COMPASS++/AMBER
A New QCD Facility at CERN SPS

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su invito di Fabio, a seguito dell'approvazione dal CERN: NA66

anche se, come anticipato, ancora presto per parlare di impegni finanziari
e costruttivi dettagliati

interazioni con Tenchini in corso, per definire i passi necessari nell'ambito INFN
presto presentazione in CSN1

Riunione Gruppo 1 TS/UD

....

presentato in CSN1 a Nov 2019

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Apparatus for Meson and Baryon Experimental Research (A new QCD facility at the M2 beam line of the CERN SPS)

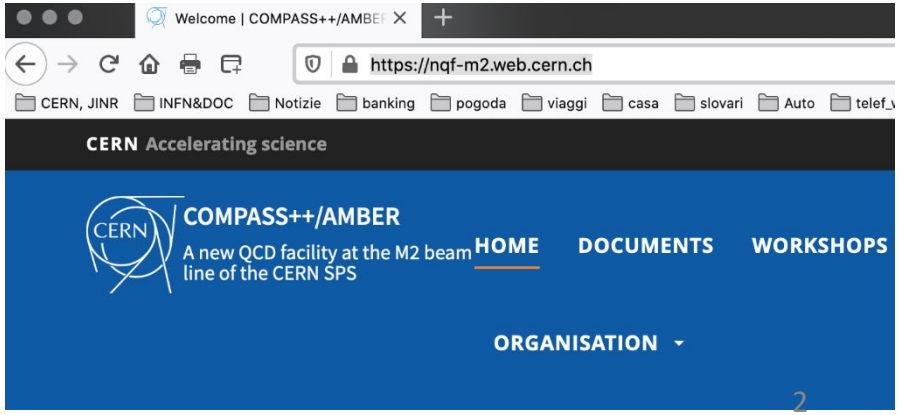
utilizza gran parte dello spettrometro COMPASS
una misura (proton radius) era gia' inserita nell'addendum alla proposta COMPASS assieme alla misura su d
(150 gg di presa dati approvati dal RB nel giugno 2018)

3.6 **COMPASS** /NA58 submitted an update of the addendum to their physics proposal [3]. The SPSC recognizes the physics case of measuring transversity for obtaining new information on the tensor charge, described in the first part of the addendum. The committee considers that the proposed deuteron run of about 150 days, which requires minimal changes to beam line and the experiment, represents a good case for COMPASS operation in the first year after LS2. **The Research Board approved the COMPASS run in 2021.**

giugno 2018

Attività iniziata da parecchio tempo e discussa in una serie di Workshop organizzati allo scopo
(ad esempio: COMPASS beyond 2020 Workshop)

Nuovo sito in preparazione anche se molte delle presentazioni ancora sul sito di COMPASS



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LoI is submitted in Jan. 2019

> 270 authors

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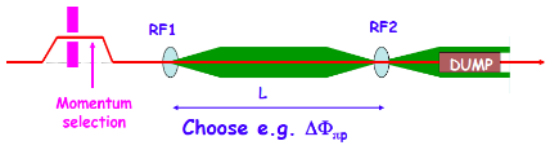
LOI - Gennaio 2019
contiene il programma completo:
Fase I + Fase II

Program	Physics Goals	Beam Energy [GeV]	Beam Intensity [s^{-1}]	Trigger Rate [kHz]	Beam Type	Target	Earliest start time, duration	Hardware additions
muon-proton elastic scattering	Precision proton-radius measurement	100	$4 \cdot 10^6$	100	$\mu^\pm$	high-pressure H2	2022 1 year	active TPC, SciFi trigger, silicon veto,
Hard exclusive reactions	GPD E	160	$2 \cdot 10^7$	10	$\mu^\pm$	$NH_3^\uparrow$	2022 2 years	recoil silicon, modified polarised target magnet
Input for Dark Matter Search	$\overline{p}$ production cross section	20-280	$5 \cdot 10^5$	25	p	LH2, LHe	2022 1 month	liquid helium target
$\overline{p}$-induced spectroscopy	Heavy quark exotics	12, 20	$5 \cdot 10^7$	25	$\overline{p}$	LH2	2022 2 years	target spectrometer: tracking, calorimetry
Drell-Yan	Pion PDFs	190	$7 \cdot 10^7$	25	$\pi^\pm$	C/W	2022 1-2 years	
Drell-Yan (RF)	Kaon PDFs & Nucleon TMDs	~100	10^8	25-50	$K^\pm, \overline{p}$	$NH_3^\uparrow$, C/W	2026 2-3 years	"active absorber", vertex detector
Primakoff (RF)	Kaon polarisability & pion life time	~100	$5 \cdot 10^6$	> 10	K^-	Ni	non-exclusive 2026 1 year	
Prompt Photons (RF)	Meson gluon PDFs	≥ 100	$5 \cdot 10^6$	10-100	$K^\pm$ $\pi^\pm$	LH2, Ni	non-exclusive 2026 1-2 years	hodoscope
K-induced Spectroscopy (RF)	High-precision strange-meson spectrum	50-100	$5 \cdot 10^6$	25	K^-	LH2	2026 1 year	recoil TOF, forward PID
Vector mesons (RF)	Spin Density Matrix Elements	50-100	$5 \cdot 10^6$	10-100	$K^\pm, \pi^\pm$	from H to Pb	2026 1 year	



$\Delta\Phi = 2\pi\ (L\ f\ /\ c)\ (\beta_1^{-1} - \beta_2^{-1})$ with $\beta_1^{-1} - \beta_2^{-1} = (m_1^2 - m_2^2)/2p^2$

PHASE-1

Conventional hadron and muon beams

2022÷2025 and beyond

PHASE-2

RF-separated hadron beam

2030 and beyond

Proposal - Settembre 2019
contiene programma Fase I

Year	Activity	Duration	Beam
2021	Proton radius test measurement	20 days	μ
2022	Proton radius measurement	120 (+40) days	μ
	Antiproton production test measurement	10 days	p
2023	Antiproton production measurement	20(+10) days	p
	Proton radius measurement	140 (+10) days	μ
2024 2024+	Drell-Yan: pion PDFs and charmonium production mechanism	$\lesssim$ 2 years	p, K^+, π^+, $\bar{p}$, K^-, π^-

PHASE-1

Conventional hadron and muon beams

2022 ÷ 2025 and beyond

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the full "LoI" programme

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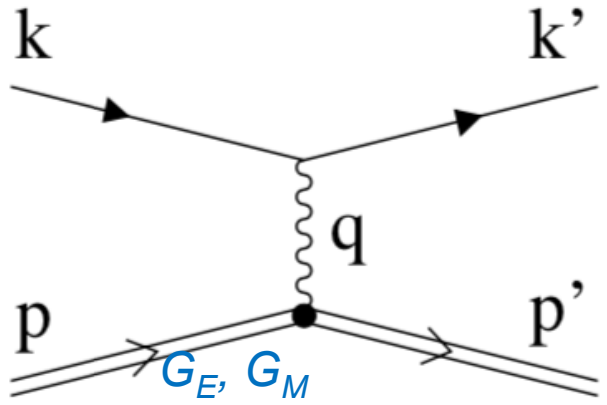

Proton radius measurement from muon-proton high-energy scattering

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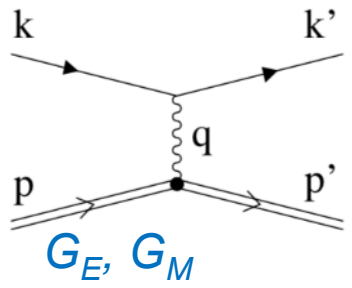
- contradictory findings for the proton radius 0.84…0.88 fm from different experimental and theoretical approaches on the 5% level
- direct determination as slope of the electric form factor G_E at Q^2 near zero
- proposed experiment with precision better than 0.01 fm
- competitive to JLab, MAMI, MUSE



$$\langle r_E^2 \rangle = -6\hbar^2 \left. \frac{dG_E(Q^2)}{dQ^2} \right|_{Q^2 \to 0}$$

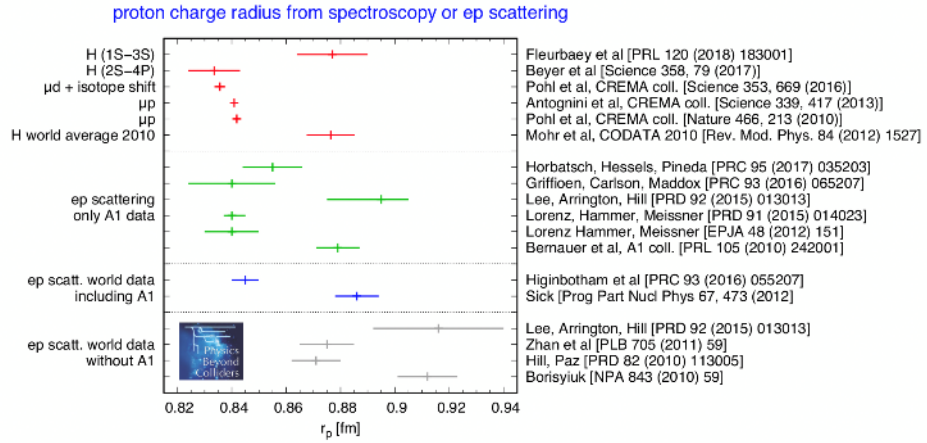
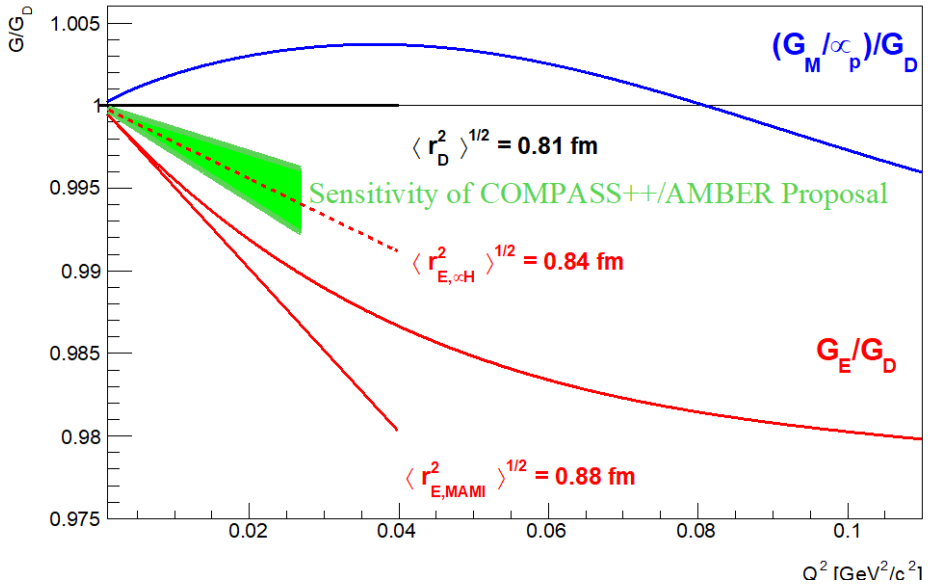


Figure 2: Compilation of the proton radius puzzle, figure taken from [7].

Overview of recent determinations of the proton charge radius r_p from spectroscopy of ordinary or muonic hydrogen (upper part) and from analyses of ep scattering data (lower three parts). The latter are grouped in analysis using only the MAMI A1 data (green), using all the world data (blue), and using the world data excluding the A1 data (grey). Some analyses use dispersion relations and thus additional data from the time-like region (Lorentz, Hammer, Meissner and Hill, Paz). The analysis of Horbatsch, Hessels, Pineda uses additional input from χPT.



Proton radius measurement from muon-proton high-energy scattering

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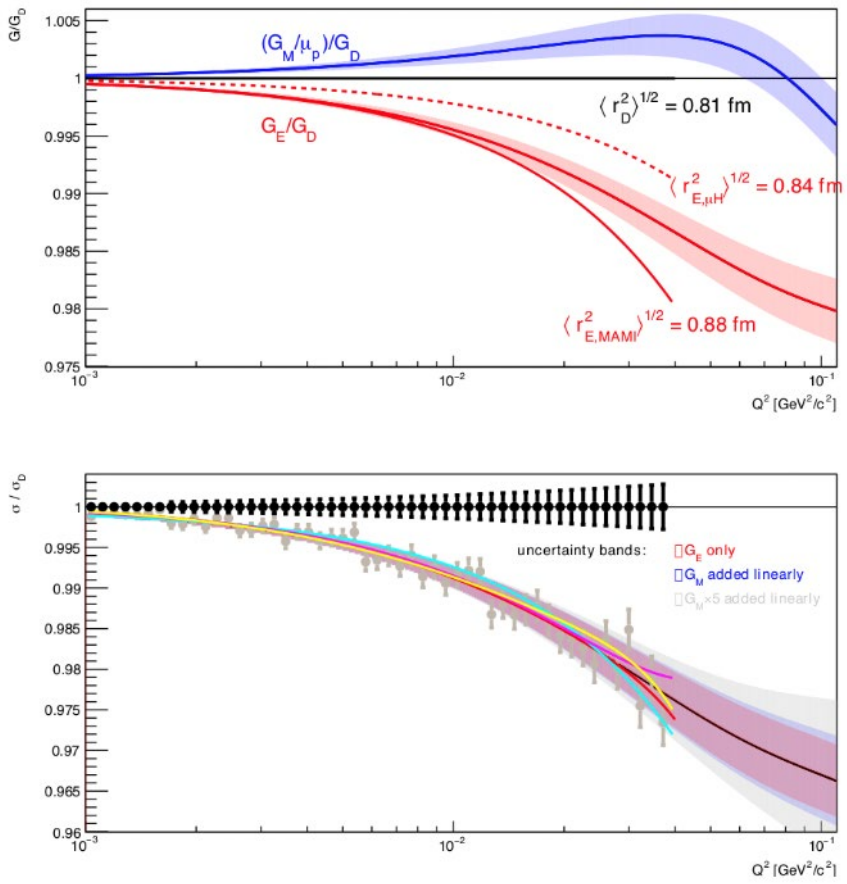
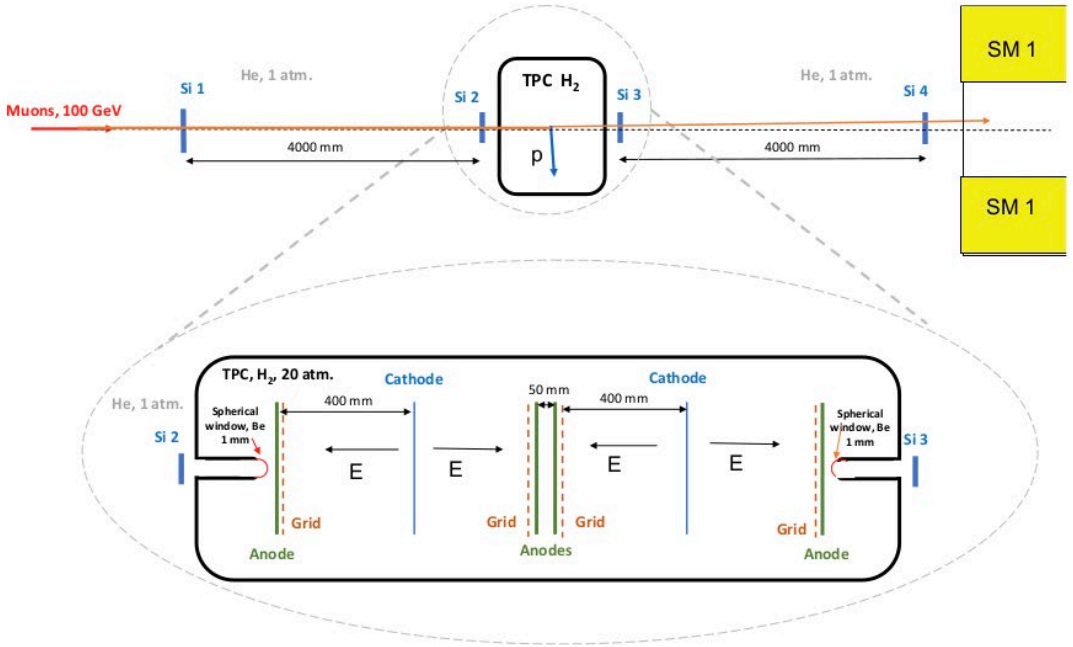
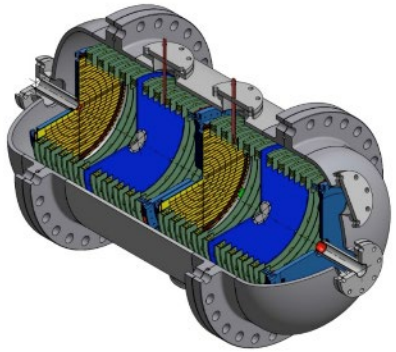


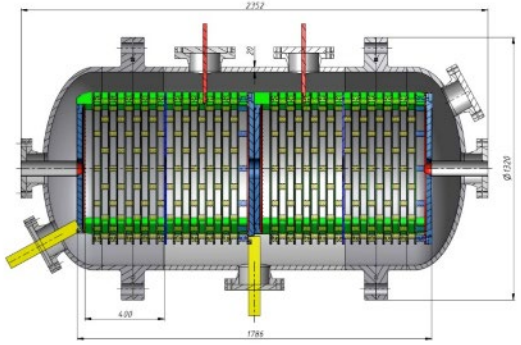
COMPASS++/AMBER proposal:

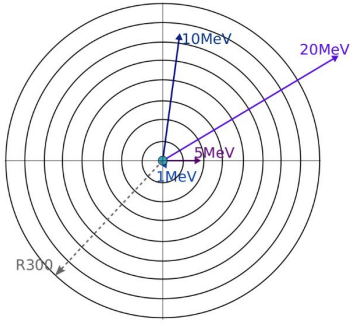
- precise measurement of recoiling proton in a pressurized active-target H_2 cell with TPC readout
- in coincidence with the scattered muon kinematics at 100 GeV beam energy
- reach a point-to-point precision of 10^{-3}
- Q^2 range $10^{-3} \div 4 \times 10^{-2}$ GeV^2fit with free parameters up to terms in Q^4 gives $\langle r^2 \rangle$ with the desired precision
- advantegous / complementary systematics compared to the other experimental approaches

New hardware: The active-target TPC for the proton radius measurement









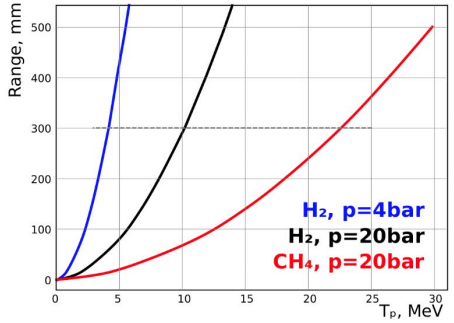


Figure 45: Engineering design for the four-cell hydrogen TPC.

New hardware: Trigger scheme

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- continuous ‘triggerless’ first-level readout
- time-slicing according to detector response time
- marking of slices for higher-level readout

Figure 39: Overview for the time-slicing

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the full "LoI" programme

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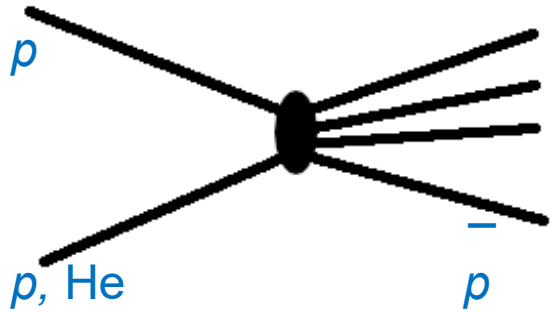

Proton beam: Search for Dark Matter

Absolute cross section measurement $p\ \mathrm{He} \longrightarrow \bar{p}\ X$

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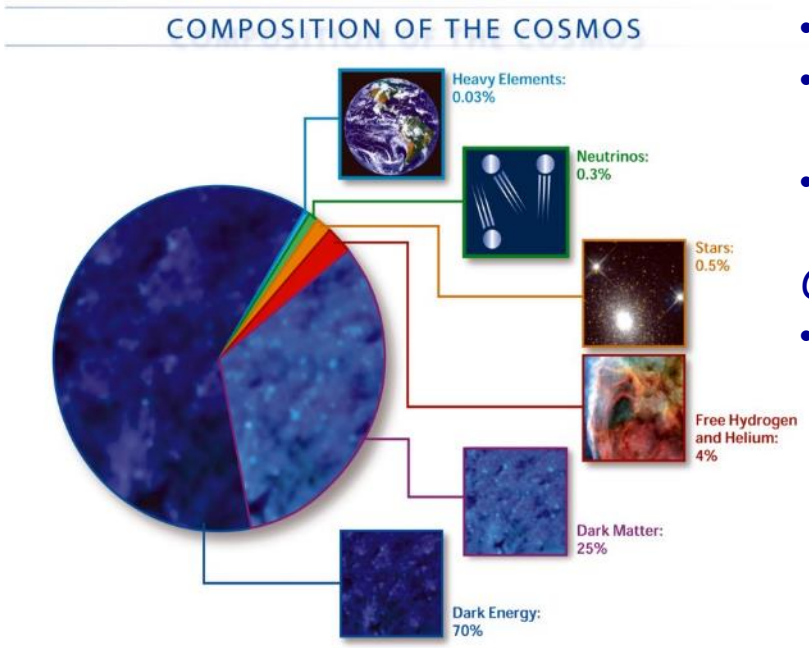


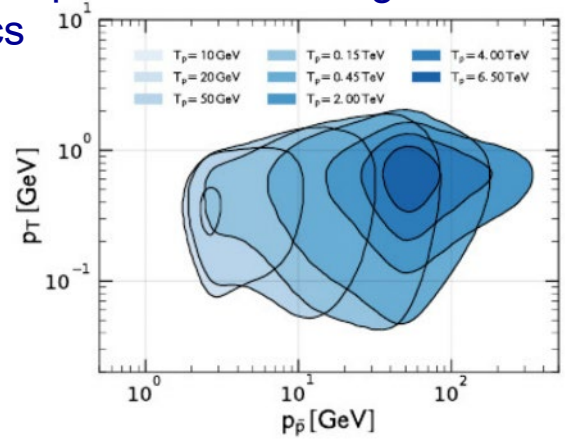
Physics case:

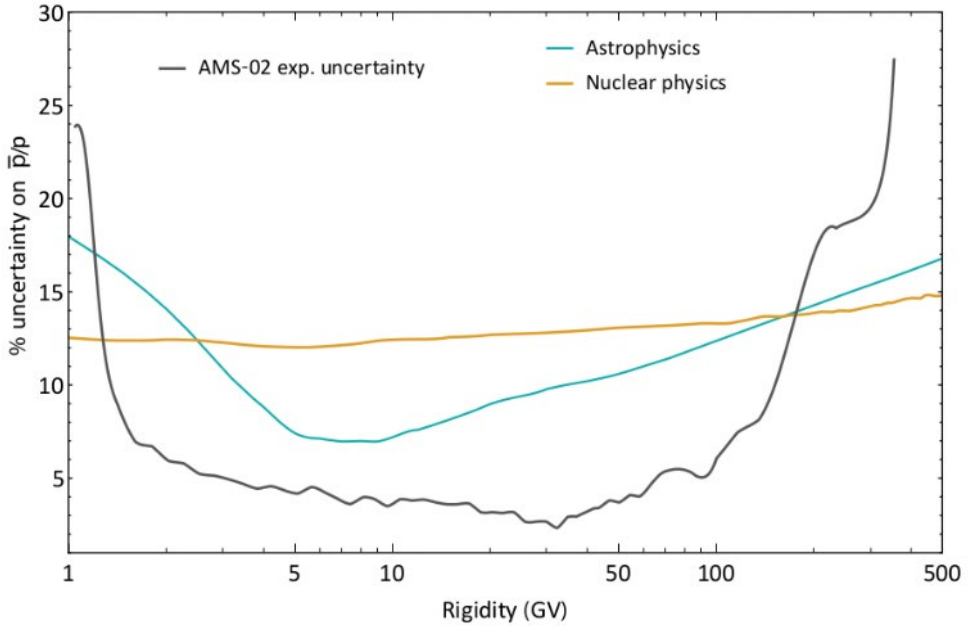
- precise data on cosmic antiparticle flux from AMS2 data
- possible sources: standard model and dark matter processes
- limiting factor for MC simulations: production cross sections, currently only known to 30-50%

COMPASS++/AMBER proposal:

- measure inclusive antiproton production cross sections in *pp* and *p*He collisions over a wide beam range of 50…250 GeV

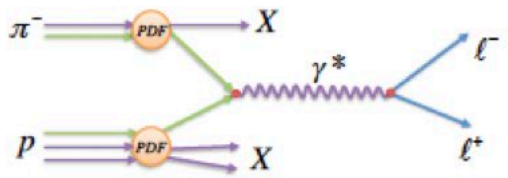
parameter space for fixed-target kinematics





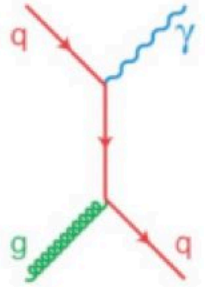
Learning about the partonic structure of pions

Drell-Yan:



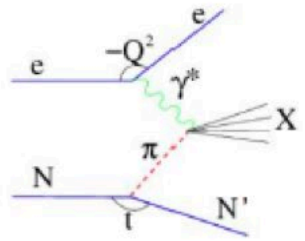
- 90's: NA3, NA10, E615
- 10's: COMPASS-II
- 20's: New Experiment

Prompt photon production:



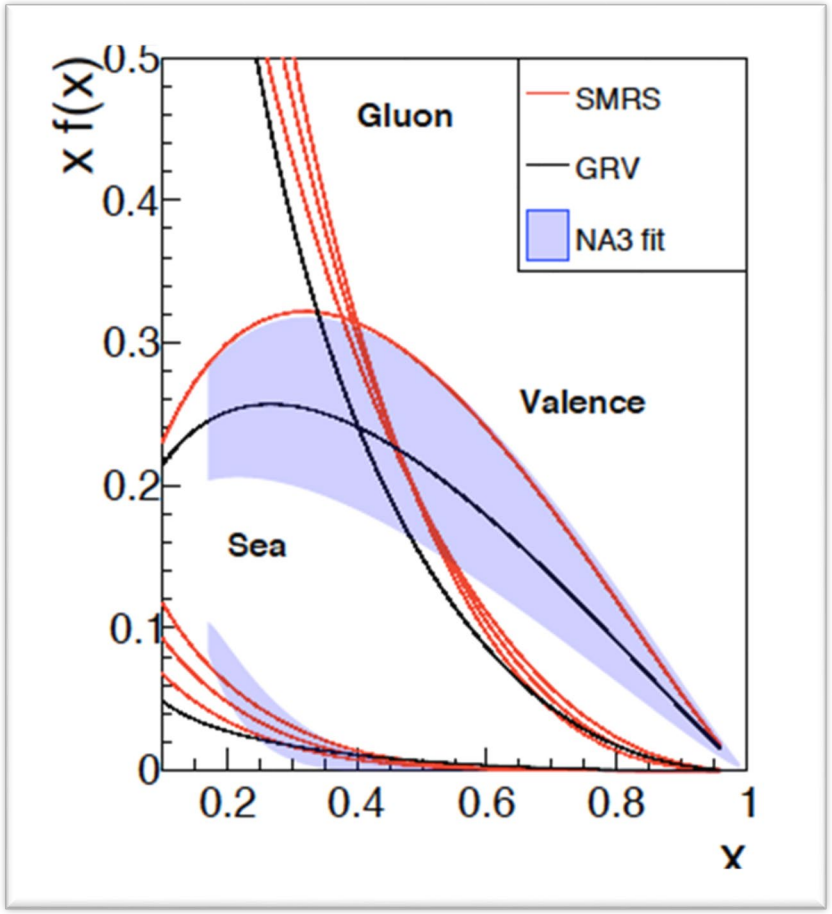
- 90's NA24, W70
- 20's New experiment

DIS with leading N:



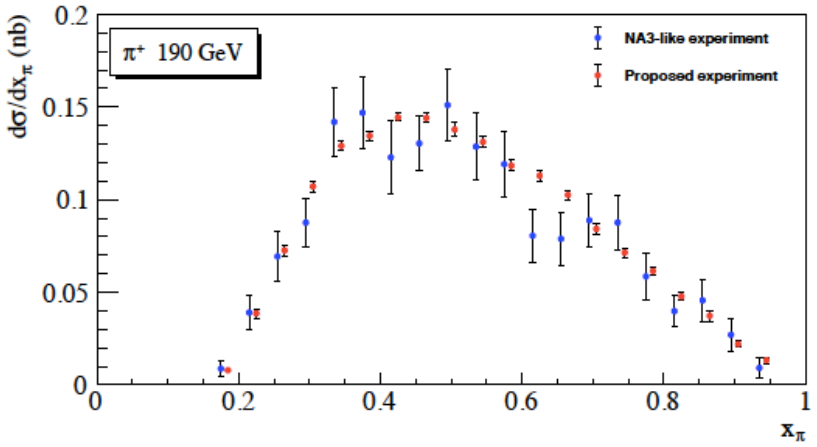
- 90's: H1, ZEUS
- 10's: JLAB TDIS
- 30's: EIC

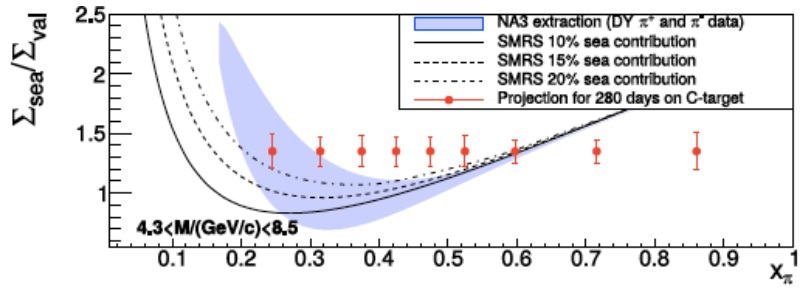
Existing hadron beam
Drell-Yan (I): pion structure

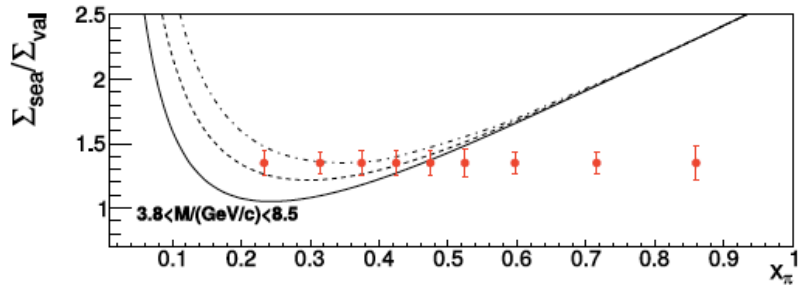


- valence, sea and gluon distributions in the pion in different models
- experimental result (NA3) with large uncertainties

Existing hadron beam
Drell-Yan (II): competitiveness



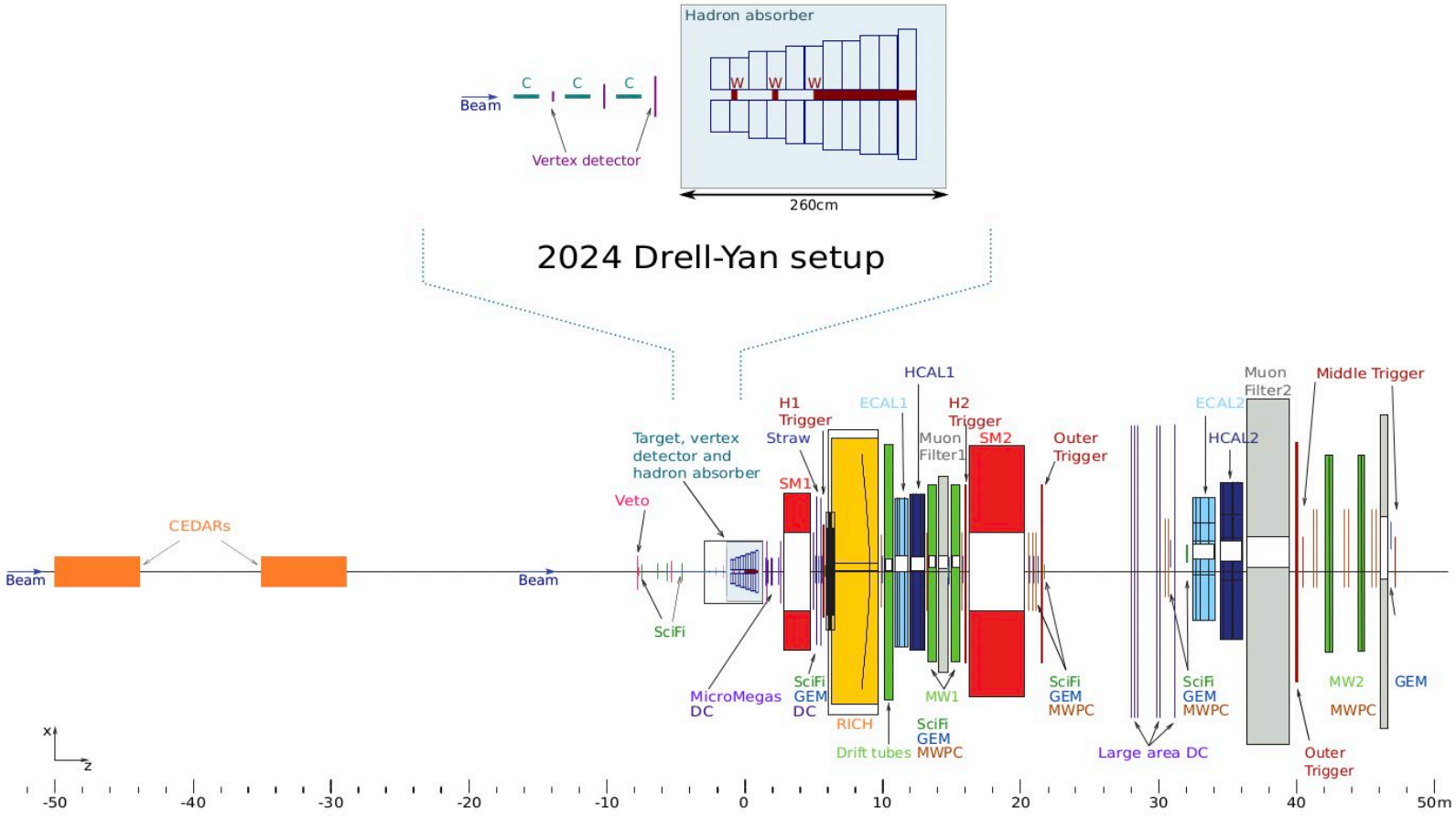




Expected accuracy as compared to NA3

- $\Sigma_V = \sigma^{\pi^- C} - \sigma^{\pi^+ C}$: only valence-valence
- $\Sigma_S = 4\sigma^{\pi^+ C} - \sigma^{\pi^- C}$: no valence-valence
- Collect at least a **factor 10 more statistics** than presently available
- Minimize nuclear effects on target side
  - Projection for 2×140 days of Drell-Yan data taking
  - π^+ to π^- 10:1 time sharing
  - 190 GeV beams on Carbon target ($1.9\lambda_{int}^{\pi}$)
  - Improvement of shielding to double the intensity is under investigation

New hardware: Vertex detector for the Drell-Yan experiment



AMBER recommendation by the SPSC on Oct. 12th 2020

preliminary minutes of the 139th SPSC meeting concerning AMBER:

"The Committee recommends approval of the proposal SPSC-P-360 by the AMBER Proto Collaboration to use the M2 beam-line before LS3 to perform measurements related to:

(i) Drell-Yan and J/Psi production using the conventional M2 hadron beam;
(ii) proton-induced antiproton production cross sections for dark matter searches;
(iii) the proton charge radius using muon-proton elastic scattering.
…

AMBER approval by RB on Dec. 2nd 2020

[…]
The AMBER collaboration has proposed a series of measurements to be made at the experimental area currently occupied by NA58/COMPASS on the M2 beam line [3]. Despite some overlap of the collaboration membership and detectors, this is considered as a new experimental proposal. Phase 1 of the programme includes measurements of Drell-Yan and J/ψ production using the conventional M2 hadron beam, proton-induced antiproton production cross-sections for dark matter searches, and the proton chargeradius using muon-proton elastic scattering. The proton-radius measurement is contingent on a successful pilot run previously approved for the first year of SPS operation after LS2.
The SPSC emphasises that the beam time allocated to AMBER for any of the measurements will be subject to the overall availability of the M2 beam line and annual discussions in the committee on its use and sharing, in particular concerning the other two proposals that are requesting beam there, NA64-mu and MUonE. **The Research Board approved AMBER for its Phase-1 measurements until LS3, with the beam allocation being subject to the optimisation of the overall schedule at the SPSC. The experiment will have reference number NA66.**
[…]

SPS SCHEDULE

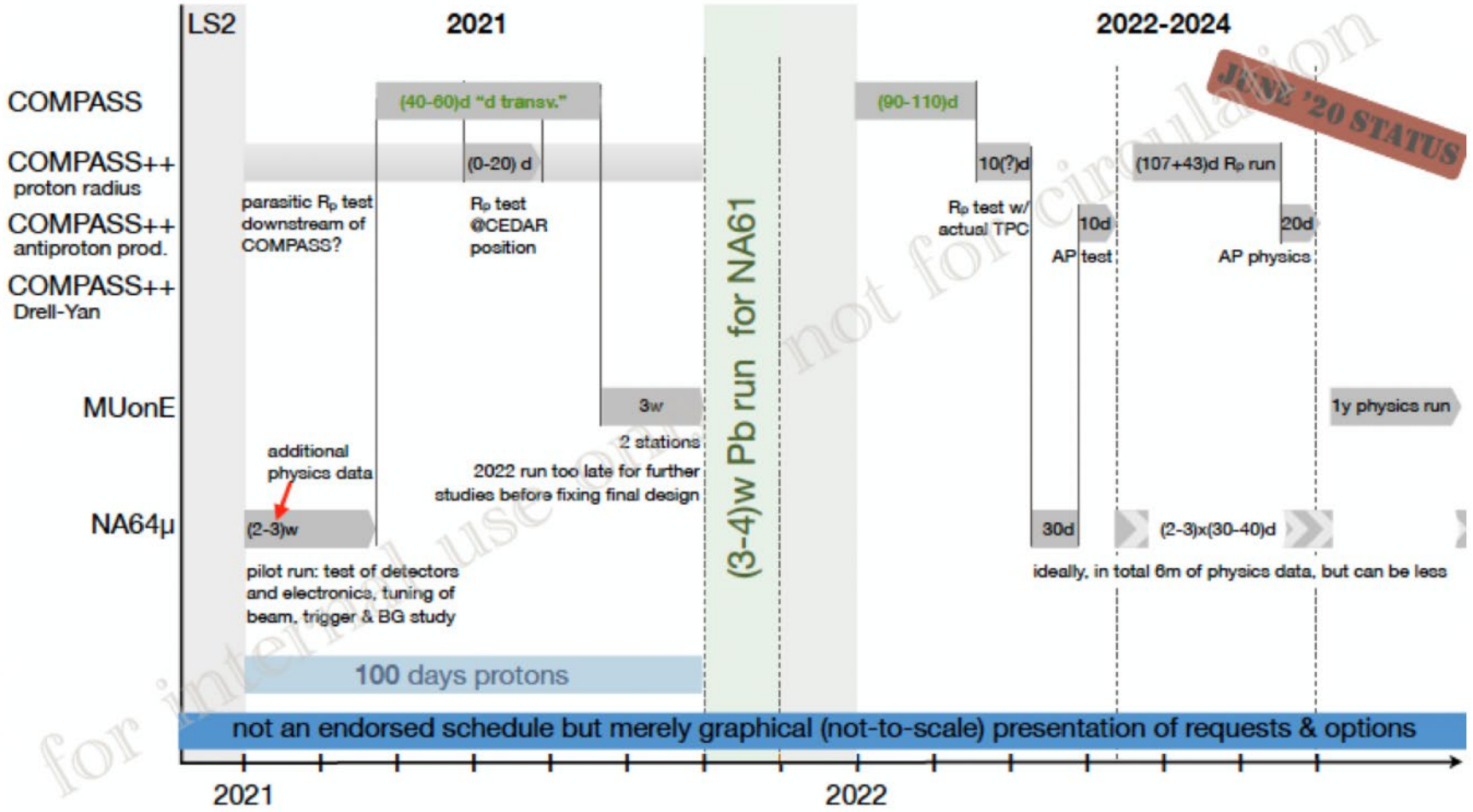
ancora incerta soprattutto a causa della pandemia

run COMPASS da luglio 2021

approvato pilot run proton radius → richiesta di 20 gg nel 2021

richieste di fascio da altri esperimenti gruppo di lavoro al CERN

tentative schedule - June 2020



la collaborazione

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- elenco istituti attuali
- TS TO TN BO

Trieste: BRADAMANTE (INFN) BRESSAN (UniTS) CHATTERJEE (INFN) CICUTTIN (ICTP) CRESPO (ICTP) D'AGO (UniTS) DALLA TORRE (INFN) DASGUPTA (INFN) FLORIAN (ICTP) GARCIA ORDÒÑEZ (ICTP) KERBIZI (INFN) LEVORATO (INFN) MAKKE (INFN) MARTIN UniTS) MOLINA (ICTP) MORETTI (UniTS) SBRIZZAI (INFN) TESSARO (INFN) TESSAROTTO (INFN) TRILOKI (INFN) VALINOTI (ICTP)

Torino: ALEKSEEV (UniTO) ALICE (UniTO) AMOROSO (UniTO) CERESA (UniTO) CHIOSSO (UniTO) DENISOV (INFN) GIORDANO (UniTO) GRASSO (UniTO) KOTZINIAN (INFN) MAGGIORA (INFN) OCCELLI (UniTO) PANZIERI (UniPO) PARSAMYAN (UniTO) TOSELLO (INFN)

Trento: Zuccon (UniTN), Nozzoli (INFN), Dass(dottorando UniTn) + esperti ALPIDE

Bologna: Masi (INFN), Oliva (INFN), dottorando (in arrivo nel 2021)

organizzazione

- contact persons: JF VA
- proto-CB da aprile 2019
  - Bylaws document (structure of the Collaboration, the formation of all major governing bodies of the Collaboration, Physics Coordinators appointment, Spokesperson election rules, finances) approvato a settembre 2020 in attesa di MoU
- CB da novembre 2020
  - Physics Coordinators appointed for:
    - Drell-Yan
    - $\bar{p}$ production cross section
    - Proton radius
  - TB: lo stesso di COMPASS, con alcuni membri aggiuntivi.
    - primo meeting di collaborazione a Maggio,
    - elezione spokesperson immediatamente dopo
    - nominato comitato MoU

goal is to have a Draft MoU in the summer and to finalise it by the end of 2021

fino ad allora nulla di definitivo

Interessi e coinvolgimento dei gruppi dell'INFN (BO, TN, TO, TS)

Interesse specifici dei diversi gruppi INFN per la fisica delle diverse misure; al momento

sezione d'urto di produzione di $\bar{p}$ TN BO

Drell-Yan TO

Raggio del protone TS

coinvolgimento nella preparazione e nell'analisi

TS raggio del protone e produzione di $\bar{p}$ in particolare

costruzione apparati: partecipazione a progetti per nuovi rivelatori dedicati e general upgrades; al momento (ma situazione in rapida evoluzione)

BO TN targhetta He per la misura di produzione di $\bar{p}$

TO LA trackers (R&D già supportato da CSN1), e , nuovo, con TN TO, silici ALPIDE

TS nDAQ (R&D già supportato da CSN1), e, nuovo, Sistema gas TPC

Alcuni commenti:

- Questo quadro e' ancora in evoluzione
- Ancora presto per parlare di impegni finanziari (saranno meglio chiariti nel processo di scrittura dell'MoU) ma non ci aspettiamo che siano troppo rilevanti.

Trieste

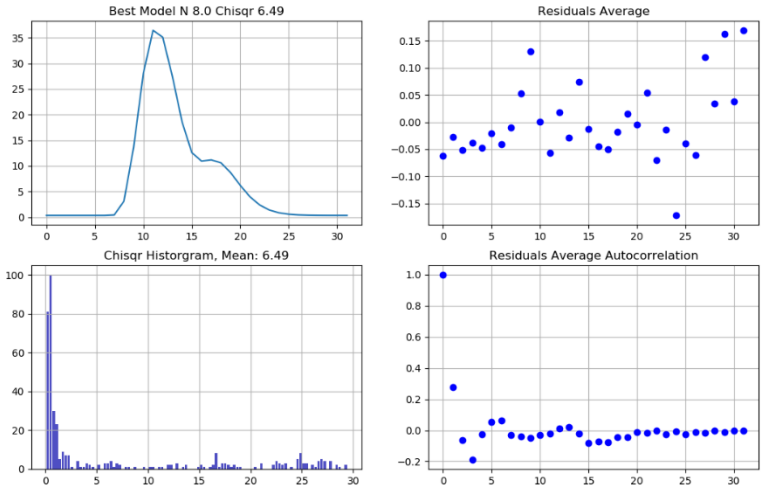
Trigerless DAQ
Trieste INFN/ICTP in collaborazione con TUM (Monaco)

- Parte del FEE di COMPASS presenta limitazioni in termini data output, inoltre parte dell'architettura del DAQ non e' compatibile con un sistema di acquisizione di tipo triggerless.
- Per il secondo calorimetro elettromagnetico di COMPASS l'approccio del programma di ammodernamento consiste nel riutilizzo degli attuali MSADCs (12 bit 40 MHz) dove attraverso un nuovo sistema di lettura basato su SOM lo stream di 32 samples @ 80 MHz viene sostituito dalle informazioni di timing di ampiezza ottenute via FIR filtering su FPGA

R&D supportato dalla CSN1 dalla fine del 2018

- Prossimo passo implementazione dell'algoritmo sul nuovo hardware per un numero limitato di canali di ECAL2 O (100). Il nuovo hardware e' basato su SOM commerciale.
- Futuro, estensione su larga scala.
- In parallelo la carrier card puo' essere riadattata per leggere diversi FEE. Stesso hardware può essere adattato alla lettura dell'ALPIDE per il tracking del PRM: collaborazione con Friburgo

Studio già iniziato utilizzando i puri raw data di ECAL2 decodificati



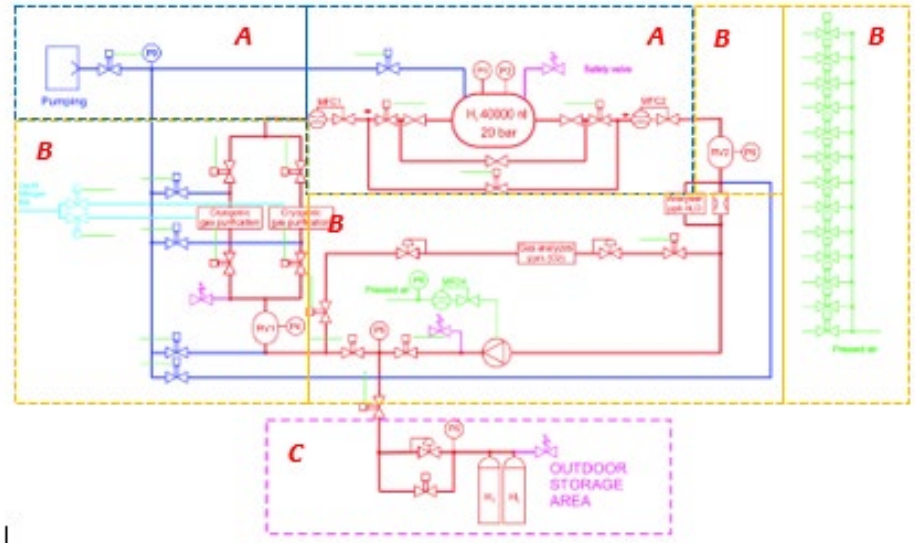
Trieste

TPC Gas System
in collaborazione con PNPI e GSI

- Il sistema gas della TPC necessaria per la misura del raggio del protone presenta aspetti di similarità al sistema GAS del RICH-1 di COMPASS, aggiungendo la complessità di lavorare in idrogeno ad alta pressione: 8 bara per il pilot run e 20 bara per Il main run.

- In considerazione il contributo del gruppo di Trieste alla realizzazione del sistema di ricircolazione e purificazione dell'Idrogeno.

Parameter	Pilot RUN	Main RUN
Pressure	Approximately 7 bara	20 bara
TPC Gas Volume	7 bara x 0.5 m^3=3500 nl	10 bara x 2 m^3=40000 nl
Circulating/stored GAS volume	10000 nl	10000 nl
Hydrogen Purity	< 100ppb	<100ppb
Gas flow	25nl/min	25nl/min
Filling/recovery flow	25 nl/min	25 nl/min
Emergency evacuation flow	TBF	TBF
Absolute long term P stabilization	$\pm 10^{-4}$ x 7 bara=±0.7 mbara	$\pm 10^{-4}$ x 20 bara=±2.0 mbara
Absolute long term T stabilization		$\pm 10^{-4}$ x 300 K= ± 0.03K



compatibilità con gli altri impegni (nessun problema)

- AMBER per ora l'attività più importante consiste nel lavoro nDAQ coinvolgimento a crescere gradualmente nei prossimi anni

- COMPASS prioritario fino a conclusione presa dati deuterio (2022) poi continuerà per almeno tre anni per completare il grosso dell'analisi

- EIC ha una scala di tempi con inizio presa dati successiva al 2030. Nei prossimi anni il coinvolgimento sarà soprattutto in R&D e simulazioni. Molto probabilmente gli impegni in costruzioni inizieranno solo dopo il 2024/25