A QCD Facility at the SPS after 2021

Letter of Intent: Instrumentation

Mini Workshop at CERN

June 20, 2018

ILLINOIS

Caroline Riedl

for the LoI team

CERN

The mission: exploring hadron structure at ENH2

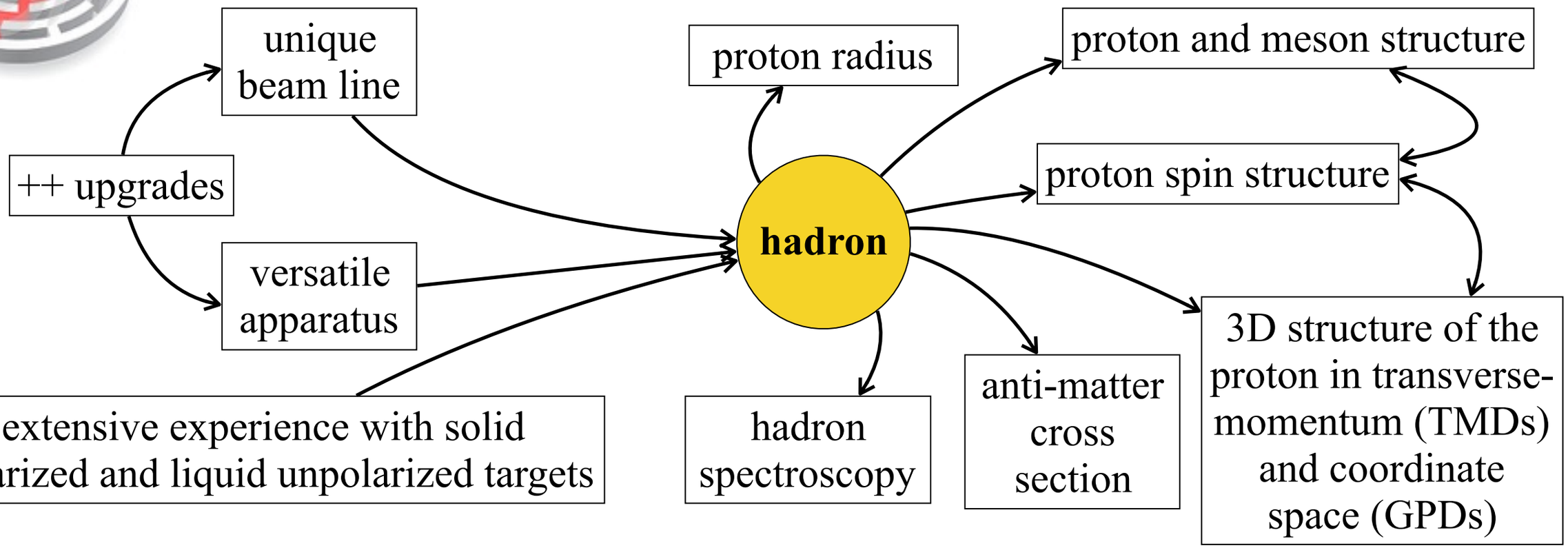


Table of TMD PDFs

nucleon (**N**)

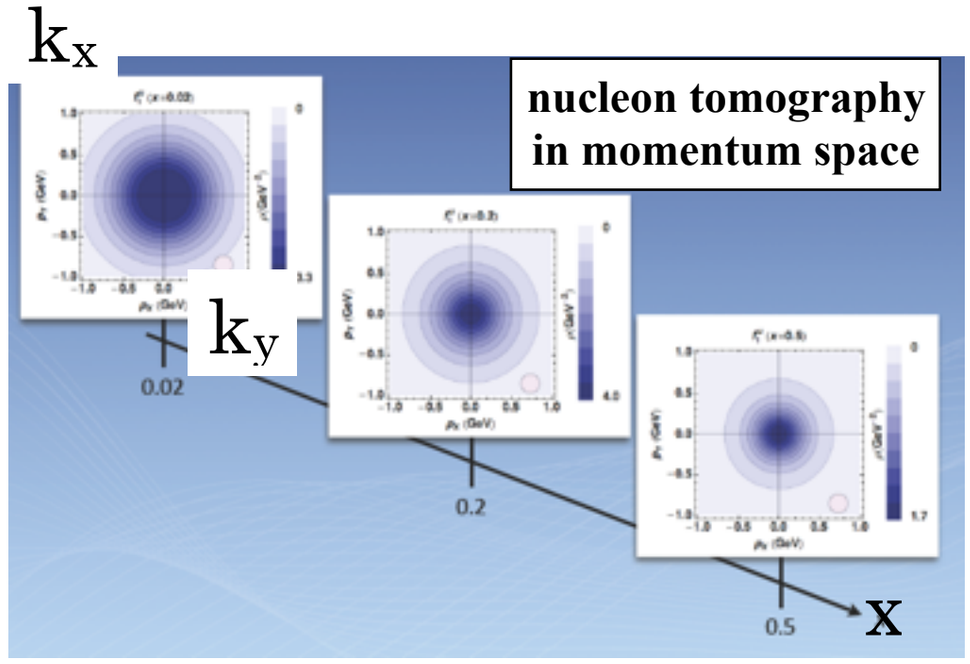
unpolarized quark (**Q**)

nucleon spin

quark spin

quark k_T

N \ Q	U	L	T
U	f_1 number density		$h_1^\perp$ Boer-Mulders
L		g_1 helicity	$h_{1L}^\perp$ worm-gear
T	$f_{1T}^\perp$ Sivers	$g_{1T}^\perp$ worm-gear	h_1 transversity; $h_{1T}^\perp$ pretzelosity

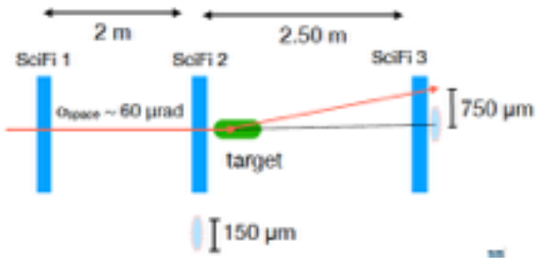


Summary table

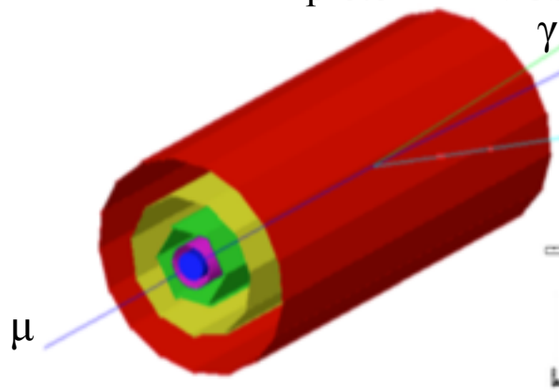
Program	Physics Goals	Beam Energy [GeV]	Beam Intensity [s^{-1}]	Trigger Rate [kHz]	Beam Type	Target	Earliest start time, duration	Hardware Additions
μp elastic scattering	Precision proton-radius measurement	100	$4 \cdot 10^6$	100	$\mu^\pm$	high-pr. H2	2022 1 year	active TPC SciFi trigger silicon veto
Hard exclusive reactions	GPD E	160	$2 \cdot 10^7$	10	$\mu^\pm$	$NH_3^\uparrow$	2022 2 years	recoil silicon, modified PT magnet
Input for DMS	$\overline{p}$ production cross-section	20-280	$5 \cdot 10^5$	25	p	LH2, LHe	2022 1 month	LHe target
$\overline{p}$-induced Spectroscopy	Heavy quark exotics	12, 20	$5 \cdot 10^7$	25	$\overline{p}$	LH2	2022 2 years	target spectr.: 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	$\sim$100	10^8	25-50	$K^\pm, \overline{p}$	$NH_3^\updownarrow$, C/W	2026 2-3 years	"active absorber", vertex det.
Primakoff (RF)	Kaon polarizi-bility & pion life time	$\sim$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	

Specific hardware upgrades

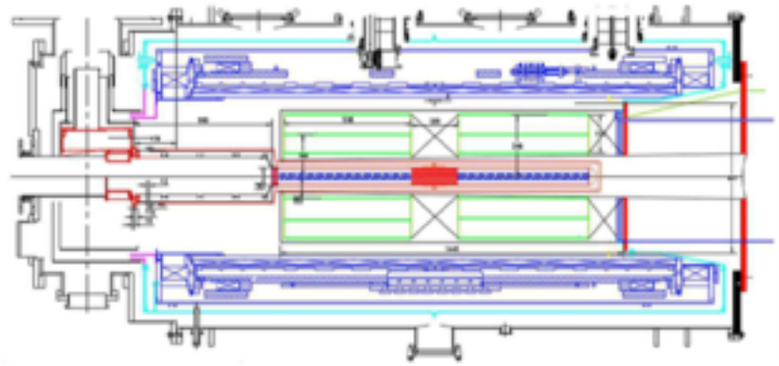
Proton radius:
- **High-pressure active TPC target or hydrogen tube** surrounded by SciFi, 4-8 layers with U/V projections
- **SciFi trigger system** on scattered muon
- Silicon trackers



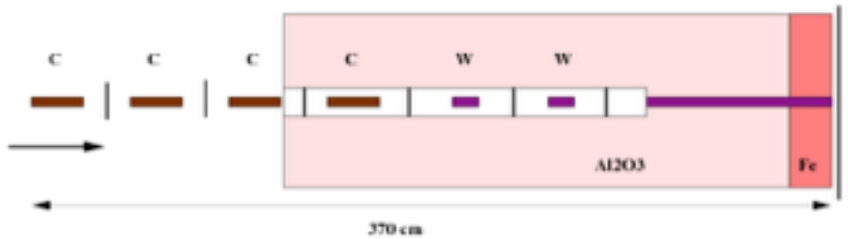
GPD E: 3-layer silicon detector at very low temperature for tracking of recoil proton in DVCS and PID via dE/dx.



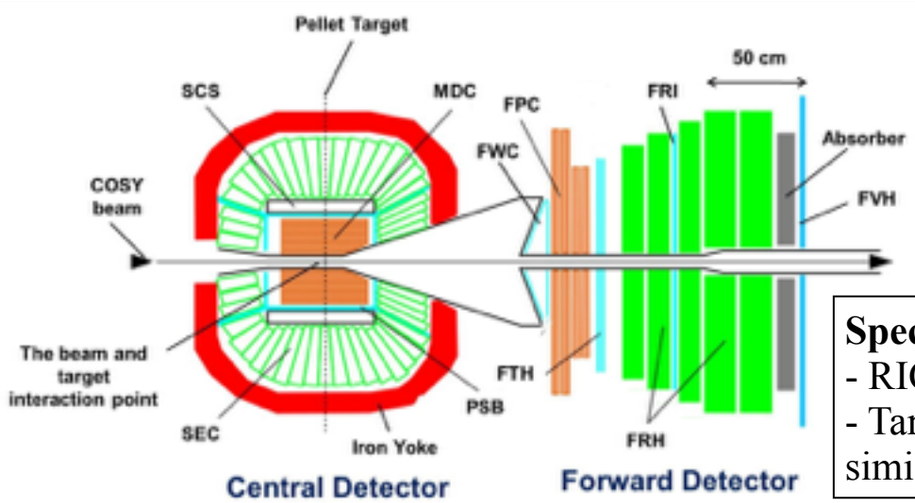
Silicon detector inside existing modified target magnet.



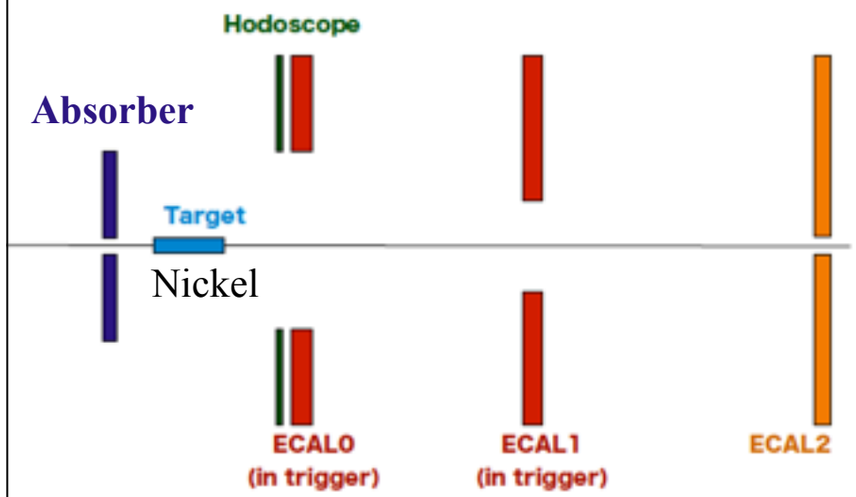
Drell-Yan general:
- High-purity and efficiency di-muon trigger
- Dedicated precise luminosity measurement
- Dedicated vertex-detection system
- Beam trackers *unpolarized target for future DY*



Drell-Yan RF separated beams:
- Due to lower beam energy, need wide aperture, up to ± 300 mrad
- High-rate and high-multiplicity capability
- "Magnetized spectrometer" ("3-in-1" detector, SM, absorber)



WASA detector with target spectrometer



Prompt Photons
- Absorber (20-30cm steel) upstream of target
- New hodoscope upstream of ECal0
- Transparent setup

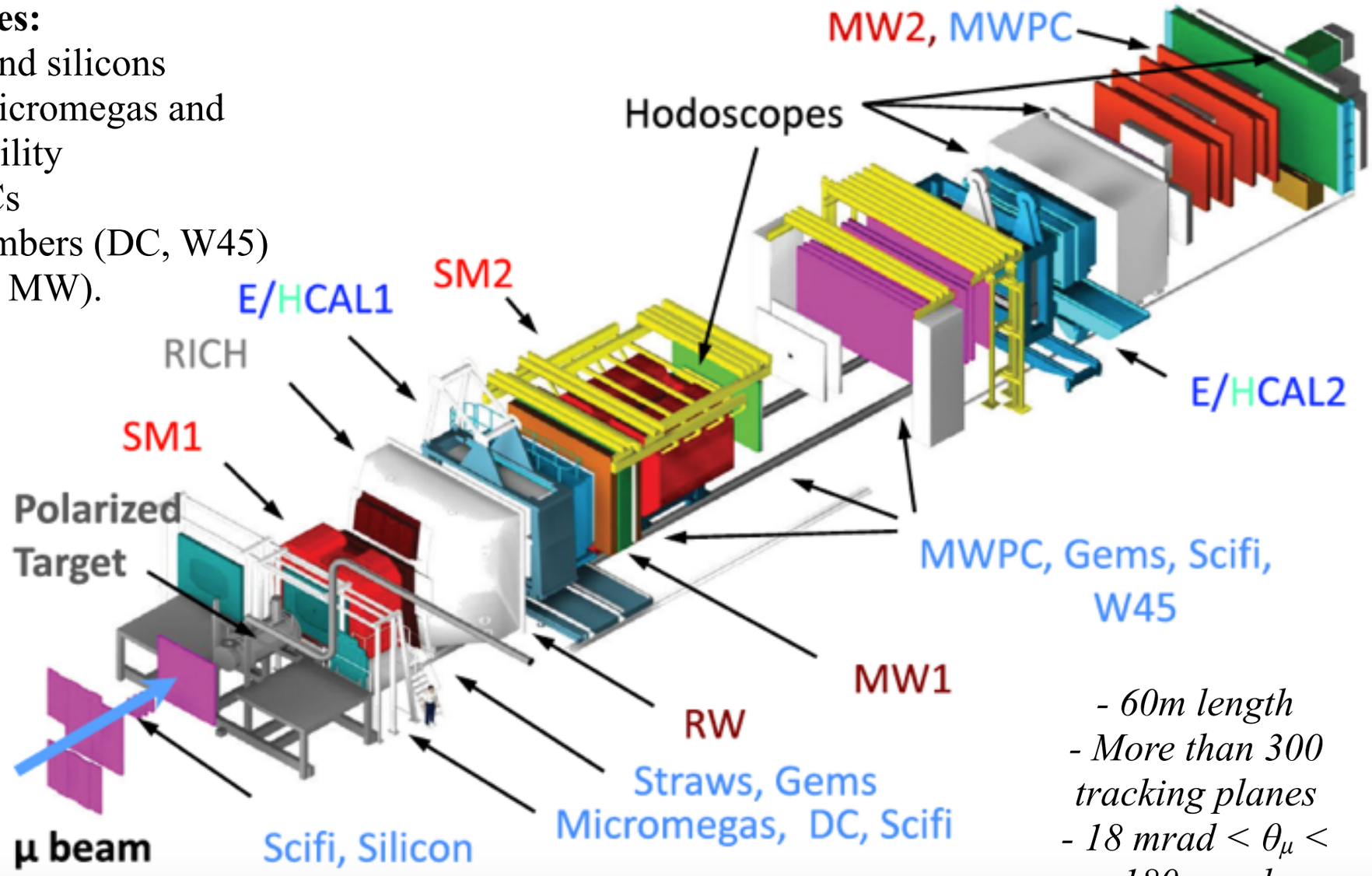
Spectroscopy with K—:
- RICH & CEDAR
- Uniform acceptance, ECals
- Good vertexing
- Recoil TOF detector

Spectroscopy with low-anergy anti-p:
- RICH & CEDAR, RICH0 for low p?
- Target spectrometer (tracking, barrel calorimeter) similar to WASA

Anti-matter cross section
- LH2 and LHe targets
- RICH0 for lower momentum to ID anti-protons?

Existing COMPASS spectrometer

- **Tracking of charged particles:**
  - in the beam region: SciFis and silicons
  - region close to the beam: Micromegas and GEMs with high-rate capability
  - intermediate region: MWPCs
  - large-are tracking: drift chambers (DC, W45) and drift tubes (Straws, RW, MW).



- 60m length
- More than 300 tracking planes
- 18 mrad < θ_μ < 180 mrad

- **Separation of produced pions & kaons:** RICH with multianode-photomultiplier tubes and MWPCs with photosensitive CsI cathodes in the periphery

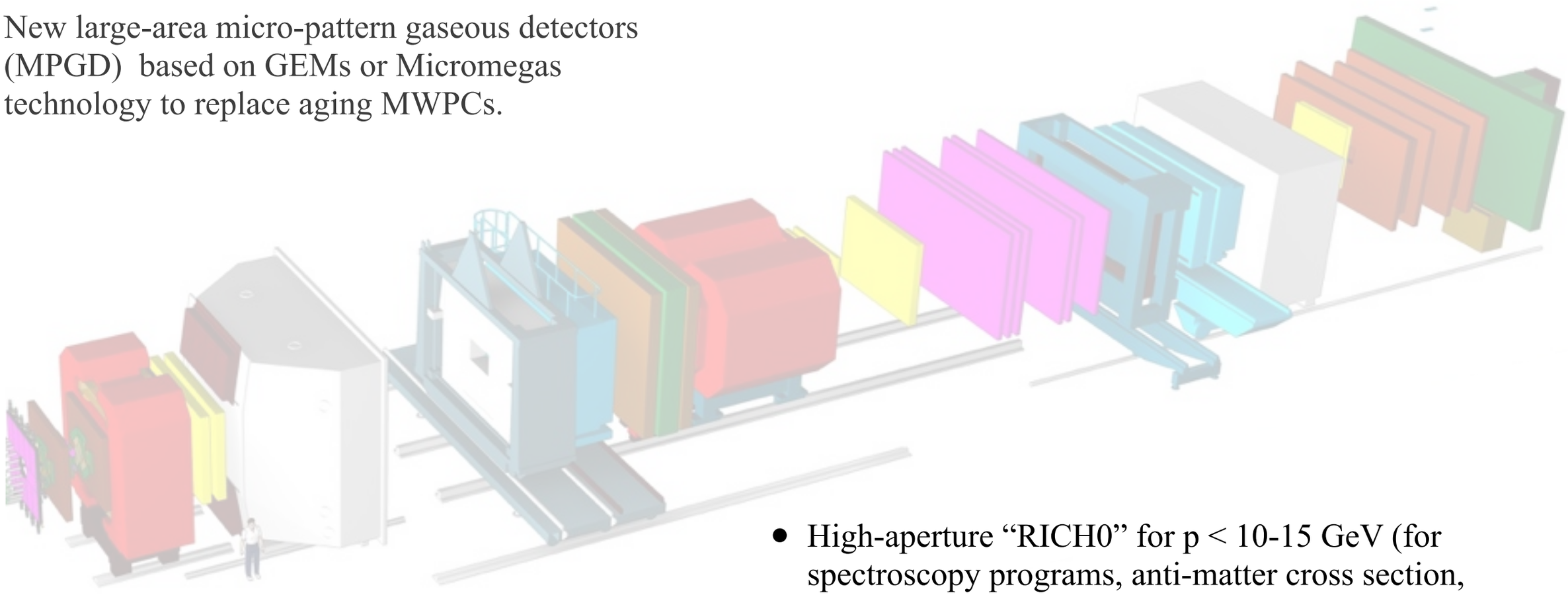
- **Energy measurement:**
  - charged particles: sampling hadron calorimeters (HCAL)
  - neutral particles, in particular high-energy photons: electromagnetic calorimeters (ECAL)

Apparatus at QCD Facility: the current vision

- Baseline: upgraded COMPASS spectrometer

- New large-size PixelGEMs as replacement and spares for aging large-area GEMs.
  - Area between 30cm x 30cm and 40cm x 40cm

- New large-area micro-pattern gaseous detectors (MPGD) based on GEMs or Micromegas technology to replace aging MWPCs.

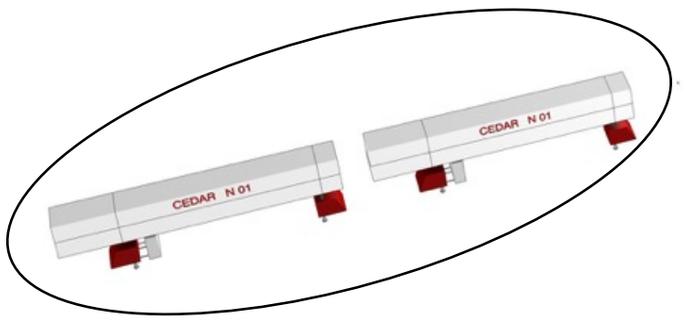


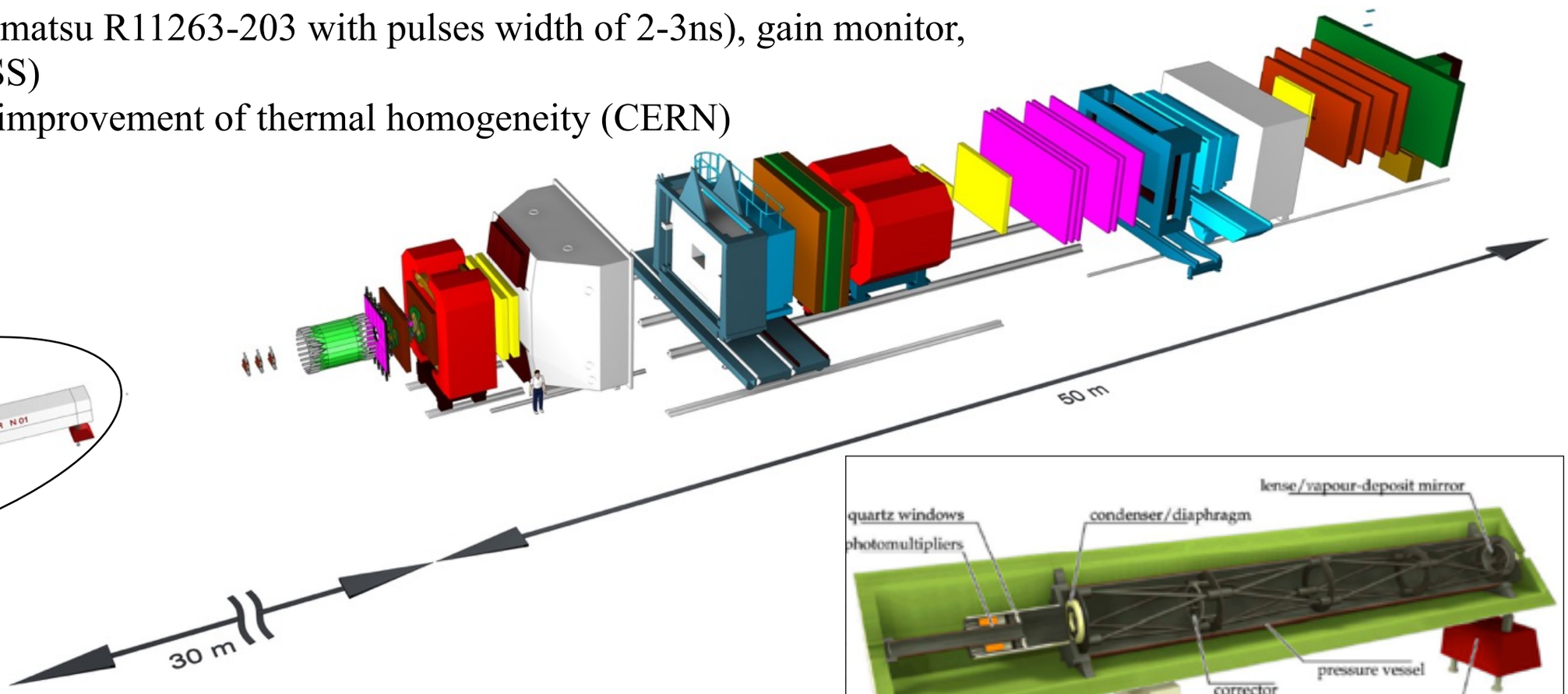
- High-aperture “RICH0” for p < 10-15 GeV (for spectroscopy programs, anti-matter cross section, Primakoff).
  Could be:
  - DIRC
  - Large-area photodetectors based on micro-channel plates. (LAPPD™ by IncomInc)
  - …

CEDAR 2018 upgrade

- Modification to withstand higher rate (≈10^8 particles/s)

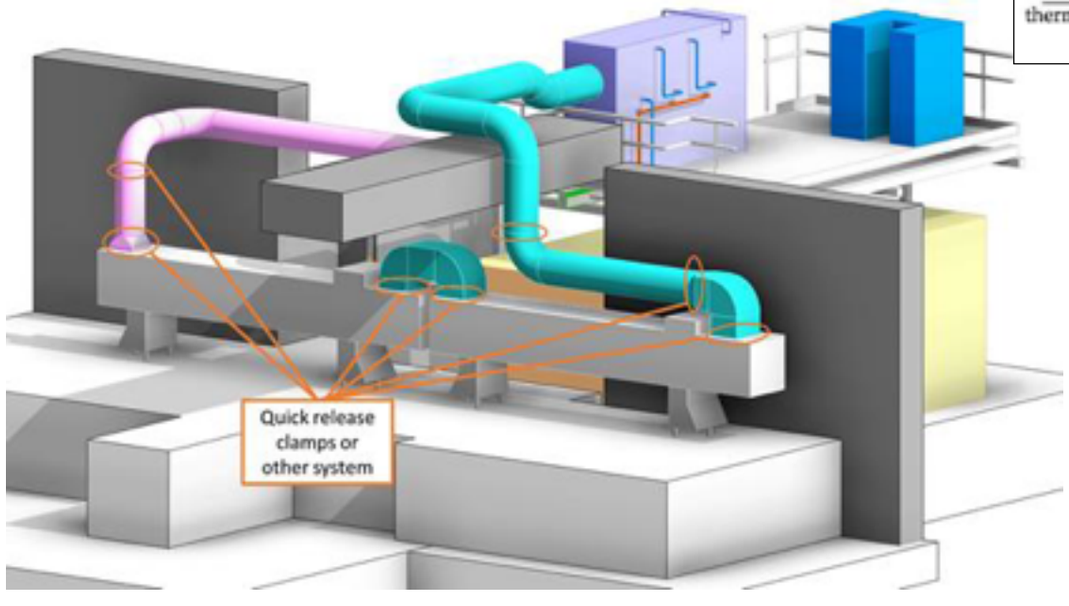
- The upgrade includes:
  – PMTs (fast Hamamatsu R11263-203 with pulses width of 2-3ns), gain monitor, read-out (COMPASS)
  – Thermal system: improvement of thermal homogeneity (CERN)





CEDAR Thermal stabilization:

- Target temperature: 23°C
- Stability: 0.1°C
- External temperature range: +15°C / +30°C
- CEDAR : total length: 6000 mm
  main diameter: 558 mm
  external surface: ~ 10 m²
  total mass: 2.3 tons
  fill: He, 4 bar
  chamber material: Steel (AC 52.3)
- Thermal housing internal diameter: 770 mm
- Insulation thickness: 50 mm
- Air volume inside the thermal housing: ~ 1.6 m³
- Internal heat load: ~ 50 W



Towards trigger-less readout & unified front-end electronics

Micro pattern detectors
- Silicon Detectors
- GEM, PGEM, PMM

APV25

Scintillating Detectors
- SciFi, BMS, Hodoscopes — **F1**
- CAMERA — **GANDALF**

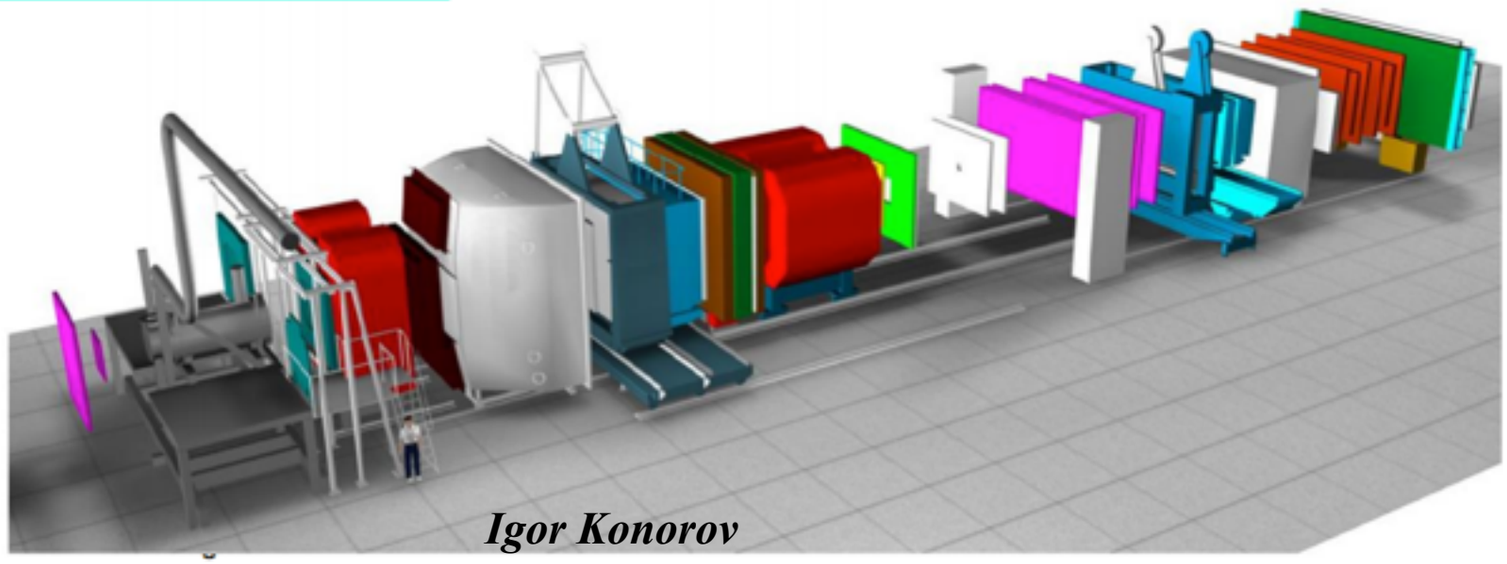
Wire Chambers
- DC, Straw, W45
- MWPC, RW, MW1, MW2

F1
- DC05 — **FPGA TDC**

Calorimeters
- HCAL1,2
- ECAL0,1,2

MSADC

RICH
- MAPMT — **F1**
- MWPC, THGEM — **APV25**



COMP *Igor Konorov*

https://indico.cern.ch/event/673073 (Prague, Nov 2017)

DAQFEET
DAQ/FEE/Trigger for COMPASS beyond 2020 Workshop

- learn about future physics programs and requirements for read-out electronics
- review existing read-out and trigger systems
- look at the developments carried out within COMPASS
- learn about developments for future experiments
- **define needs and strategy for the further development**
- **identify interested groups within the collaboration to participate in this R&D**
- **distribute tasks.**

Trigger conditions for future programs

Program	Trigger rate (est.) [kHz]	Trigger signature / list of detectors in trigger logic	Trigger challenge factor
Proton radius	<= 100	scattered-muon or recoil-proton trigger	
GPD E	10	MT, LT, OT, LAST. (if higher beam intensity: photon or proton trigger?)	
anti-p x-section	25	Beam trigger, hodoscope veto Sandwich veto Beam killer	
Spectroscopy anti-p	25	CEDARs?	
Drell-Yan conventional	25	As 2015: MT+LAST, OT+LAST, LAST 2mu	
Drell-Yan RF-separated	25-50	As above + ? new hodoscopes for SAS-SAS trigger	
Primakoff	>> 10	ECal2 ΔE>threshold	
Prompt photons	10-100	ECal0, ECal1 ΔE>threshold, or “true pT” trigger	
Spectroscopy K-	25	minimum-bias diffractive trigger Trigger on recoil proton for high t, multiplicity trigger for all t	
Vector mesons	10-100	2 charged particles in final state	

Future Task Forces

- **What is critical? “DAQ & FEE”**

  - Unified front-end electronics across the entire experiment:
    FPGA-based TDC with time resolution down to 100ps (iFTDC).
  - Upgrade to a modern DAQ with trigger-less readout and trigger rates 90-200 kHz (factor of 2.5-5 higher)

- **What is critical? “DCS & Power Supplies”**

  - Deprecated and no longer supported control and data acquisition systems (e.g. WINCC)
  - Old and no longer produced equipment like I/O modules (e.g. Embedded Local Monitor Board ELMB)
  - Phasing out of client-server architectures (e.g. OPC-DA), rendering certain hardware unusable.
  - Certain (CAEN, ISEG, Wiener) modules becoming too old: not controllable, not repairable (at companies), and/or simply breaking apart.

- It is therefore essential to create future task forces that plan and carry out in a common effort new projects.

  - **”DAQ & FEE”**: *task force founded and active, recommended by COMPASS Collaboration Board.*
    o Development stage 2018-2021
    o Plan pilot run with test proton radius measurement in 2021

  - **”DCS & Power Supplies”**: *formation considered and encouraged by COMPASS Technical Board.*

  - *“…”*

Time line of COMPASS & future QCD facility
(the current best knowledge - very preliminary)

2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	…
DY NH3 pions	**DY** NH3↑ pions	**GPD** LH2 muons	**GPD** LH2 muons	**DY** NH3↑ pions	LS2	LS2	**SIDIS** 6LiD ↑	**LoI** **LoI**	**LoI** **LoI**	(LS3) **LoI** **LoI**	LS3	**LoI**	**LoI**	**LoI**	**LoI**	LS4	…
COMPASS	COMPASS	COMPASS	COMPASS	COMPASS			COMPASS	X	X	X		X	X	X	X		…

Readiness of experiments:

Program	duration	2022	2023	2024	2025	2026	2027	2028	2029	…
Proton radius	1 year									
GPD E	2 years									
anti-p x-section	1 month									
anti-p spectroscopy	2 years									
Drell Yan	1-2 years									
Drell Yan (RF)	2-3 years									
Primakoff	1 year					non-excl	non-excl	non-excl	non-excl	
Prompt photons	1-2 years					non-excl	non-excl	non-excl	non-excl	
K- spectroscopy	1 year									
Vector mesons	1 year									

Closing remarks: A QCD Facility at the SPS after 2021

What we offer:

- Versatile apparatus.
- Unique beam line.
- Extensive experience with solid polarized and liquid unpolarized targets.

What lies ahead of us:

- R&D possibilities
- Optimization of future setups
- Total cost: est. 10-20M CHF

Our message to you:

- Many possibilities for involvements of new groups.
- Join our endeavor!

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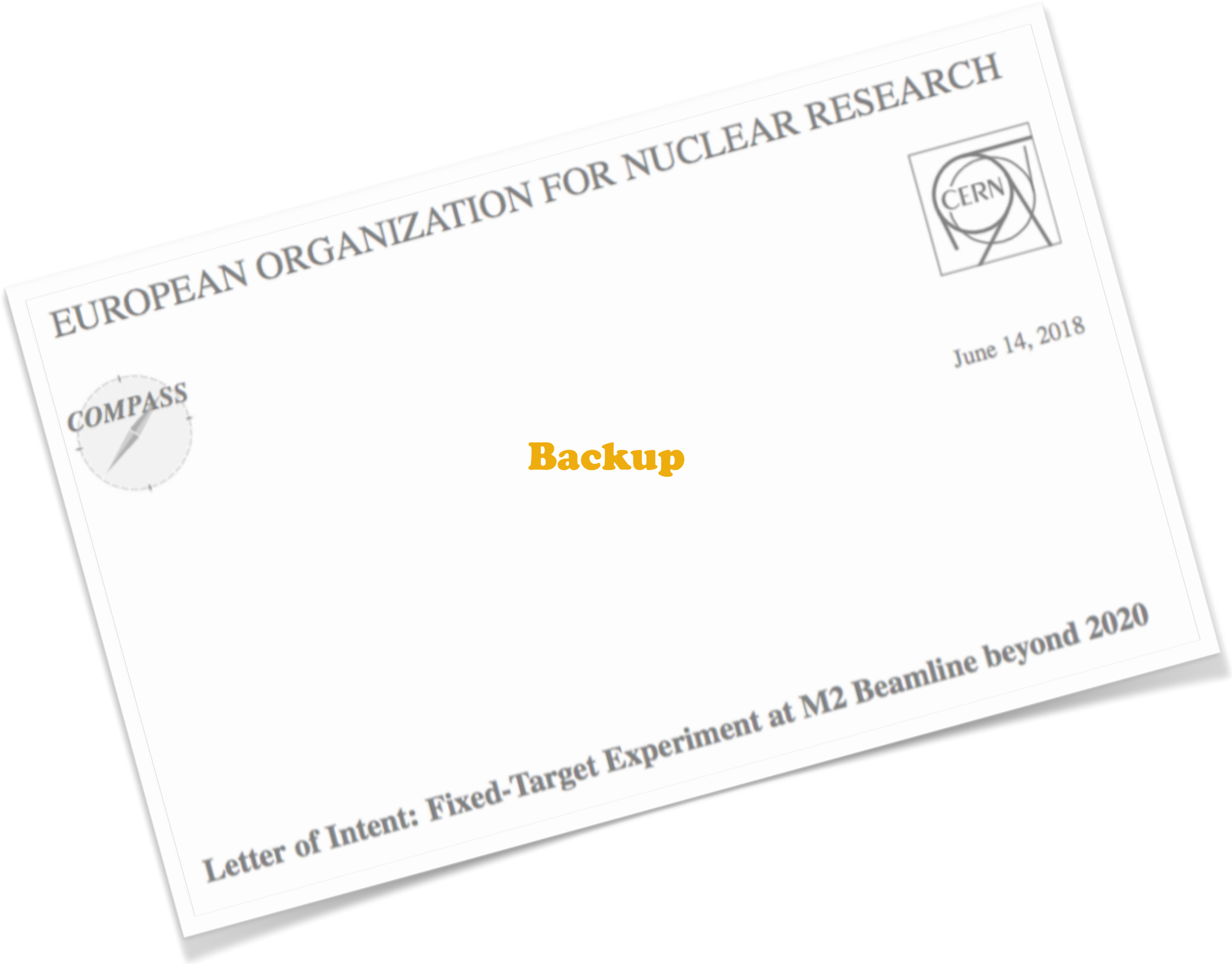
Backup


EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN

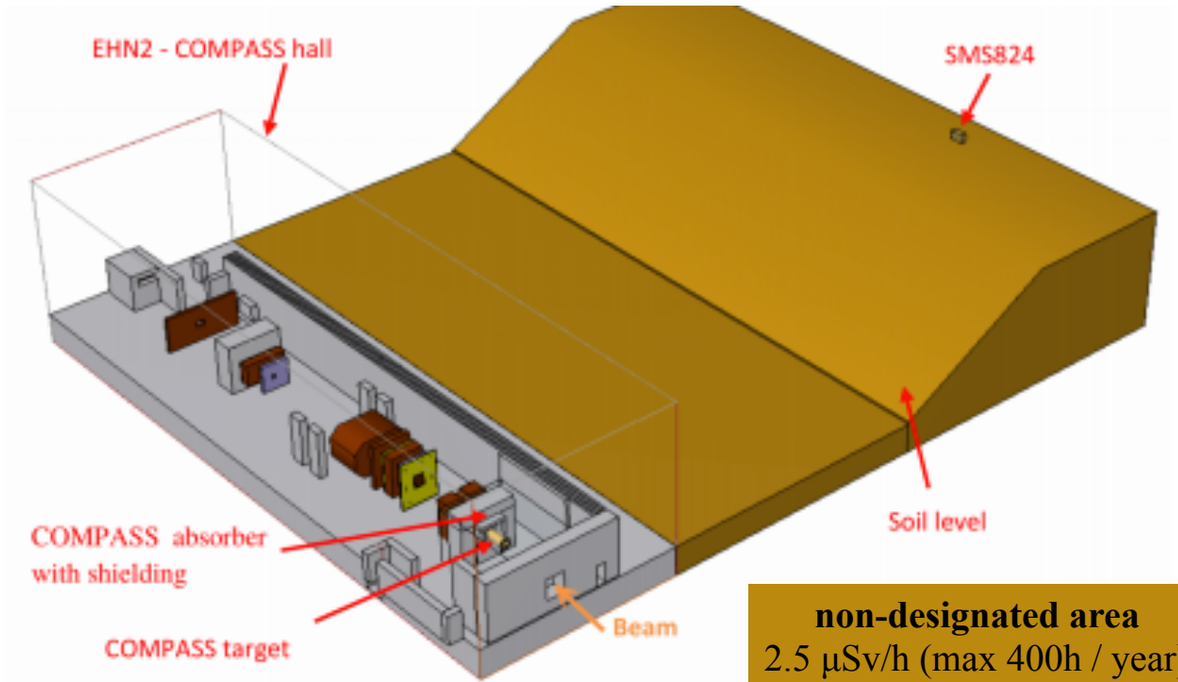
June 14, 2018

COMPASS

Letter of Intent: Fixed-Target Experiment at M2 Beamline beyond 2020

Limits on beam intensity

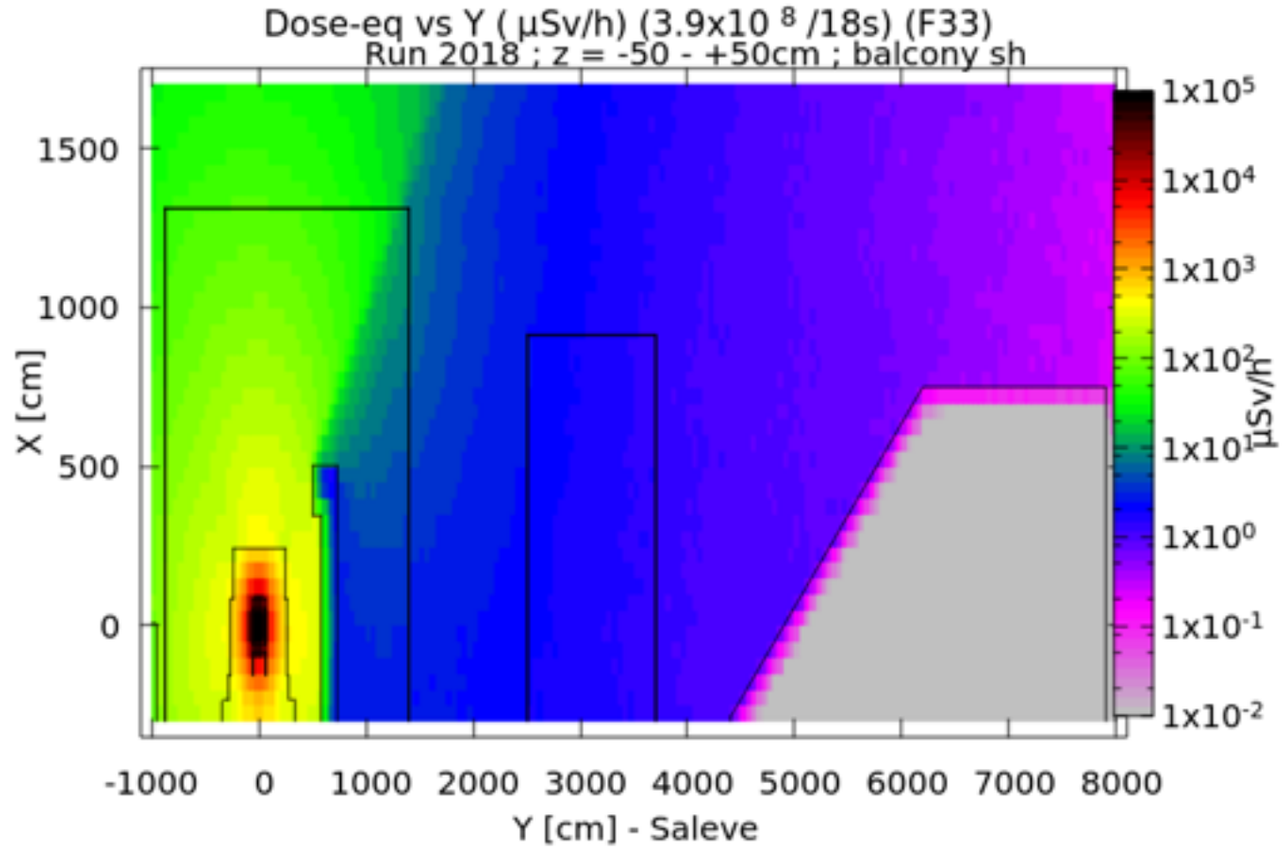
- Radio protection provides upper limit for beam intensities.
- Investigate improved shielding options if the new experiment will not be underground.



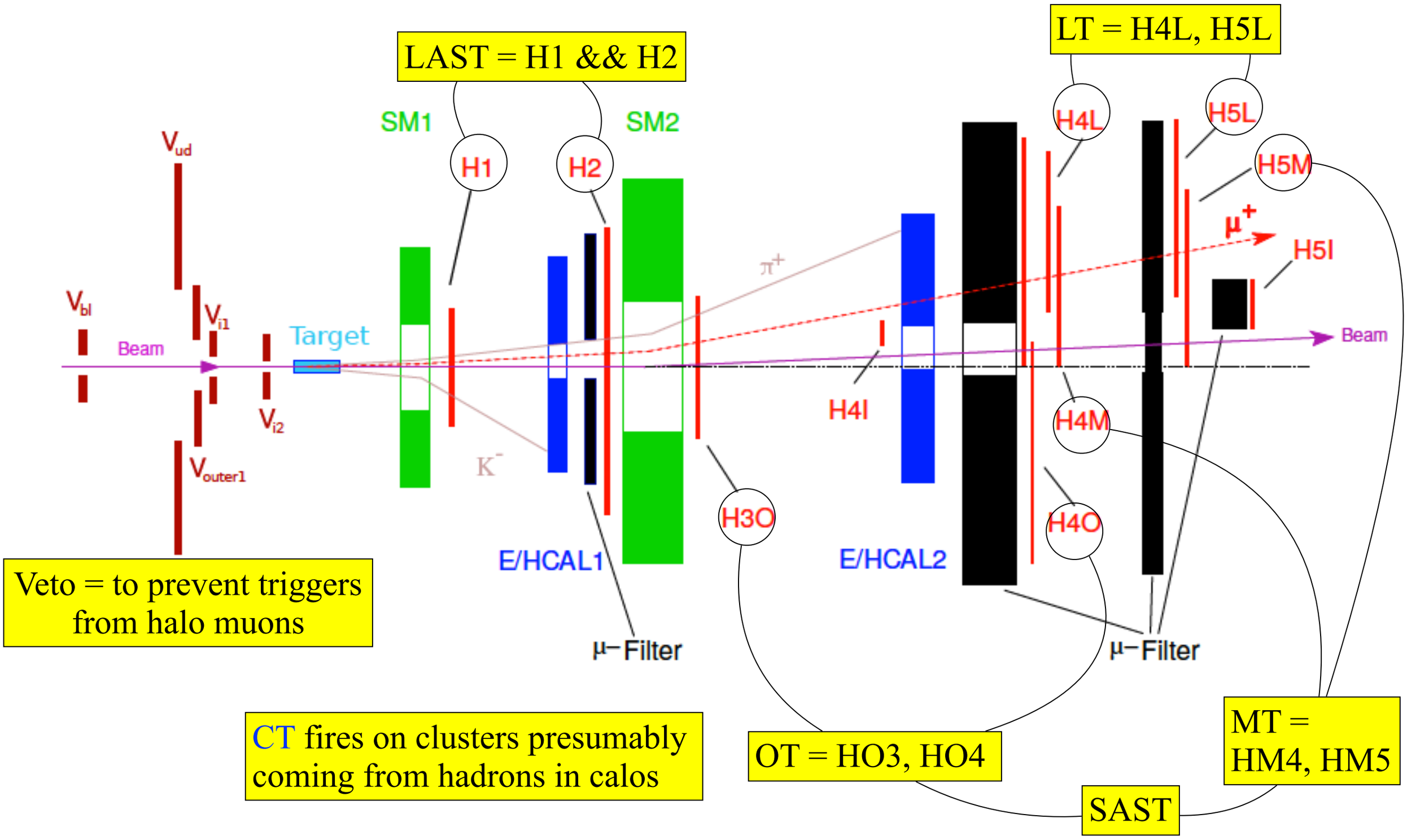
non-designated area
2.5 µSv/h (max 400h / year)
1 mSv / year dose limit

supervised radiation area
= 6 x

- FLUKA simulation of COMPASS 2018 run.



COMPASS (muon) trigger system



OT, MT, LAST = target-pointing triggers
LT, IT = energy-loss triggers

COMPASS RICH-1

- Built late 1990s, upgraded 2005-06 and 2015-16.

- Large acceptance Cherenkov imaging counter: ±200 mrad in the vertical plane, ±250 mrad in the horizontal plane

- Photon detection
  - central region (25% of surface, higher rate): MAPMTS coupled to individual fused silica lens telescopes
  - peripheral region: gaseous detectors with CsI photoconverters:
    - MWPCs
    - hybrid MPGD-type detector with two THick GEM (THGEM) layers followed by a Micromegas multiplication stage

- Hadron PID 3 to 60 GeV/c (3 GeV/c = effective threshold for pion ID and pions-kaons can be separated at 90% confidence level at 60 GeV/c)