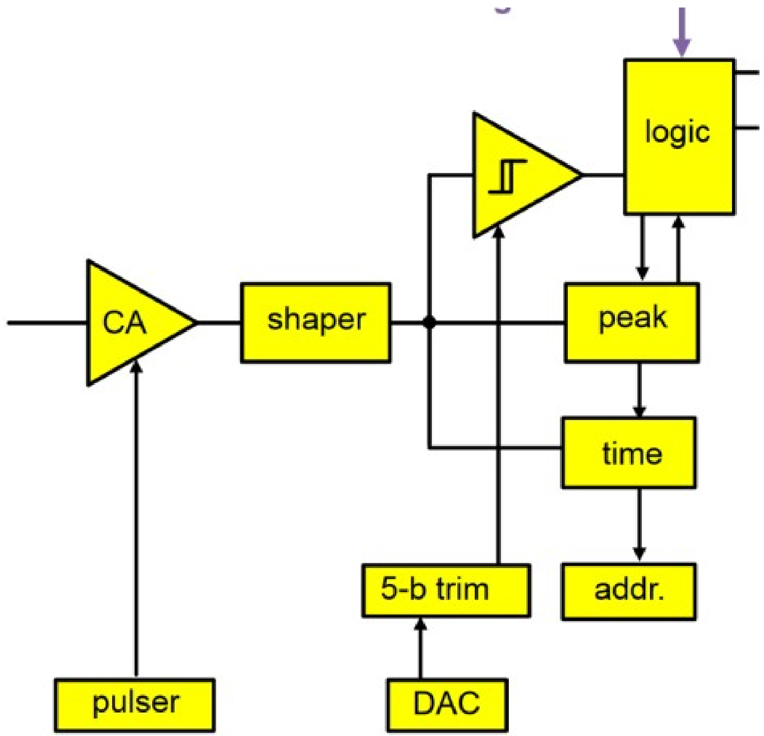
- Development of assembly procedure for full scale modules

- Cooling system

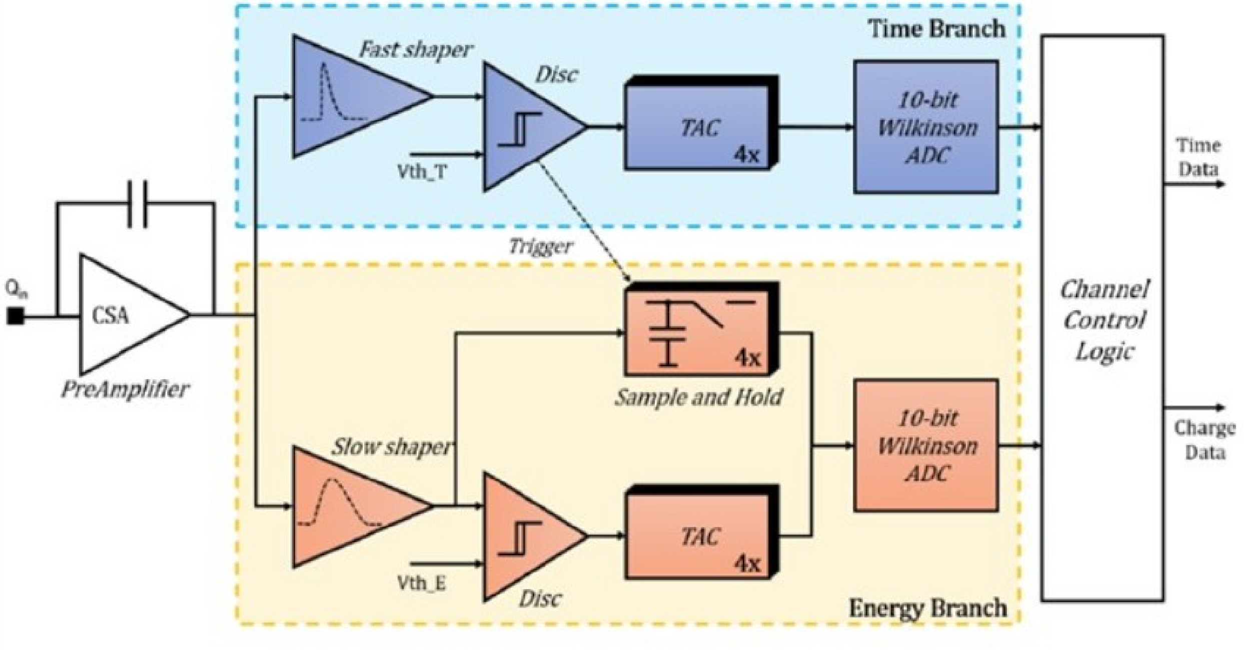
- Gas system

- Simulation (acceptance studies)

ASIC selection: VMM3 vs TIGER



VMM3 Architecture



TIGER Architecture

BOTH ASICS NEED TO BE REVISED:

VMM3 has a bug on Energy measurement for low signals.
(VMM3a has fixed the energy bug but has a bug on time measurement).

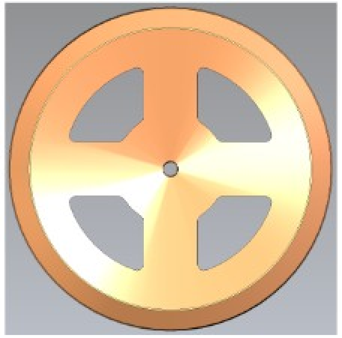
TIGER has two different shapers for Time and Energy measurements. Two threshold levels are also possible. Dynamic range needs to be adapted.

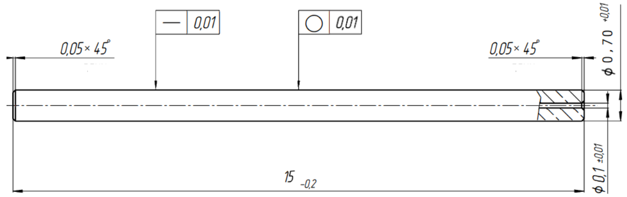
ASIC requirements

- Modularity: 64 channels
- Input capacitance: 10-40 pF (optimize for 40 pF)
- Flat cable length: 10-60 cm (capacitance 1-5 pF)
- Architecture: dual sub-channel with independent gain and shaper and integrated digital path
  (i) fast shaper & high gain for time measurement
  (ii) slow shaper & low gain for energy measurement
- Minimum charge: 4 fC (time measurement), 20-40 fC (energy measurement)
- Maximal charge: 10-20 pC (energy measurement)
- Dynamic range: 1,000 (energy measurement)
- Timing resolution: < 1 ns
- Gain settings: (i) 6, 9, 12 mV/fC for time measurement
  (ii) 0.1-0.5 mV/fC for energy measurement
- Peaking times: (i) 6, 10, 25 ns fast shaper
  (ii) 50, 100, 200 ns slow shaper
- Power consumption: <10 mW/channel
- Expected rates: ≪1 kHz

These requirements have been discussed with:
- Gianluigi De Geronimo (VMM3)
- Alberto Bortone (TIGER)

Straw endplugs and wire pins





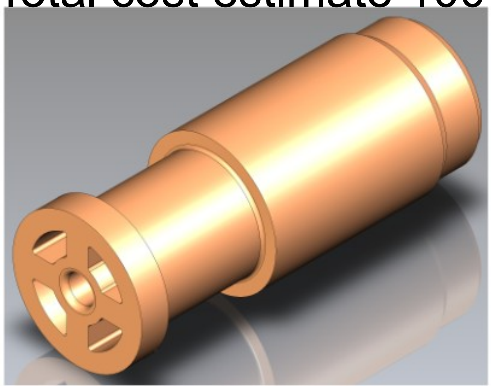
Straw endplugs must:
- Hold the crimping pins in the required position
- Guarantee a good gas flow (self-cooling)
- Enable wire replacement

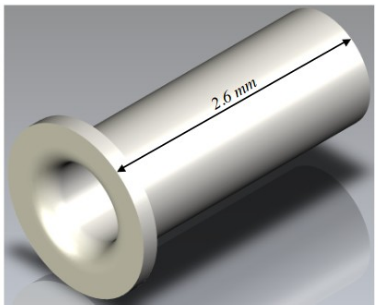
Wire pins must:
- Hold the wire under tension (~50 g)
- Center the 20 μm wire with accuracy < 40 μm
- Provide electrical contacts

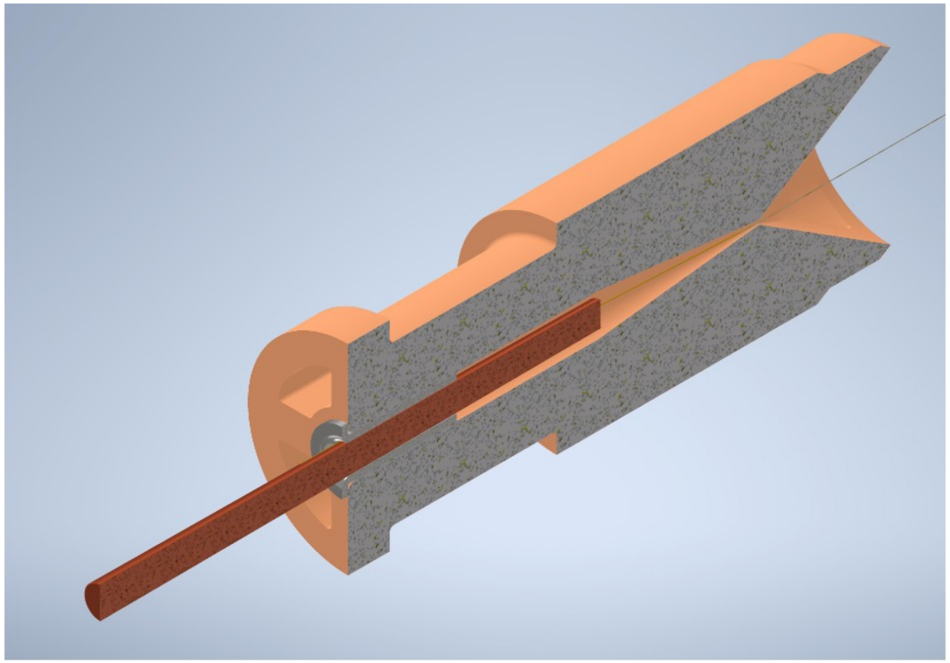
Original choice (adopted by many past experiments) **not viable**:
old pins are out of production. Only offer available 2$/pin x $6 \cdot 10^5$ pins > 1 million $!!

Alternative design (to be tested!):
separate centering and holding features using a larger pin hole and a stick

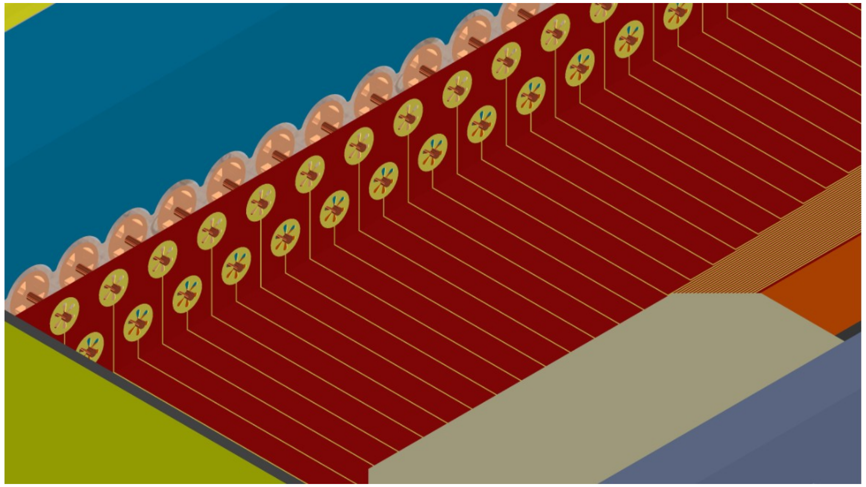
Total cost estimate 100-200K$

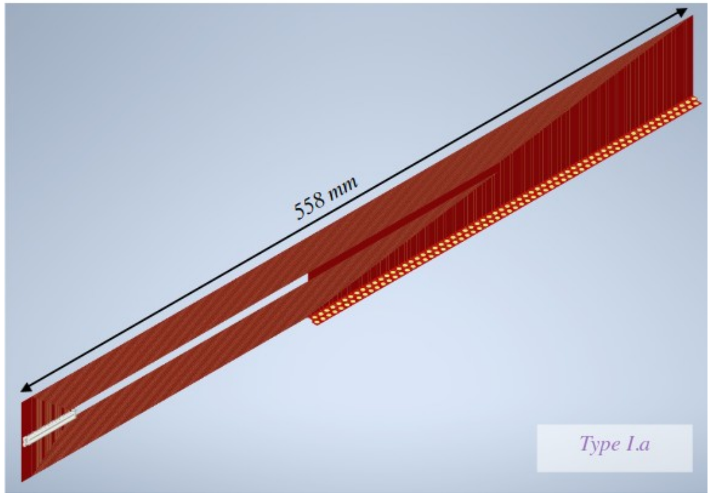


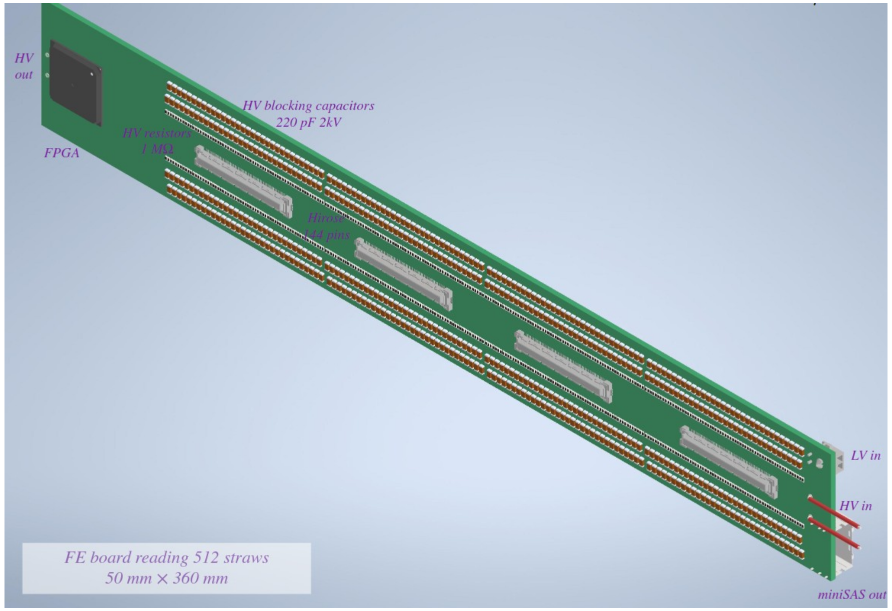


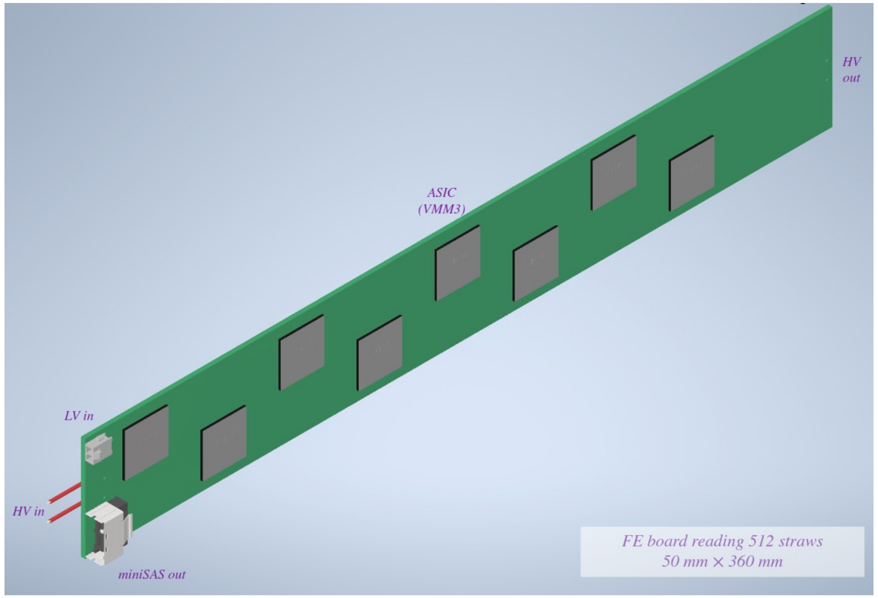


Electrical connection and FEE boards









Combined signal/HV connection of straw pins with flexible Kapton PCB

Technology developed for ATLAS TRT end-cap and used also in NA62 straw tracker

Gas system

Total detector volume: 14 m^3

Ar/CO_2: 14 modules

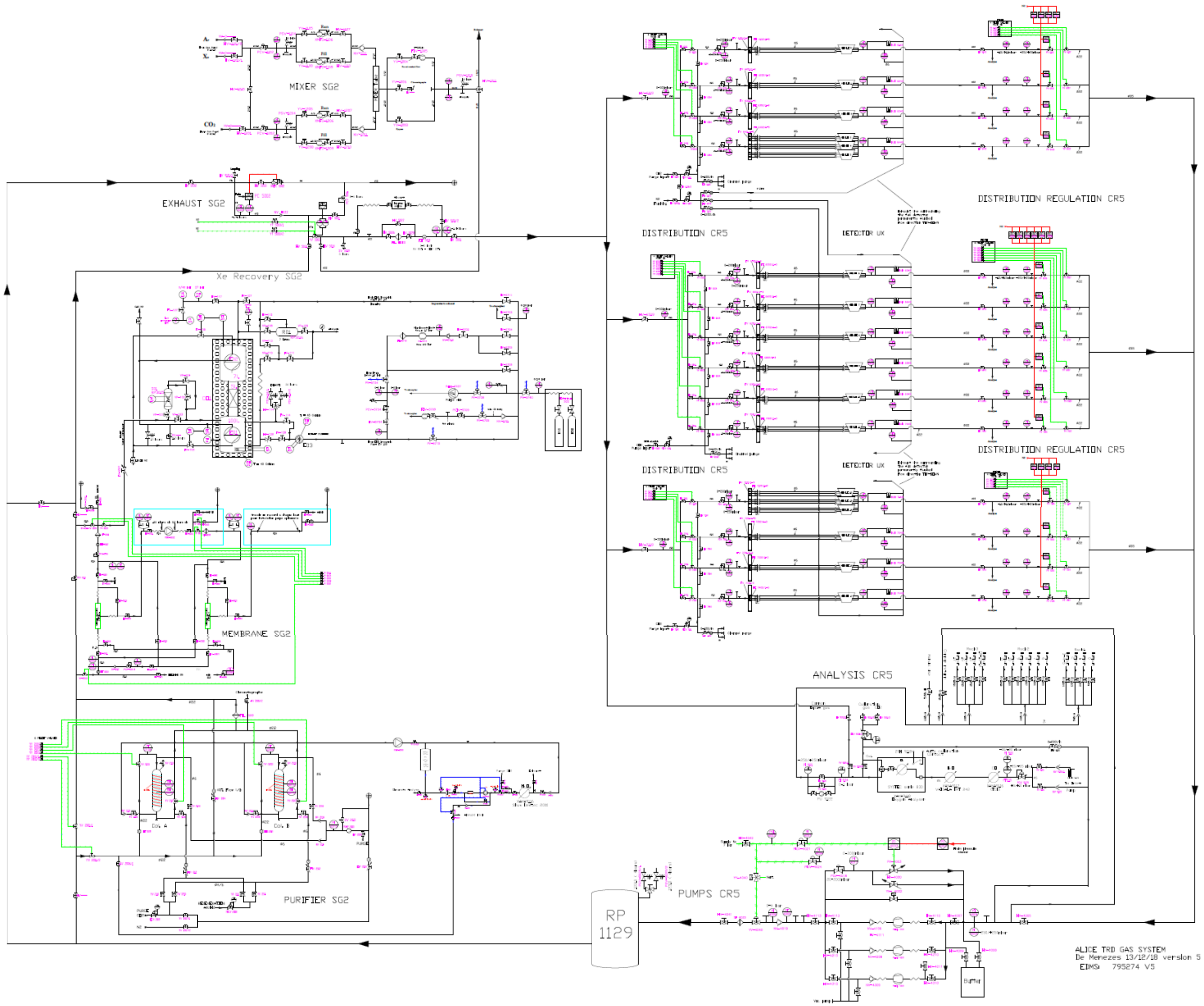
Xe/CO_2: 70 modules

Self-cooling : 10 nl/min/module

Total Xe/CO_2 flow: ~ 42 nm^3/h
flow per detector module ~ 600 n
10 distribution circuits
(1 each 8 modules)
flow per distribution circuit ~ 4 nm

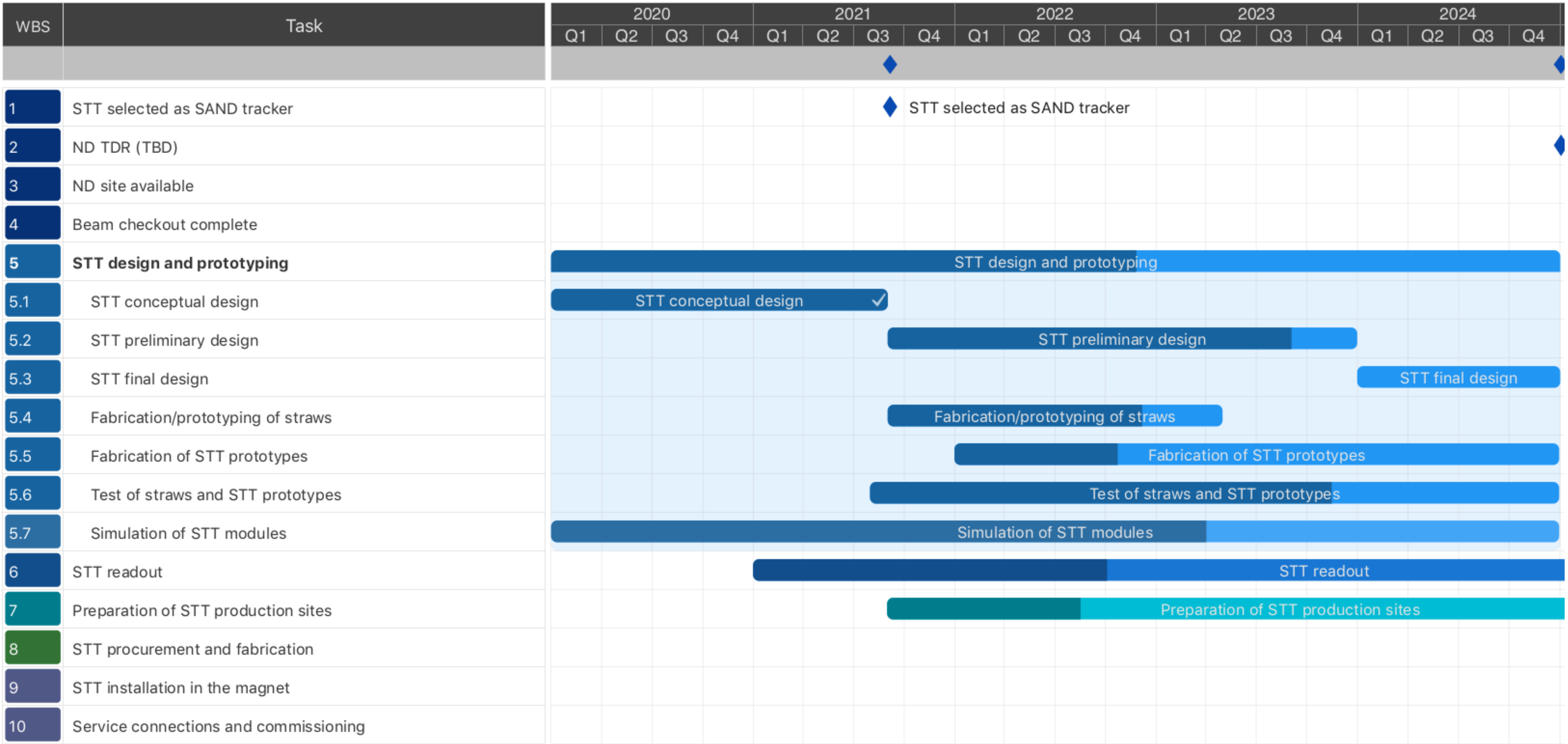
Estimated cost: 55 KCHF

Estimated time for delivery:
44 weeks



Example of ALICE gas System (R. Guida, Cern)

Schedule



Construction of full scale prototype: 2024→ 2025

Expected Final Design: End of 2024 → End of 2025

Production sites still to be defined

Expected 4 years for STT production in case of 5-8 production centers

	ATLAS TRT end-cap	DUNE STT
Number of straws	*245,760*	*∼ 220,000*
R&D and prototyping	*6 (1994-2000)*	*4*
Production years	*6 (2000-2006)*	*4*
Production centers	*2 (JINR, PNPI)*	*5-8*
Average modules per year per center	*5.5*	*4*
Average straws per module	*4,096*	*2,600*
Channels per year per center	*22,528*	*10,400*

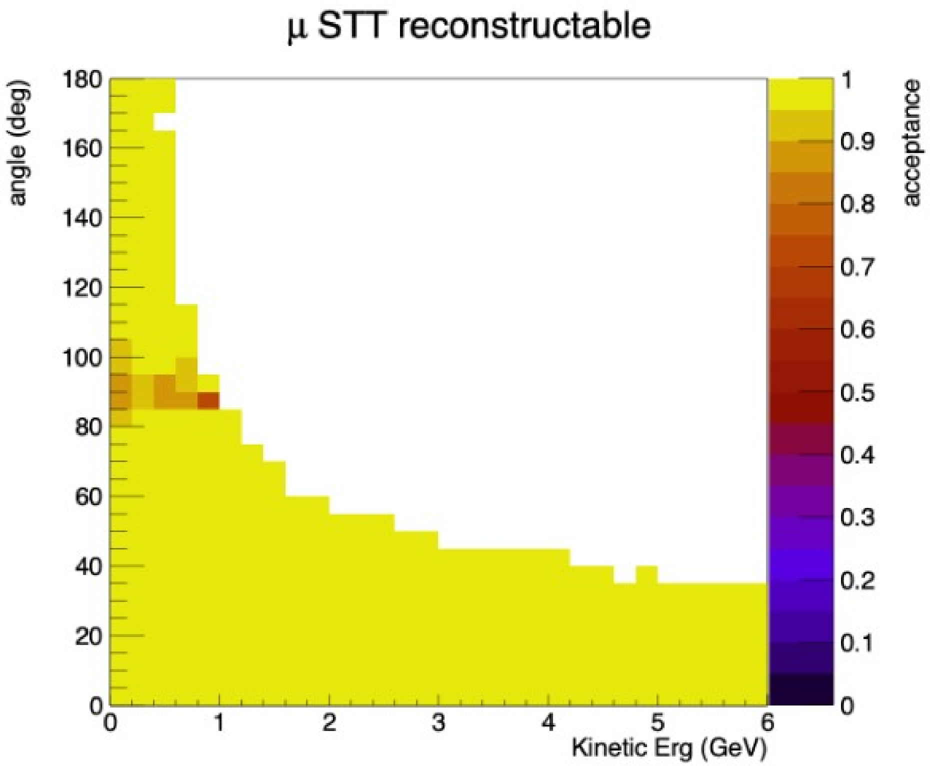
Cost estimate (from 2021)

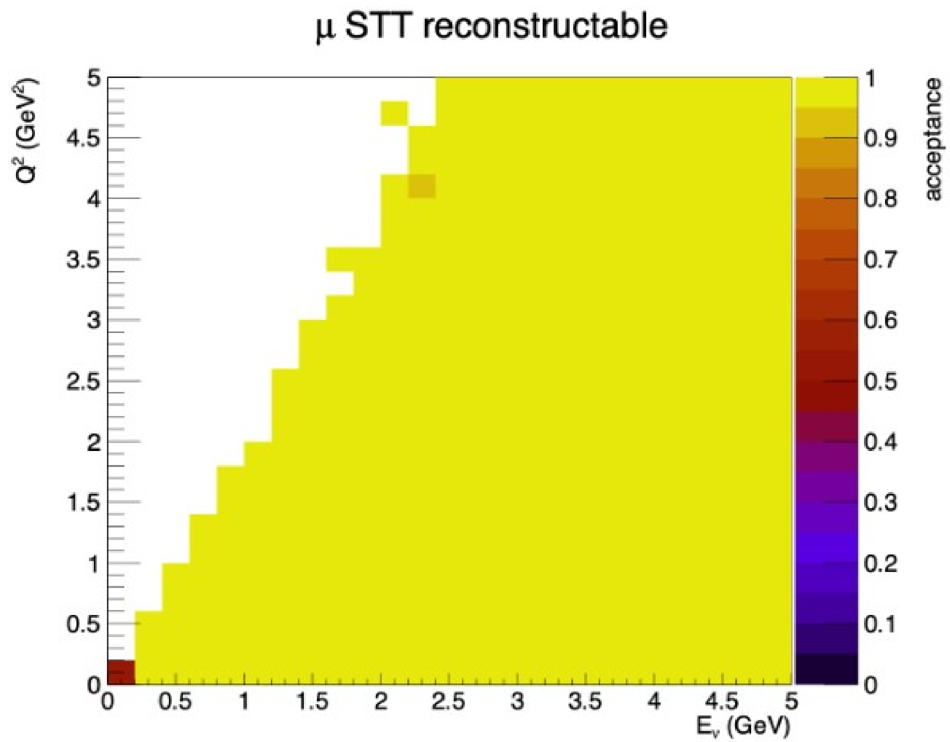
Item	Cost (USD)	Comment
Procure straws	1,550,731	Quote from Lamina Tubular Tech., UK [7]
Procure end plugs	335,911	Quote from FBM, Italy
Procure wire spacers	335,911	Quote from FBM, Italy
Procure crimping pins	295,183	Quote from Medspeztrub, Russia
Procure anode wire	211,038	Quote from Luma metall AB, Sweden
Procure miscellaneous components	123,000	Cost from NA62, ATLAS TRT
Procure mechanics & C-fiber frames	990,000	Quote from Bercella, Italy
Procure STT tools (3 sites)	249,000	Cost from existing facilities
Procure equipment & consumables	100,000	Cost from other straw detectors
Procure gas system (Xe/CO_2 + Ar/CO_2 + cooling)	495,600	Quote from CERN gas group
Procure radiator foils	112,000	Quote from Bloomer Plastics, USA
Procure polypropylene targets	32,200	Quote from Boedeker Plastics, USA
Procure graphite targets (ET10)	49,400	Quote from Weaver Industries, USA
Procure front-end electronics (VMM3)	283,469	Quote from Fraunhofer/BNL
Procure back-end electronics (FELIX)	93,708	Cost from ProtoDUNE
Procure HV components	97,489	Quote from CAEN, Italy
Procure LV components	64,299	Quote from CAEN, Italy
Procure distribution boards	57,360	Cost from ATLAS NSW
Procure cables & connectors	62,310	Quote from CERN store
Total	5,538,609	

Table 43: Estimated core costs for the construction of the baseline STT design described in Sec. 3.3.3. We assume a standard 20% contingency to be added to the core costs.

Acceptance optimization

Muon acceptance in [angle, KE] and [Q^2,E_ν] plane





The graphite target thickness has been optimized looking at the muon acceptance

Straw vs Drift chamber

SLAC-PUB-5232
March, 1990

1.1 Advantages

The advantages of a straw chamber when compared to multiwire chambers are;

1) The straw chamber is inexpensive, robust and relatively simple to construct.

2) The damage and possible down time caused by wire breakage is minimal since the broken wire is isolated in the tube cell and will only need to be disconnected.

3) The effects of signal cross talk are minimized as the straw cathode provides a complete ground shield between nearby wires.

4) The problems of electrostatic alignment distortions are minimal when the anode is kept reasonably centered in the straw.

1.2 Disadvantages

The main disadvantage of a straw chamber is the amount of material the straw introduces into the chamber. This causes more multiple scattering and reduces the momentum resolution. However, in thin walled tubes the amount of radiation length for a 50 micron thick mylar straw of 8 mm diameter is comparable to that of Argon gas at 4 atmospheres pressure. In some designs from the AMY[6] and Novosibirsk[9] groups, the straw itself is pressurized and the only multiple scattering is from the straw itself since the requirement of an outer pressure vessel (Carbon Fiber is typically .2% R.L.) is removed. In addition, the Novosibirsk group has reported the construction of thin mylar straws of 25 micron thickness which would translate into only 0.0174% R.L. per straw.

Disallineamento dei fili e rischio di scarica

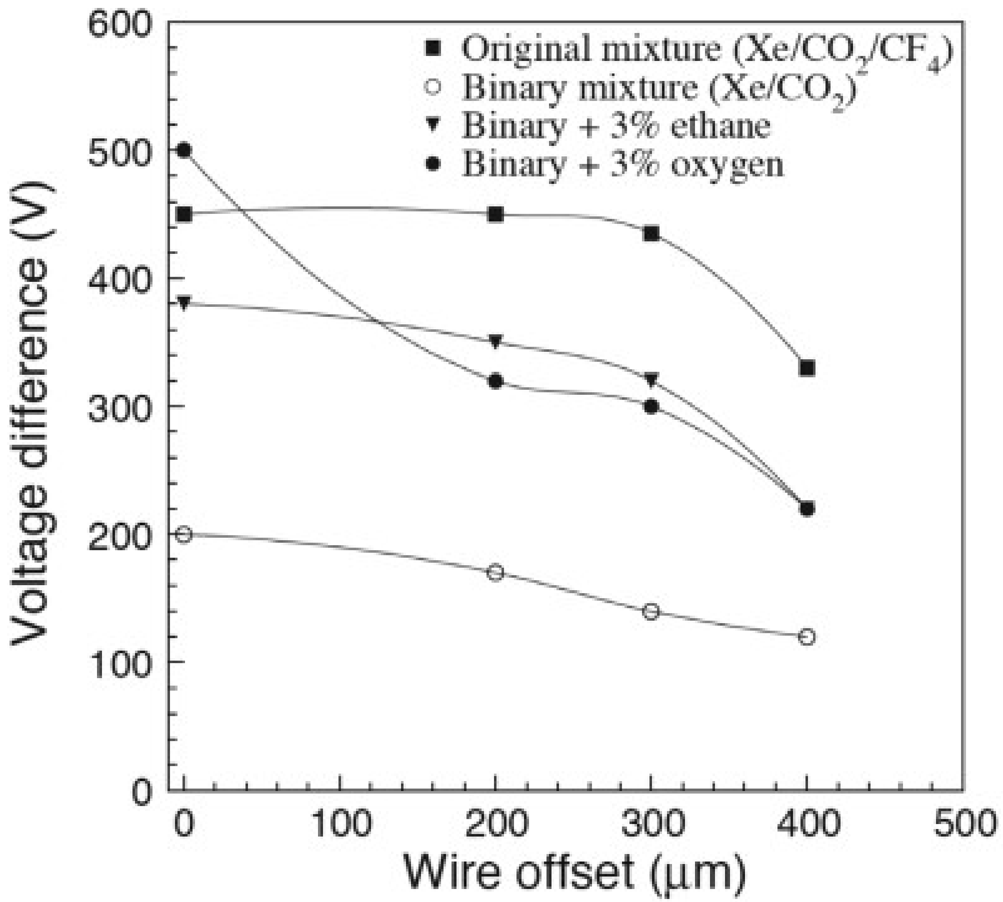


Figure 11.19 Voltage difference between operation and breakdowns as a function of wire offset in the ATLAS TRT (Akesson *et al.*, 2004b). By kind permission of Elsevier.

https://doi.org/10.1017/9781009291200.013

Spostamento al centro a partire da un disallineamento iniziale

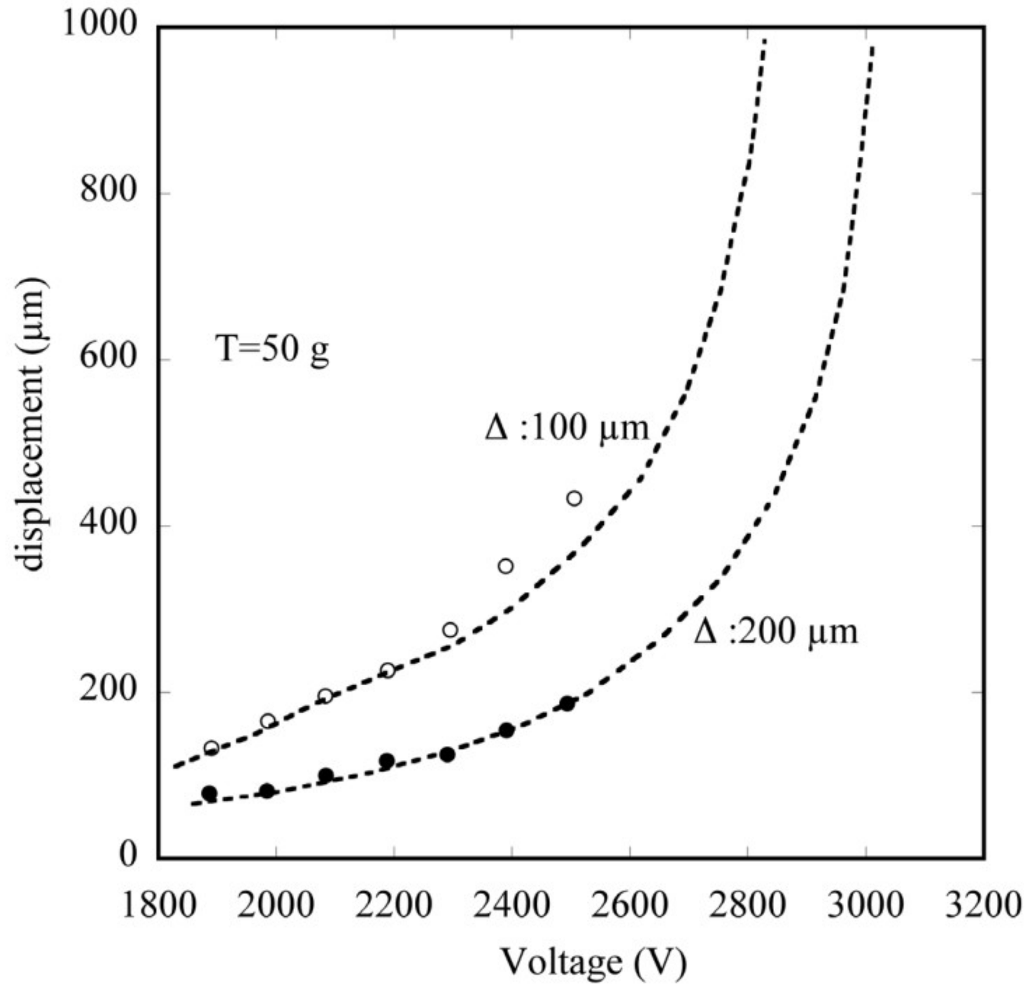


Figure 11.21 Central wire displacement as a function of voltage for two initial offsets, 100 µm (full points) and 200 µm (circles) (Ogren, 1995). By kind permission of Elsevier.

https://doi.org/10.1017/9781009291200.013

Massima tensione di lavoro in funzione del disallineamento

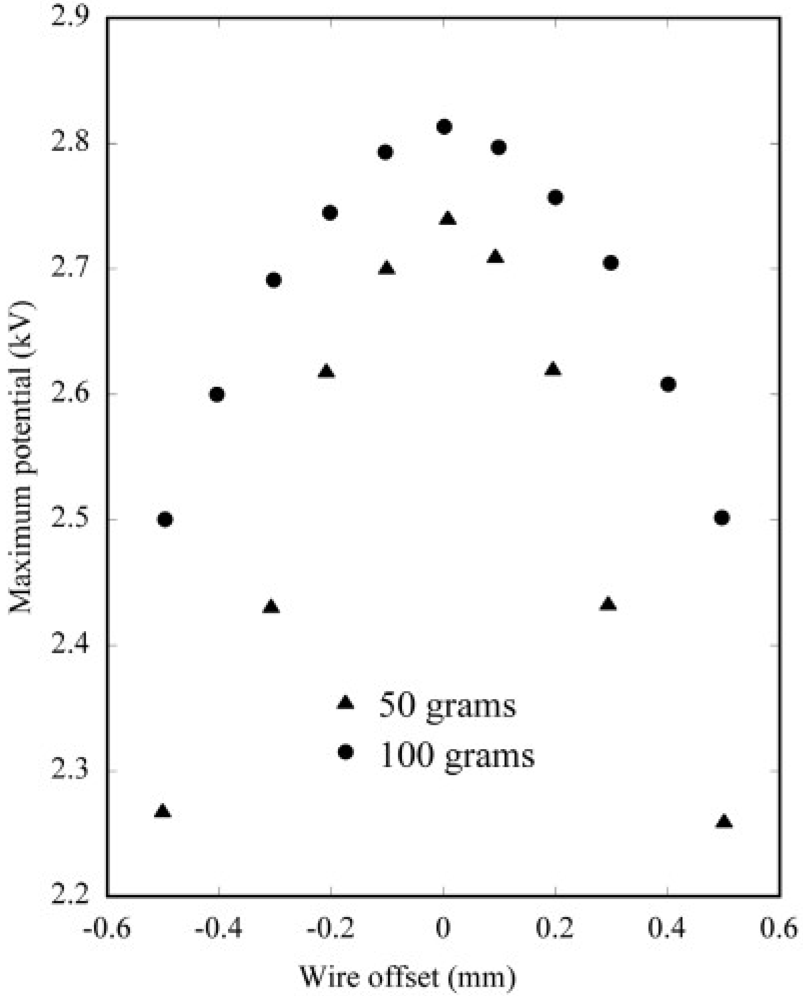


Figure 11.20 Maximum operating voltage as a function of wire offset and two values of tension (Akesson *et al.*, 1995). By kind permission of Elsevier.

$$T \geq \frac{2\varepsilon_0 V^2 L^2}{\pi R^2 (\ln(R/r))^2}$$

https://doi.org/10.1017/9781009291200.013

Effetto dell'umidità sulla lunghezza degli straw

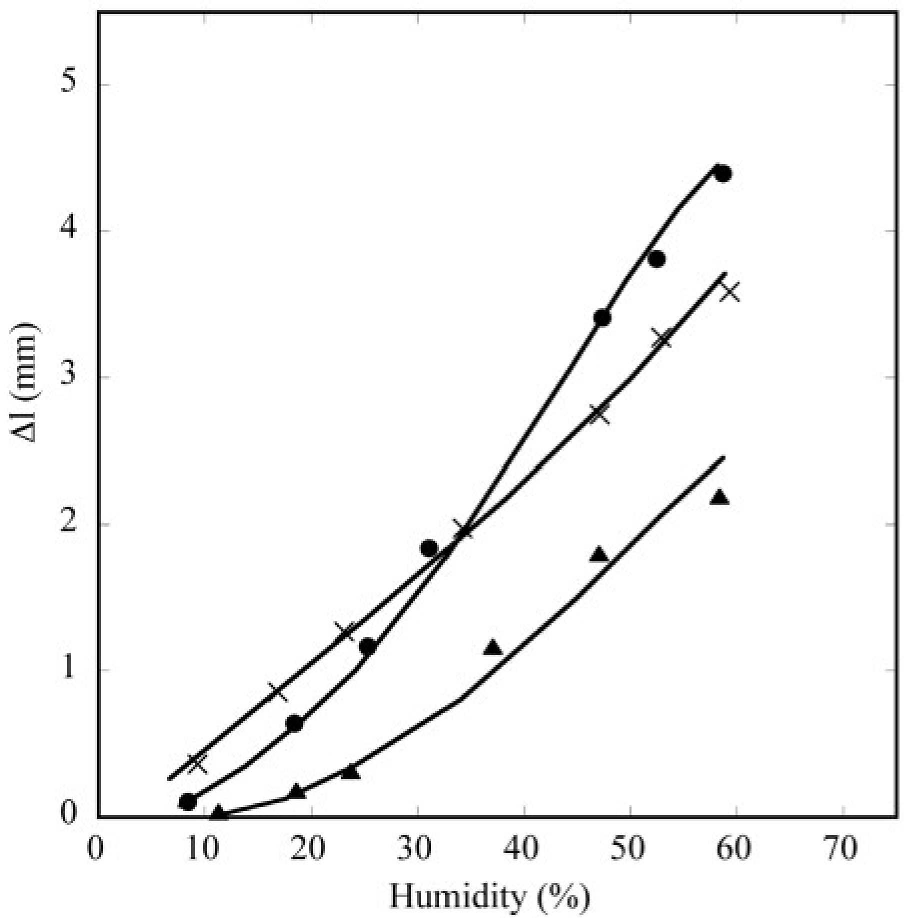


Figure 11.22 Length variations of three 3.2 m long straws as a function of humidity (Bychkov *et al*., 2006). By kind permission of Elsevier.

https://doi.org/10.1017/9781009291200.013

Procurement del film Mylar

E’ in corso l’ordine per 150 km di Mylar alla Fraunhofer:

- The minimal quantity is 150 km of film cut in strips ready to be used by our ultrasonic welding machines (total of 500 coils). The cost of a smaller quantity would be the same.
- We agreed all key parameters and the quality controls for the production of the film.
- The total cost is 48,000 EUR and is higher than the one from the preliminary quote of November 2022, mostly due to additional quality controls and the agreed parameters.
- We expect the quality of the Fraunhofer film to be much better than the Russian film we have been using so far. Fraunhofer already produced the film used for the NA62 straws.

Si chiederà di destinare circa la metà di questo film alla produzione di camere a deriva