Future 2020++ at the CERN M2 beam line:

COMPASS & a COMPASS-like experiment

DAQFEET

DAQ/FEE/Trigger for COMPASS beyond 2020 Workshop

CTU FNSPE Prague

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Caroline Riedl

On behalf of the COMPASS proposal- and LoI-writing teams

With input from Vincent Andrieux, Jens Barth, Johannes Bernhard, Franco Bradamante, Michela Chiosso, Nicole D'Hose, Andrea Ferrero, Jan Friedrich, Lau Gatignon, Alexey Gushkov, Bernhard Ketzer, Gerhard Mallot, Anna Martin, Stephan Paul, Catarina Quintans, Igor Savin, and others

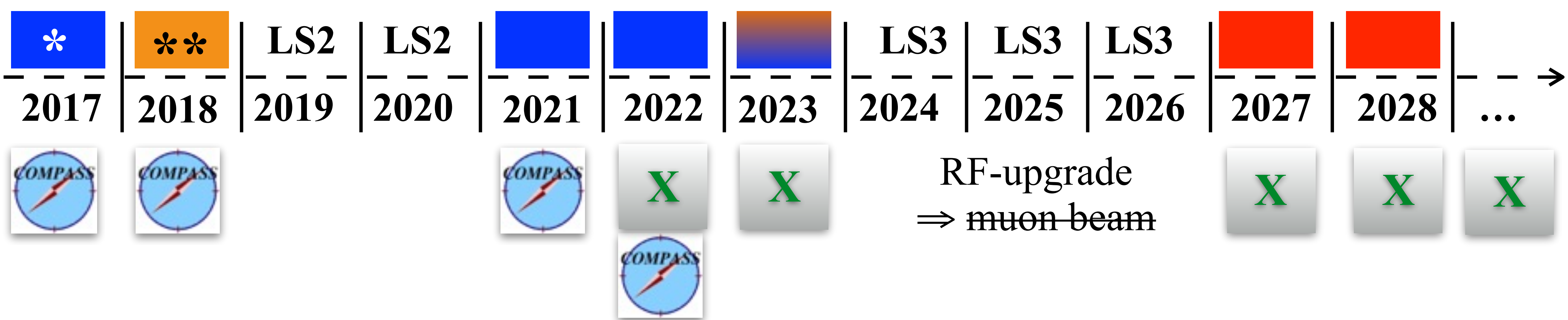
The M2 beamline: a unique hadron & muon facility

hadron & muon beams
two charges
high energy (100 GeV++)
high intensity (1e08/sec)

- Starting point: March 2016 "COMPASS beyond 2020" workshop
  https://indico.cern.ch/event/502879
- **2021 (/ 22): Proposal** submitted to SPSC in October 2017 for the extension of the COMPASS-II program.
- **2022++: Letter of Intent (LoI)** in preparation for a new COMPASS-like experiment at the M2 beam line.

conventional muon beams

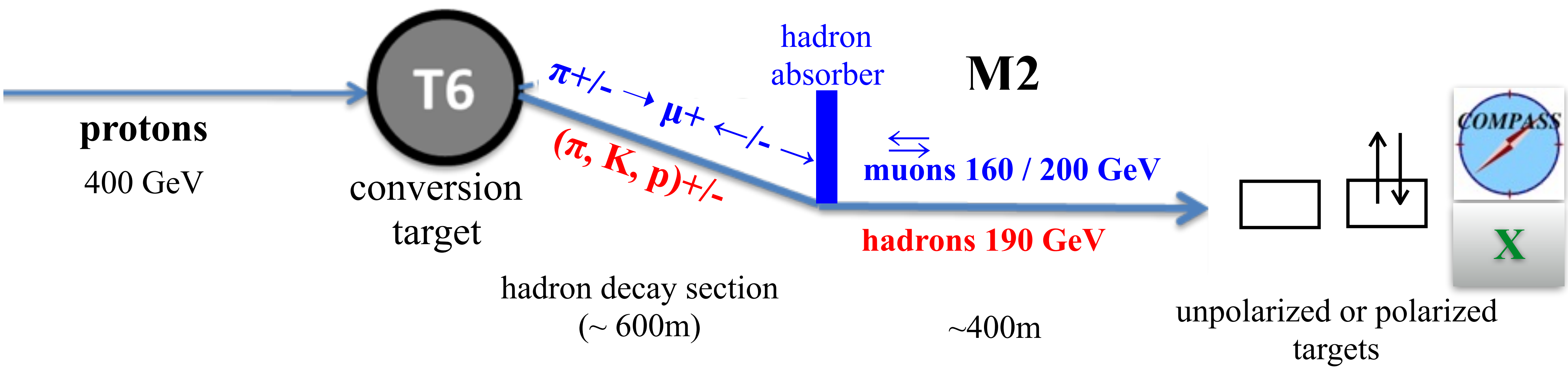
A) conventional pion & muon beams
B) RF-separated anti-proton- and kaon-enhanced beams



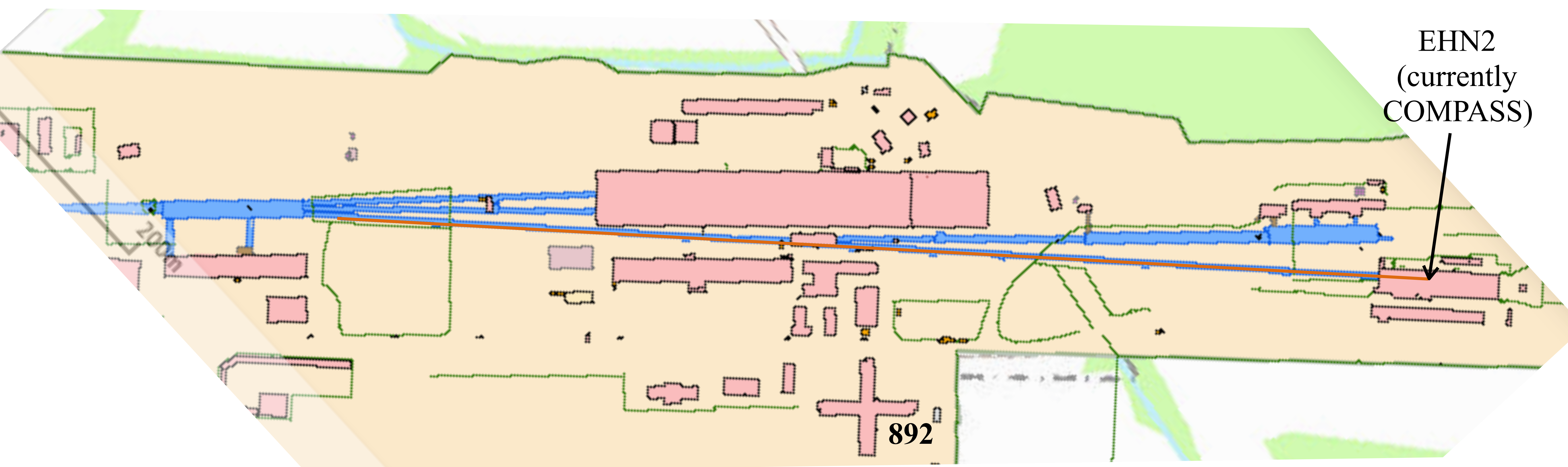
* COMPASS-II DVCS, completed

** COMPASS-II spin-dependent Drell-Yan to start on April 9, 2018

The M2 beam line at CERN's North Area

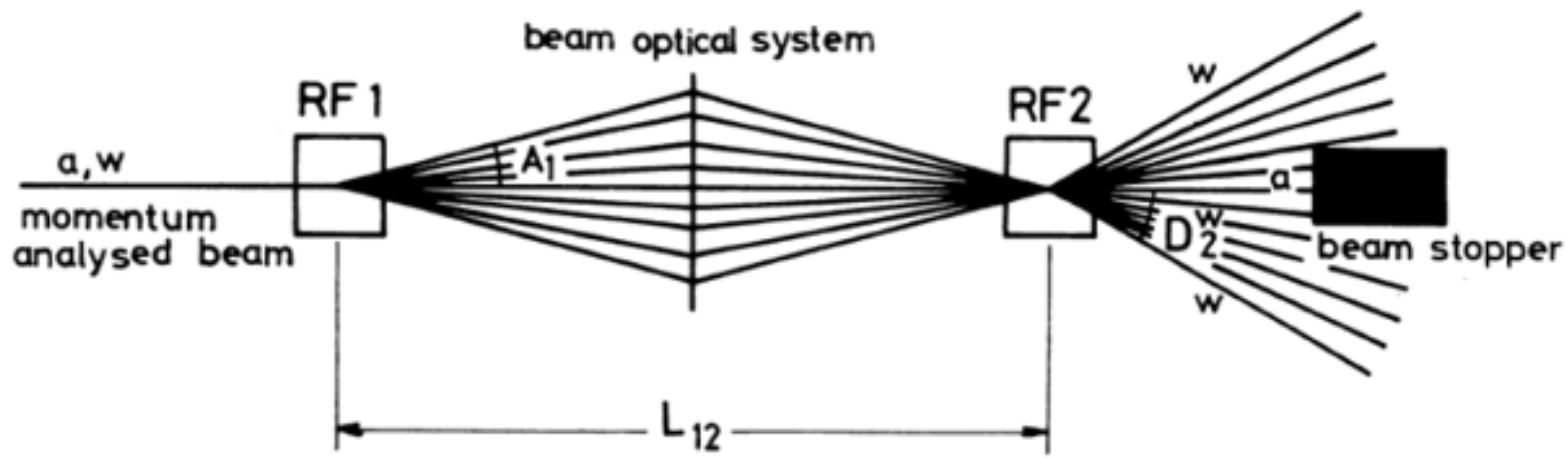


high intensity: up to 10e8 particles per second
(limited mostly by radio protection)



M2 beam line: RF-separated meson beams to enhance kaon and anti-proton fractions

Panofsky-Schnell-System with two cavities (CERN 68-29):



- Particle species have same momenta but different velocities
- Time-dependent transverse kick by RF cavities in dipole mode
- RF1 kick compensated or amplified by RF2
- Selection of particle species by selection of phase difference
  $\Delta\Phi = 2\pi\,(L\,f\,/\,c)\,(\beta_1^{-1} - \beta_2^{-1})$

J. Bernhard and L. Gatignon at IWHSS17

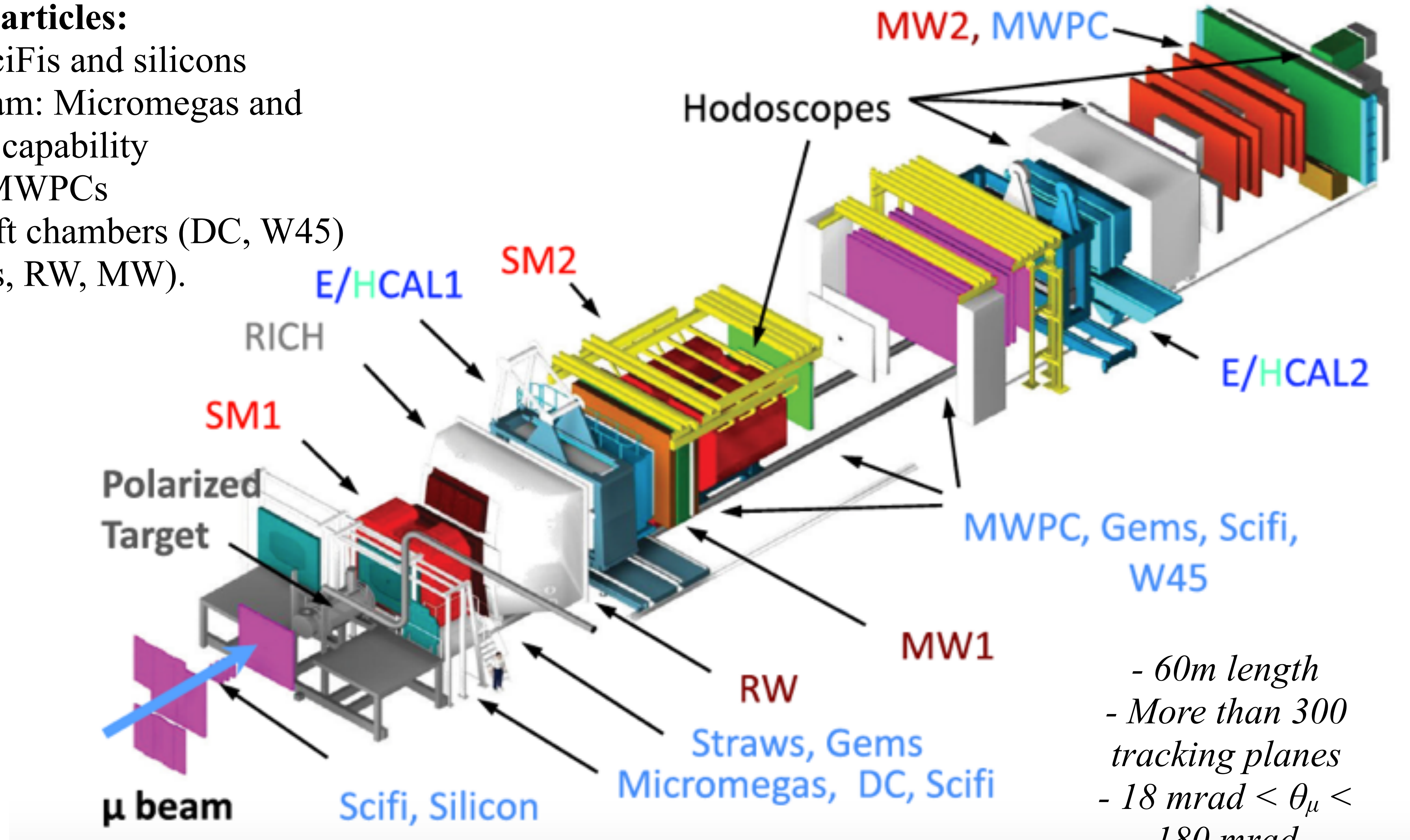
- Conventional p = -190 GeV: 97% pions, 2% kaons, 1% anti-protons
  Conventional p = +190 GeV: 24% pions *(can be enhanced by polyethylene absorber)*, remainder mostly protons.
  RF-separated p = -100 GeV: 13% pions, 37% kaons, 50% anti-protons (prelim)
  RF-separated p = +100 GeV: 25% kaons (prelim)

- Energy of RF-separated beams will be lower because of space limitations between RF cavities along M2 beam line.

- For more details, see L. Gatignon’s talk at March 2016 workshop:
  https://indico.cern.ch/event/502879/contributions/1179927/attachments/1246986/1836912/Compass-Presentation-22032016.pdf

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)

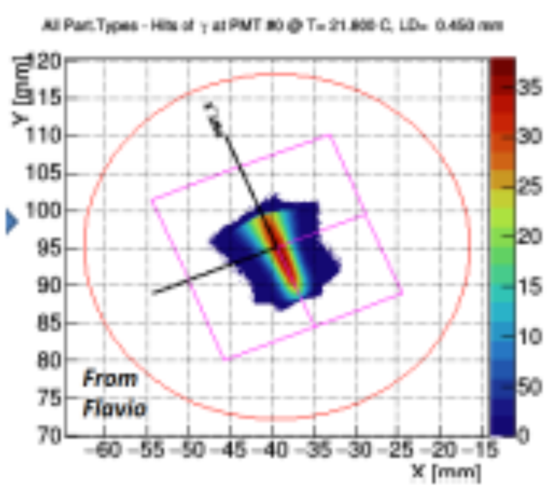
General detector upgrades

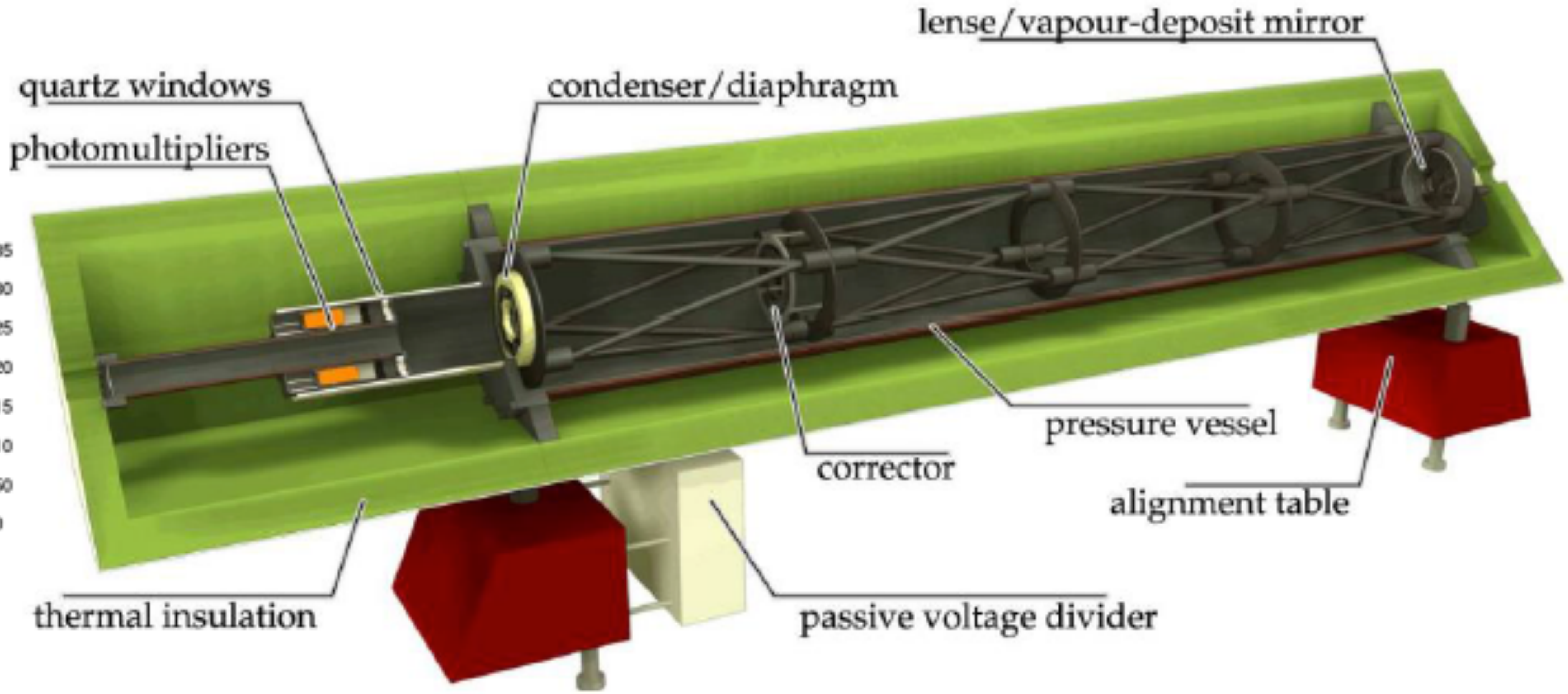
- Baseline: COMPASS apparatus w/o RICH1
- New large-size PixelGEMs
- GEMs or Micromegas to replace aging MWPCs

- High-aperture "RICH0" for p < 10-15 GeV?
  - DIRC
  - Large-area photodetectors based on micro-channel plates. University of Chicago. Prototypes: time resolution < 50 ps, spatial resolution ~ 0.5 mm.
- "RICH2" for higher momenta ?
  (currently not required by any of the proposed programs)

CEDAR Upgrade

- CEDAR upgrade for better rate and thermal stability, goal: project ready for 03/2018
  - New PMTs, gain monitor, and read-out (COMPASS)
  - New thermalisation (EN-EA / MME / CV)
- S. Mathot is project leader for CERN, M. Ziembicki coordinates Front-end for COMPASS, BE-BI will check compatibility and use this as a pilot project





The mission: exploring hadron structure at ENH2

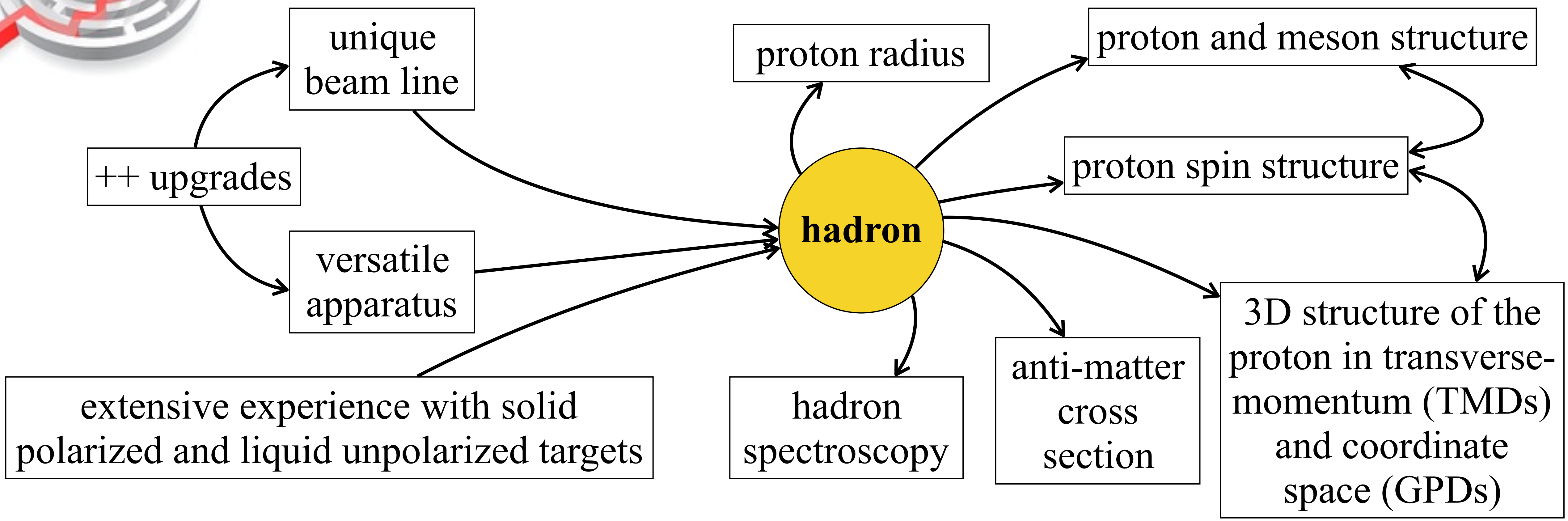
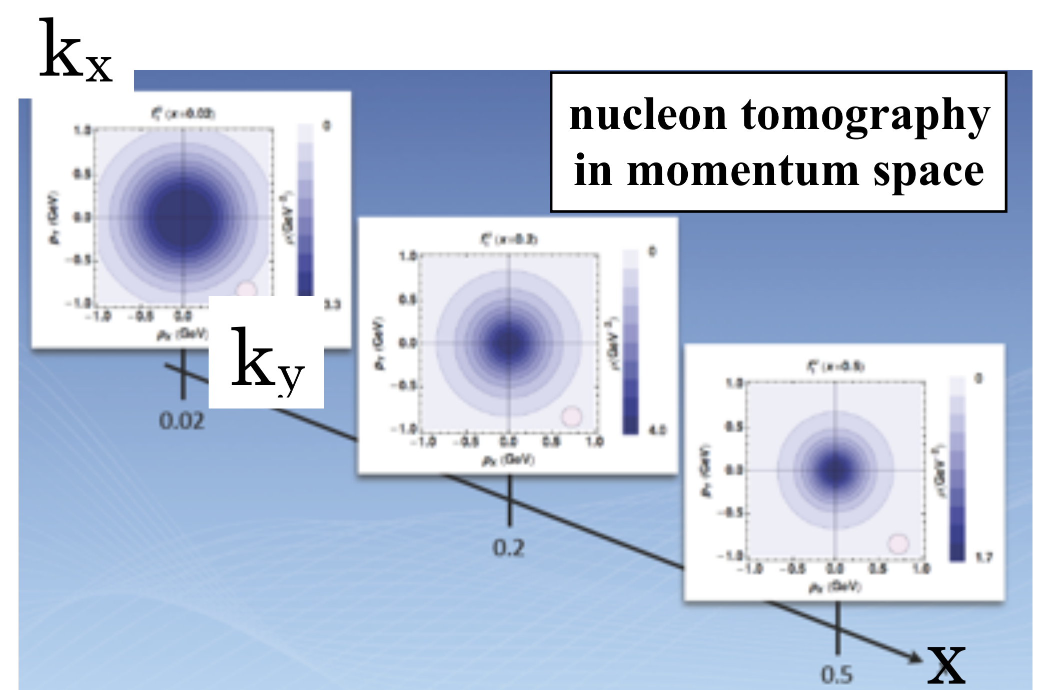


Table of TMD PDFs

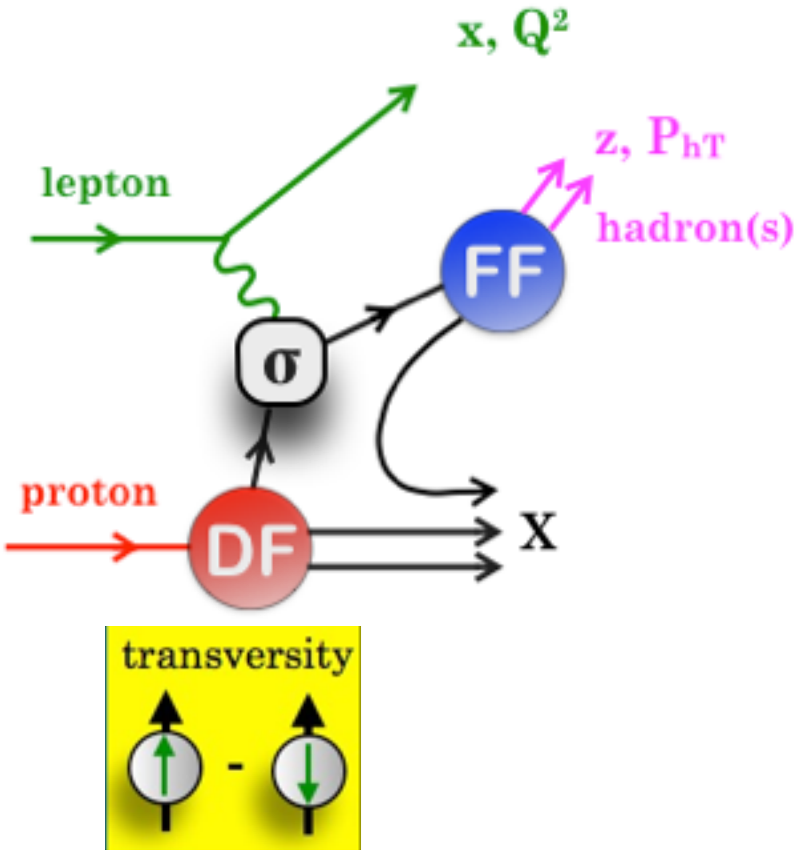
- nucleon (N)
- unpolarized quark (Q)
- nucleon spin
- quark spin
- quark k_T

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



d-quark transversity from SIDIS on ^{6}LiD↑ target

proposed for 2021 muon beam

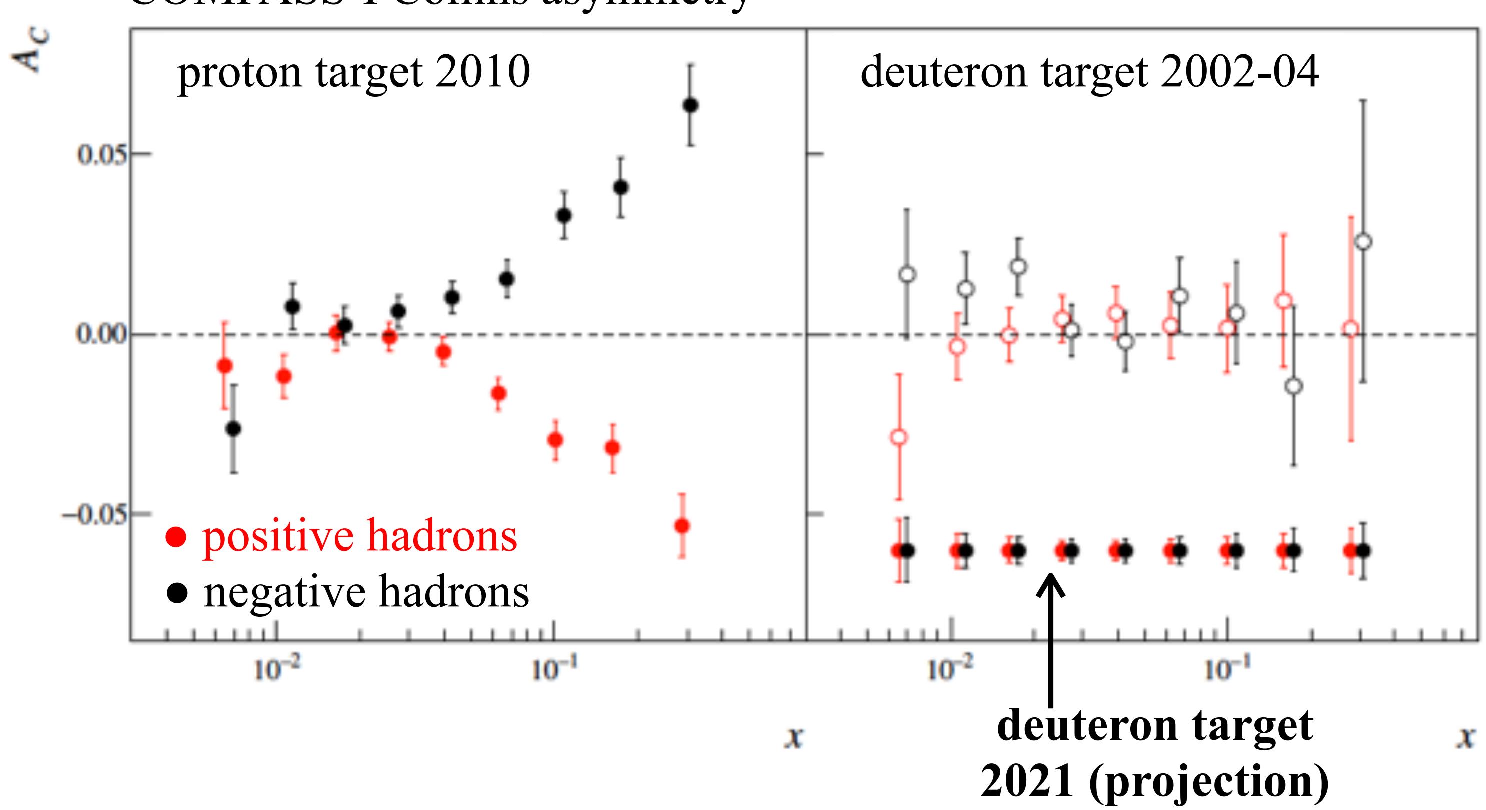


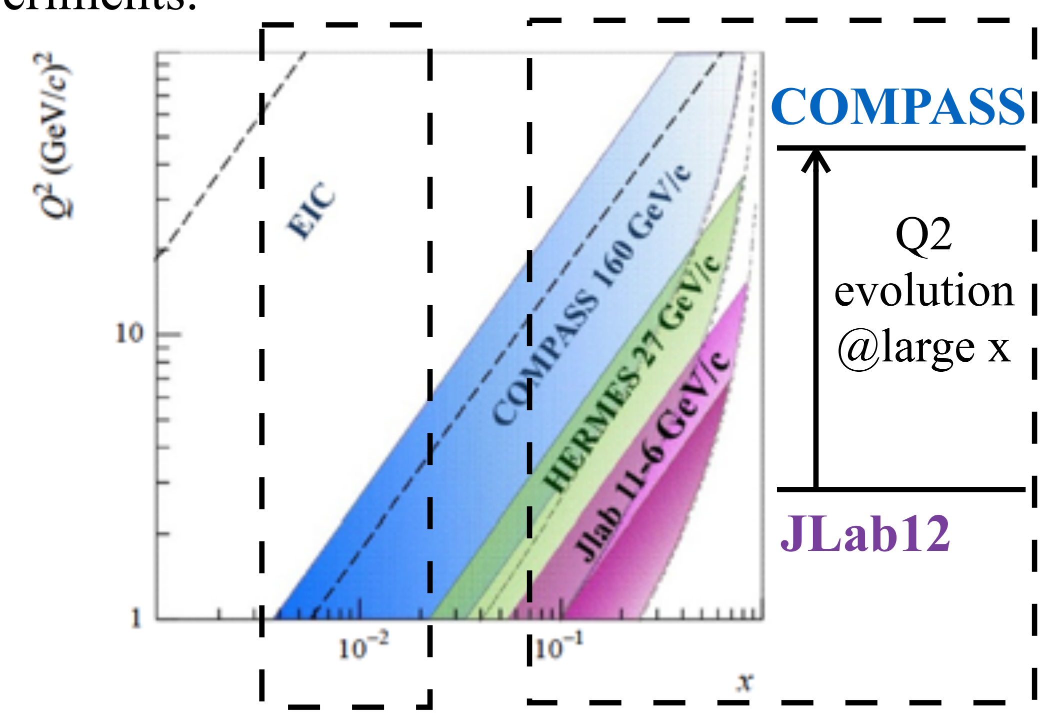
Isovector nucleon tensor charge: δu - δd with

$$\delta q(Q^2) = \int_0^1 dx[h_1^q(x,Q^2) - h_1^{\bar{q}}(x,Q^2)]$$

- Fundamental property of the nucleon, calculated in lattice QCD to far better precision than what is available from experimental data.
- Only worldwide available SIDIS data on transversely polarized deuteron target: COMPASS-I with low-aperature SMC target magnet.
  ⇒ d-quark transversity poorly known
- Complementary to JLab12 experiments.

COMPASS-I Collins asymmetry

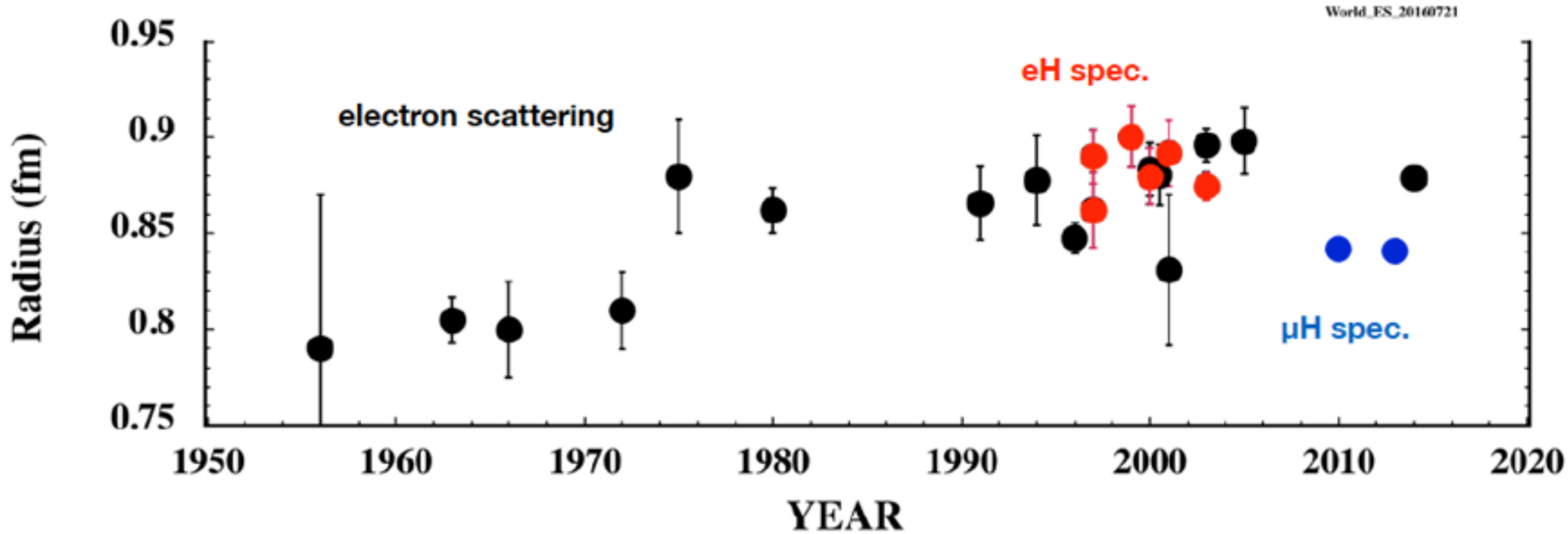




small x: essential for integral & for sea-quark transversity

What is the radius of the proton?

muon beam
proposed for >2021



- Proton radius puzzle: discrepancy between electronic hydrogen spectroscopy / elastic e-p scattering and muonic hydrogen spectroscopy (> 5 sigma)
- Is this due to a wrong treatment of systematic uncertainties? Due to the violation of lepton universality? Due to…?
- The missing puzzle piece is elastic μ-p scattering.

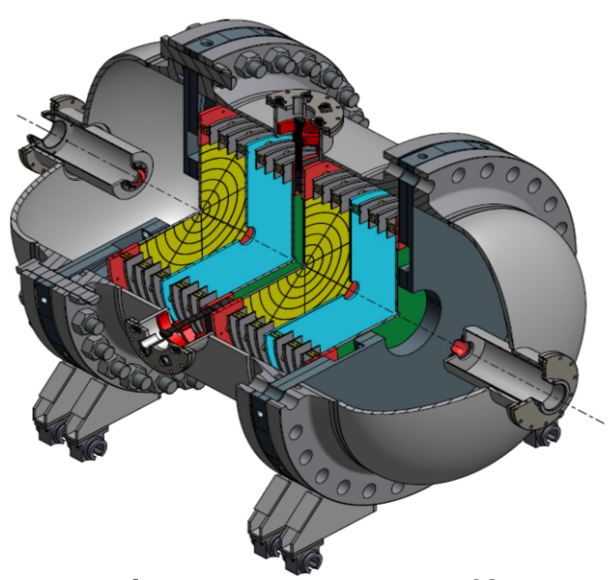
COMPASS Proton Radius Measurement
via high-energy muon-proton scattering

Slide courtesy J. Friedrich
More details in next talk by S. Uhl

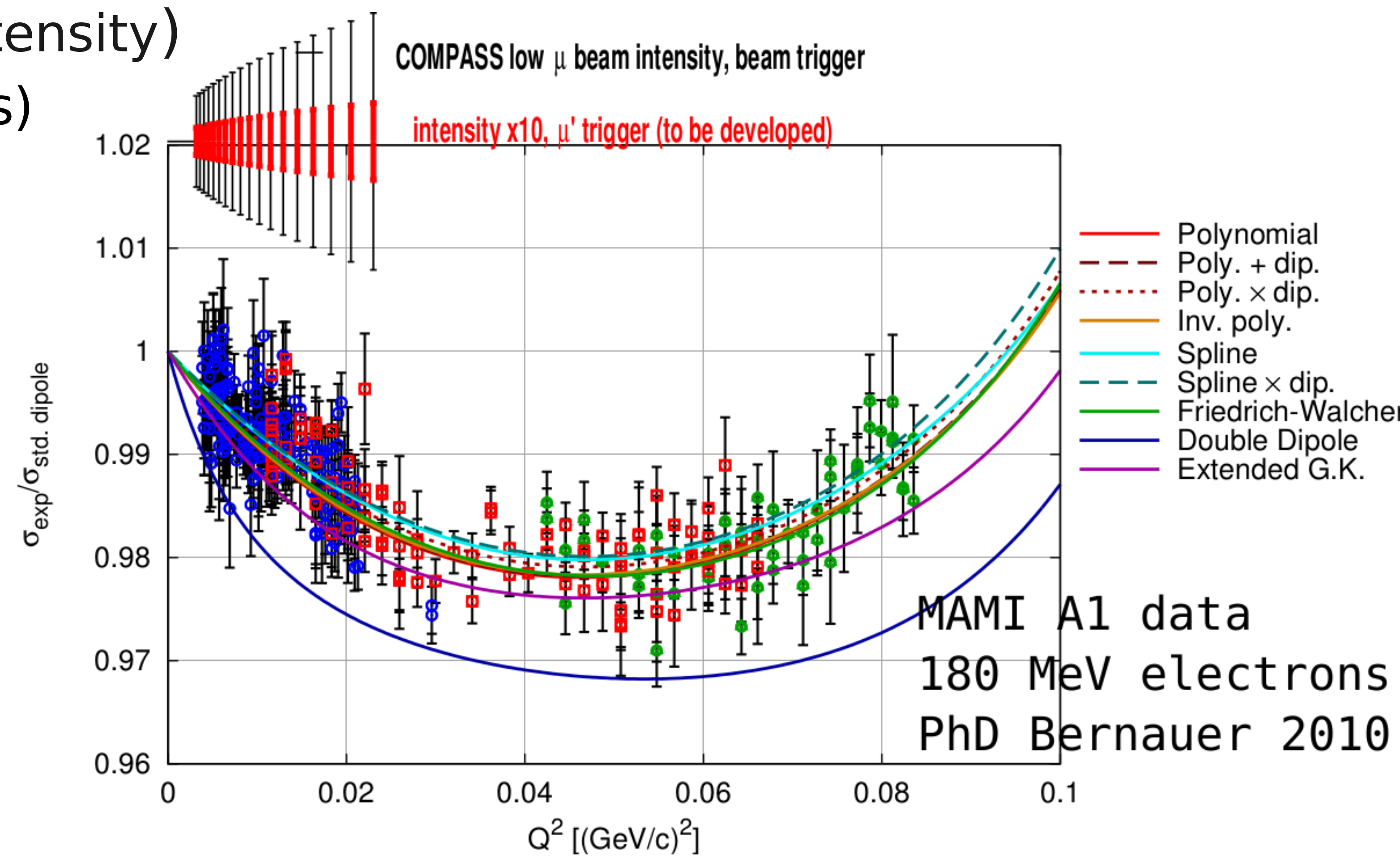
- 100 GeV SPS muon beam (M2)
- Hydrogen high-pressure active TPC target cell (PNPI development)
- Measure the cross-section (shape) over broad Q^2 range 10^{-4} … 10^{-1}
- From 10^{-3} … $2{*}10^{-2}$ fit the proton radius (slope of electric form factor)
  - Precision 0.03 fm with conservative beam trigger (0.5% beam intensity)
  - Goal: 0.01 fm (from 180 days) trigger concept to be solved

unique because...

- muon beam requires a factor 10 smaller radiative corrections than e^- beams (vs. Mainz, Jlab)
- high-energy muon beam, very small scattering angles: practically no Coulomb correction (vs. MUSE)
- *best systematics control*



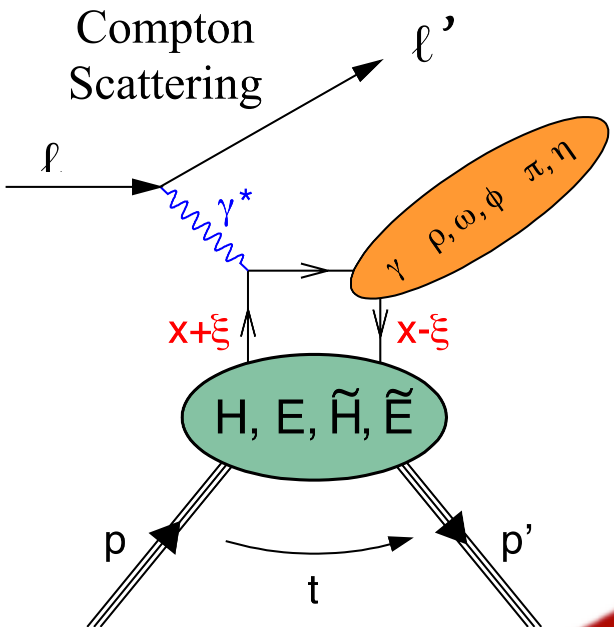
IKAR active target cell
A. Vorobyev, St. Petersburg



What is the total angular momentum of quarks?

LoI (draft)
muon beam

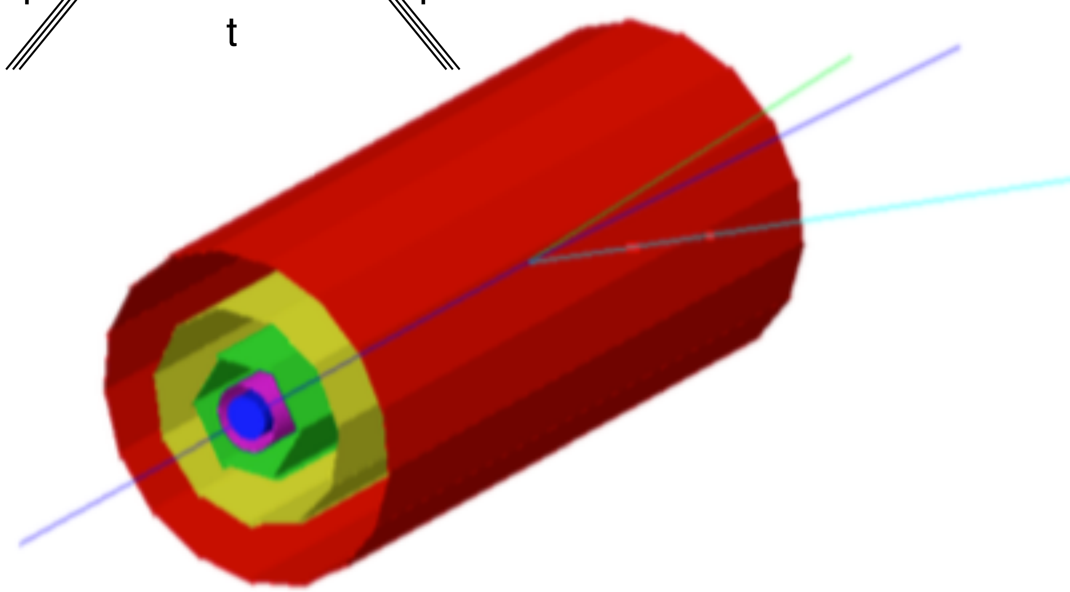
Deeply Virtual Compton Scattering

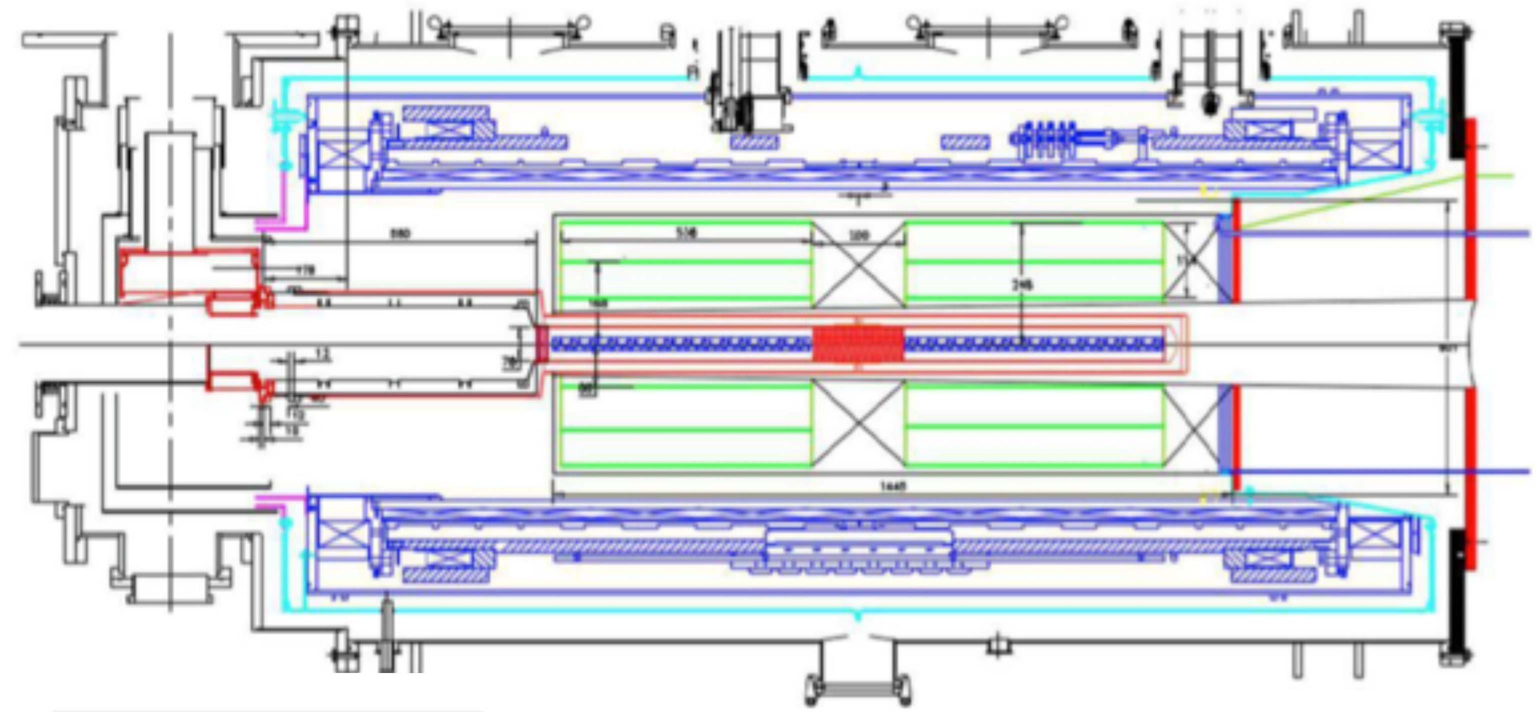


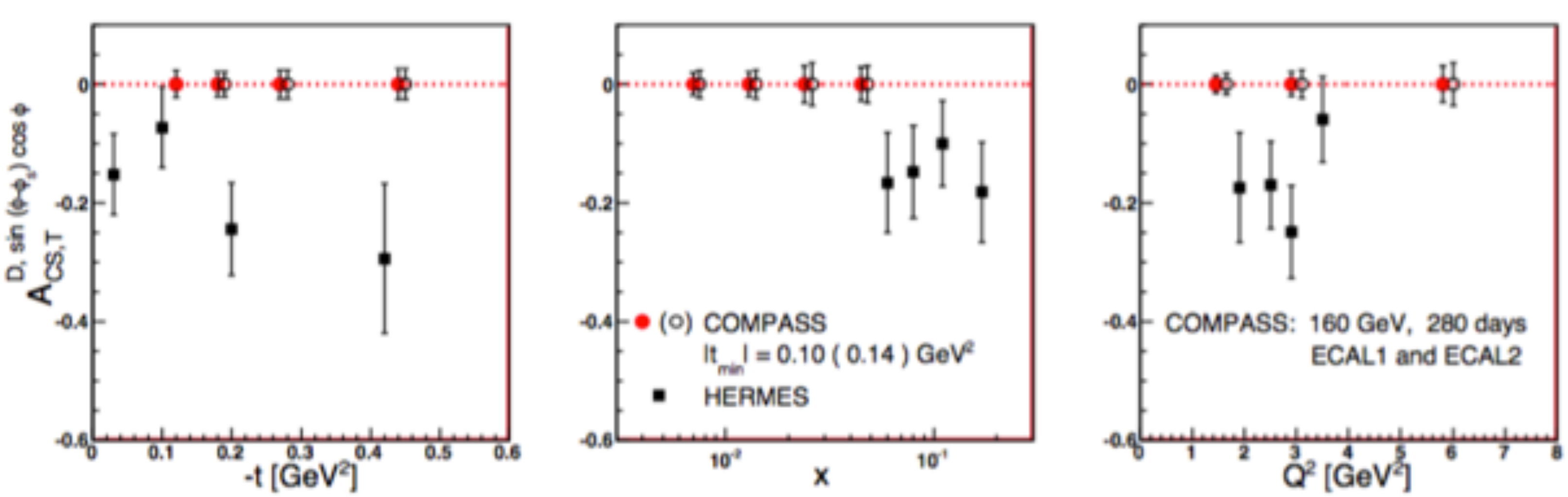
- Ji sum rule for the nucleon (Ji, PRL 78 (1997) 610):

$$J_q = \frac{1}{2} \lim_{t\to 0} \int_{-1}^{1} dx\, x \left[H^q(x,\xi,t) + E^q(x,\xi,t)\right]$$

- Spin-dependent **GPD E** requires transverse target polarization
- DVCS exclusive-event reconstruction at COMPASS requires recoil-proton detector





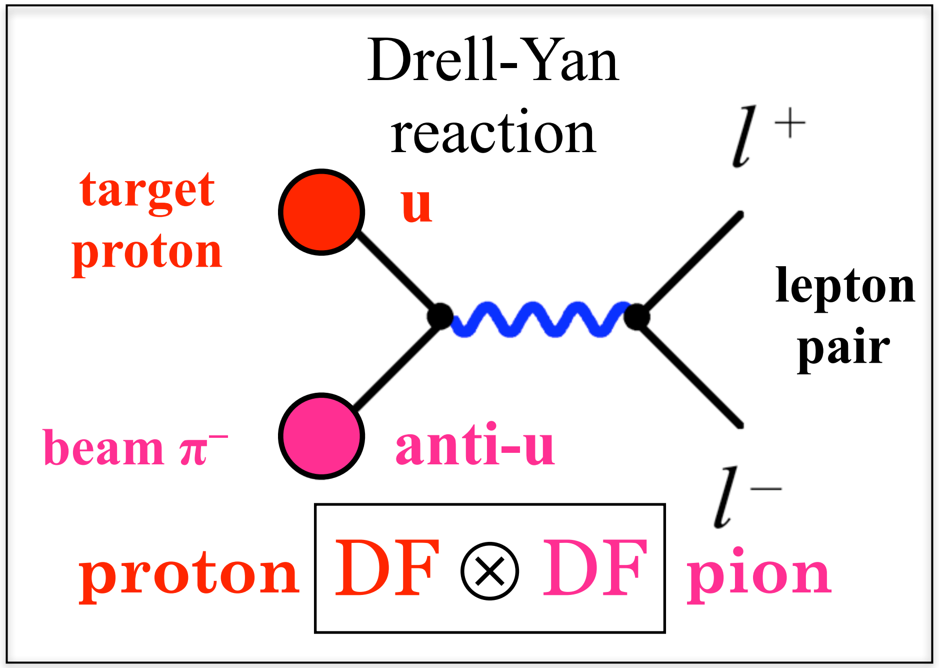


● $t_{min} = 0.10\ GeV^2$
o $t_{min} = 0.14\ GeV^2$

More about DVCS with polarized target & recoil detector Saturday (Nagaytsev and Meshcheryakov)

Pion structure: why are pions so much lighter than protons?

LoI (draft)
pion beam



- **The pion:** one of the most simple QCD objects.
  qq bound state & pseudo-Nambu-Goldstone boson acquiring mass via dynamical chiral symmetry breaking.

- **Proton quark & gluon structure**: detailed experimental information from (SI)DIS and jet, hadron, and Drell-Yan cross sections in pp / p$\bar{p}$

- **Mesons** only poorly constrained from early Drell-Yan cross section measurements for pions and completely unconstrained for Kaons.

- Pion valence- and sea-quark distributions
  - Valence and sea separation using π^+ and π^- beams of as high energy as possible
  - So far only NA3 & E615 end of 1980s. Low stat. Affected by nuclear effects.

- Charmonium production mechanism ⇒ pion gluon distributions .
  Available statistics can be increased by more than an order of magnitude.

- Nuclear effects: precise measurement of nuclear PDFs in the valence-quark region and check of flavor- (in)dependence of EMC effect

Full, detailed picture of pion structure

Nuclear medium modifications ("EMC-type" effect)

Drell-Yan with π^+ and π^- on unpolarized targets
- long light isoscalar target to avoid nuclear effects, e.g. carbon
- shorter and heavier nuclear target, e.g. tungsten or platinum

Drell-Yan with kaon and anti-proton beams

LoI (draft)

RF-separated beams

- Pion (*ud*) vs. kaon (*us*): presence of the heavier valence strange-quark might alter kaon properties.
- Kaon s-quark carries larger fraction of kaon momentum:
  ⇒ Valence distributions differ kaon vs. pion.
  ⇒ Less gluons in kaon than in pion (heavier quarks radiate softer gluons).
- Only experimental information on valence kaon PDF 30 years old: NA3. Sea unknown.
- Valence and sea separation in kaons using isoscalar targets and high-intensity K^+ and K^- beams.
- Kaon-induced J/ψ production to map kaon u-quark distribution
- Nucleon spin structure with anti-proton beams: measurements of observables related to proton TMDs with reduced systematic uncertainties. Example for Boer-Mulders TMD (BM):
  πp scattering: $(BM)_p \otimes (BM)_\pi$
  $\bar{p}$p scattering: $(BM)_p \otimes (BM)_{\bar{p}}$
  ⇒ Access to valence-quark TMDs of the proton only.

Drell-Yan with K^+, K^- and $\bar{p}$ beams on targets:
- liquid deuterium
- polarized ^{6}LiD
- nuclear

Hardware upgrades for Drell-Yan (all beams)

- In principle, same trigger topology as in 2015/18, but improvements are under discussion: creation of **high purity and efficiency dimuon trigger**, with target pointing capability.
- **Potentially new hodoscopes** with optimized shape. Goal is symmetric spectrometer & trigger. The introduction of a SAS-SAS trigger (currently only LAS-LAS & LAS-SAS) is considered (FPGA-based).
- Improvement of **read-out of the two CEDARs** (beam PID efficiency >90%, and high purity)
- Dedicated detector for precise **luminosity measurement** (precision in the order of 3%)
- **Beam trackers** for precise beam reconstruction
- Dedicated **vertex detection** system for improved vertex resolution
- (BMS to measure pion energy)

Kaon gluon structure and polarizability

LoI (draft)

RF-separated beams

- **Prompt photon production: kaon gluon structure**

$$d\sigma_{AB\to\gamma X} = d\sigma_{dir} + d\sigma_{frag} = \sum_{a,b=q,\bar{q},g} \int dx_a dx_b f_a^A(x_a, Q^2) f_b^B(x_b, \mu^2) d\sigma_{ab\to\gamma x}(x_a, x_b, Q^2) + d\sigma_{frag}$$

K+ beam (also π+ beam for reference) on long LH2.

- CEDARs to reject non-kaonic beam particles.
- New tracking detector upstream of ECal0 to reject charged particles with high pT.
- Trigger signature: 3 possibilities under investigation:

  1) Total energy deposition above some threshold (like ECAL2 in Primakoff run). Trigger rate: ~100 KHz

  2) As 1) but cell energies are summed with weights proportional to distance to the beam axis. TR: ~100 KHz

  3) True pT trigger - presence of at least 1 cluster with Pt>Pt0. It is assumed that the cluster was produced by a photon emitted from the target center. TR: ~ 10 kHz

- **Primakoff: Kaon polarizability**
  - Analogous setup as for the pion polarizability measurements 2009 and 2012
  - Central region of ECAL2 with some threshold(s).
  - Rates will strongly depend on the scale factor and threshold ~ >> 10 kHz.

$$K^- Z \to Z' K^- \gamma$$

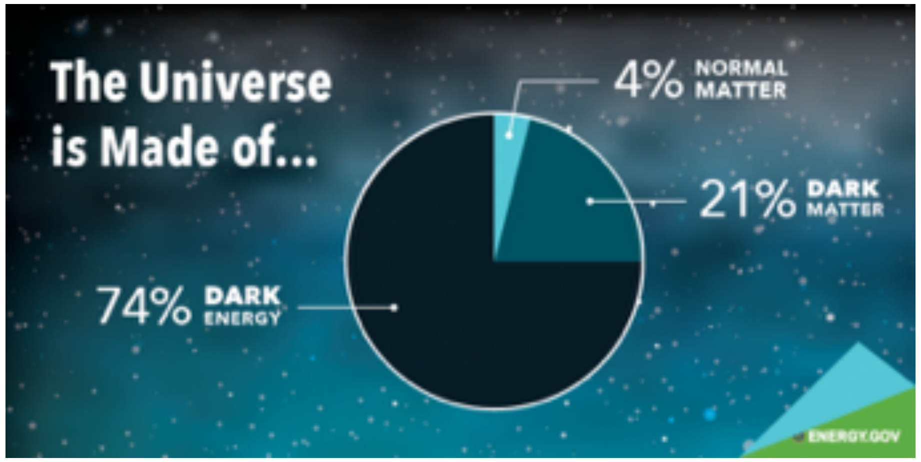
Anti-matter cross-section for Dark Matter Search

LoI (draft)
proton beam

- Indirect detection of DM: search for the products of DM annihilation or decay.

$$\chi + \chi \to q\bar{q}, W^-W^+, \ldots \to \bar{p}, \bar{D}, e^+, \gamma, \nu$$

- Measurements production cross sections to reduce present uncertainties: anti-proton 20-30% and anti-deuteron



Proton beam on LH2 and LHe targets

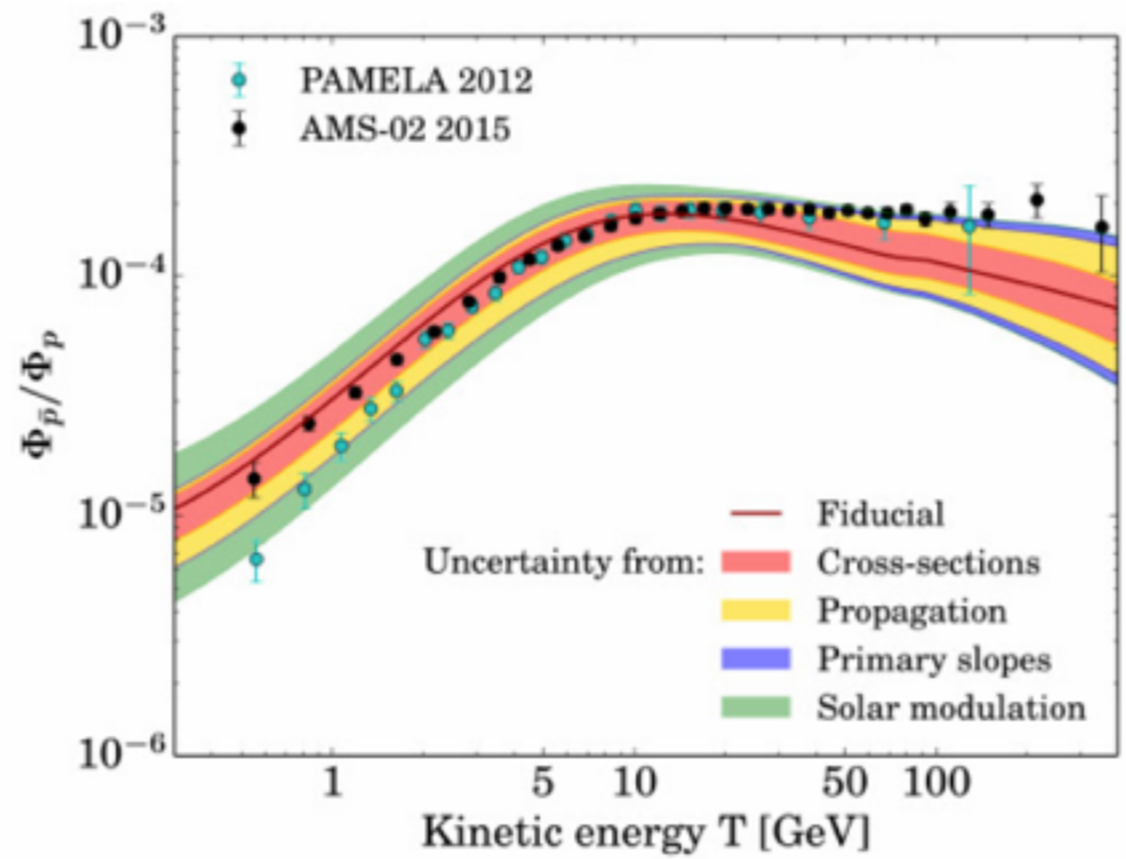
- Minimum bias trigger including

  - Beam trigger + hodoscope veto: ensures that the particle reaches COMPASS within the target cross section.
  Also includes a preselection of protons from the CEDARs.

  - Sandwich veto: exclude events with signals outside the COMPASS acceptance after the target.

  - Beam killer: remove events where protons keep the beam direction 32 m downstream the target.

- RICH0 for lower-momentum particles would be advantageous to ID anti-protons, otherwise use RICH1 in veto mode



Spectroscopy with low-energy anti-protons

LoI (draft)

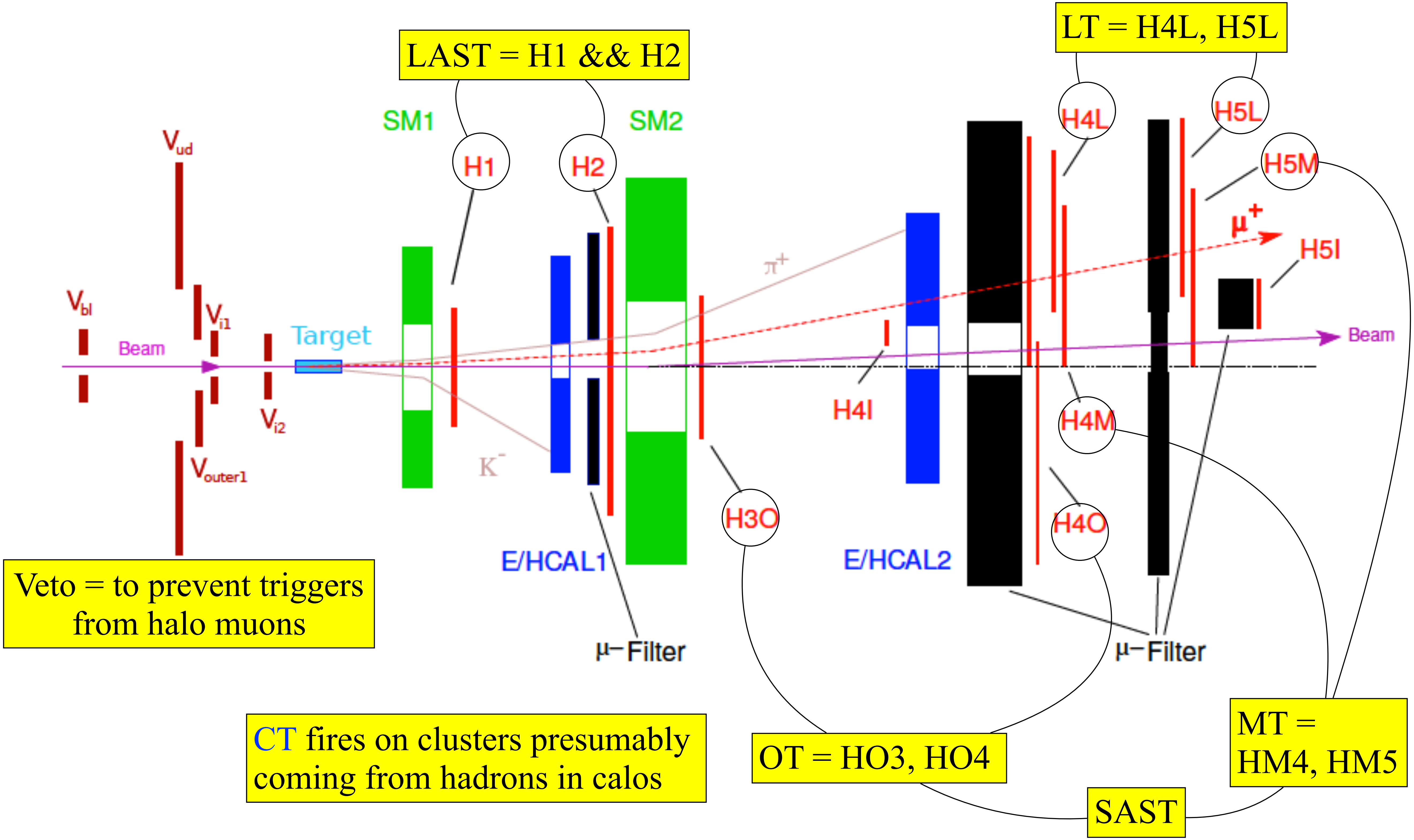
anti-proton beam

- Antiproton annihilation cross sections to open and hidden charm (bottom?)
- Production and spectroscopy of charmonium-like mesons

12-20 GeV anti-protons (and electrons) on targets: LH2, foil, wire

- Beam PID: CEDARs (high rates)
- Target spectrometer: Tracking, ECAL (barrel calorimeter)
- Forward spectrometer: COMPASS
- PID: μ, K ID, p suppression (RICH0?)
- Luminosity monitor

COMPASS (muon) trigger system



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

COMPASS hadron trigger (example)

Primakoff 2012

<table>
<tr><th>Bit</th><th>Name</th><th>Definition</th></tr>
<tr><td>01</td><td>DT0</td><td>aBT && !(Veto) && RPD</td></tr>
<tr><td>02</td><td>Prim1</td><td>aBT && ![Veto_hodo || Veto_Sandwich] && ECAL2center(thr.0)</td></tr>
<tr><td>03</td><td>Prim2</td><td>aBT && ![Veto_hodo || Veto_Sandwich] && ECAL2cluster</td></tr>
<tr><td>04</td><td>Prim3</td><td>aBT && ![Veto_hodo || Veto_Sandwich] && ECAL2center(thr.1)</td></tr>
<tr><td>05</td><td>minBias</td><td>aBT && !(Veto)</td></tr>
<tr><td>06</td><td>VI</td><td>Veto_Inner1 && Veto_Inner2</td></tr>
<tr><td>07</td><td>Halo</td><td>Veto_Outer && HOuter4</td></tr>
<tr><td>08</td><td>BT</td><td>Beam trigger</td></tr>
<tr><td>09</td><td>aBT</td><td>altern. Beam trigger</td></tr>
<tr><td>10</td><td>KT</td><td>aBT && !(Veto) && [CEDAR1(>6) || CEDAR2(>6)]</td></tr>
<tr><td>11</td><td>TRand</td><td>True Random Trigger</td></tr>
<tr><td>12</td><td>NRand</td><td>Noise Random Trigger</td></tr>
</table>

ECAL2(thr.0) = 60 GeV ECAL2(thr.1) = 20 GeV; Prim3 pre-scaled by factor 20 F

Conditions for future programs

Additional questions: trigger latency?
Hardware (FPGA) or software trigger?
Earliest possible realization?

(*) or list of detectors to be included in trigger logic

Program	Type / set of detectors baseline: COMPASS w/o RICH1	Beam energy [GeV]	Rate on target [sec^{-1}]	Trigger rate (est.) [kHz]	Trigger signature (*)	Trigger challenge factor
d-quark Transversity	RICH1	160	3×10^6	25	As 2010: IT, MT, LT, OT, CT, LAST	
Proton radius	active hydrogen target, silicon (2+1) or SciFi (2+2) telescopes	100	4×10^6	<= 100	~~beam trigger?~~ scattered-muon trigger? (recoil-proton trigger?)	
GPD E	recoil detector around transpol polarized target	160	10^7	10	MT, LT, OT, LAST. If higher beam intensity: photon or proton trigger?	
Drell-Yan conventional	vertex detector	190	$0.2\text{-}6.8 \times 10^7$	25	As 2015: MT+LAST, OT +LAST, LAST 2mu	
Drell-Yan RF-separated	vertex detector, larger tracking detectors?	~100	10^8	25-50	As above + ? new hodoscopes for SAS-SAS trigger	
Primakoff RF-separated	RICH1	~100		>> 10	ECal2 ΔE>threshold	
Prompt photon prod.		>= 100	5×10^6	10-100	ECal0, ECal1 ΔE>threshold, or “true pT” trigger	
Anti-matter x-section	RICH1 (RICH0?)	50 100 190,..	5×10^5	25	As 2012 Primakoff: (a)BT, VI, ΔECals>threshold	
Spectroscopy anti-p	target spectrometer: tracking & calorimetry, RICH (RICH0?)	12 20			CEDARs?	

Next PBC workshop

Physics Beyond Colliders

Physics Beyond Colliders Annual Workshop

Registration is open!

21-22 November 2017
CERN
Europe/Zurich timezone

Search...

- Overview
- Scientific Programme
- Call for Abstracts
- Timetable
- Registration
- Participant List
- Accommodation

Organisation

PBC.com@cern.ch
+41754113293

The aim of the Physics Beyond Colliders study group is to explore the opportunities offered by the CERN accelerator complex and infrastructure to gain new insights into some of today's outstanding questions in particle physics through projects complementary to high-energy colliders and other initiatives in the world. The focus is on fundamental physics questions that are similar in spirit to those addressed by high-energy colliders, but that may require different types of experiments.

This follow-up workshop is intended to review the status of the projects proposed at the kick-off workshop of September 2016, and to stimulate further new ideas for which we encourage the submission of abstracts.

Organizing Committee: Joerg Jaeckel, Mike Lamont, Connie Potter, Claude Vallée

Starts 21 Nov 2017 08:00
Ends 22 Nov 2017 23:20
Europe/Zurich

CERN
500-1-001 - Main Auditorium

J.Bernhard CBWG - EHN2 Meeting #1 10

Summary: Future 2020++ at the CERN M2 beam line with COMPASS and a COMPASS-like experiment

- CERN M2 beam line: unique hadron and muon facility
- COMPASS spectrometer as baseline for future experiments, with various upgrade projects
- Rich program proposed or intended: proton and meson (spin) structure, cross section measurements, spectroscopy, proton radius
- **New collaborators very welcome!**
- **Proposal 2021(/22) submitted, Letter of Intent (2022++) will be submitted by the end of the year.**

COMPASS trigger hodoscopes

System	Hodoscope	No. of stripes	Width (mm)	z-Pos.	Area (cm^2)	PMT type
Inner	H4I (up)	32	6	32	17.34×19.4	R7400
	H4I (dn)	32	6	32	17.34×19.4	R7400
	H5I (up)	32	12	51	35.3×25.95	XP2900
	H5I (dn)	32	12	51	35.3×25.95	XP2900
Ladder	H4L	32	22-57	40.65	128.2×40	XP2900
						2090,2020
	H5L	32	27-87	48.05	168.2×47.5	XP2900
						2090,2020
Middle	HM4X (up)	20	62	40.3	120 × 35.5	XP2072B
	HM4X (dn)	20	62	40.3	120 × 35.5	XP2072B
	HM4Y (up)	32	21.5-25	40.4	120 × 35.5	XP2900
	HM4Y (dn)	32	21.5-25	40.4	120 × 35.5	XP2900
	HM5X (up)	20	77	47.7	150 × 42.5	EMI9954B
	HM5X (dn)	20	77	47.7	150 × 42.5	EMI9954B
	HM5Y (up)	32	25-30	47.8	150 × 42.5	XP2900
	HM5Y (dn)	32	25-30	47.8	150 × 42.5	XP2900
Outer	HO3	16	70	23	200 × 100	9813/XP2020
	HO4	32	150	40	480 × 225	9813/XP2020
LAS	H1	32	60	5.8	230 × 192	XP2900/2982
	H2	32	136	16	500 × 420	9813KB

COMPASS RICH-1

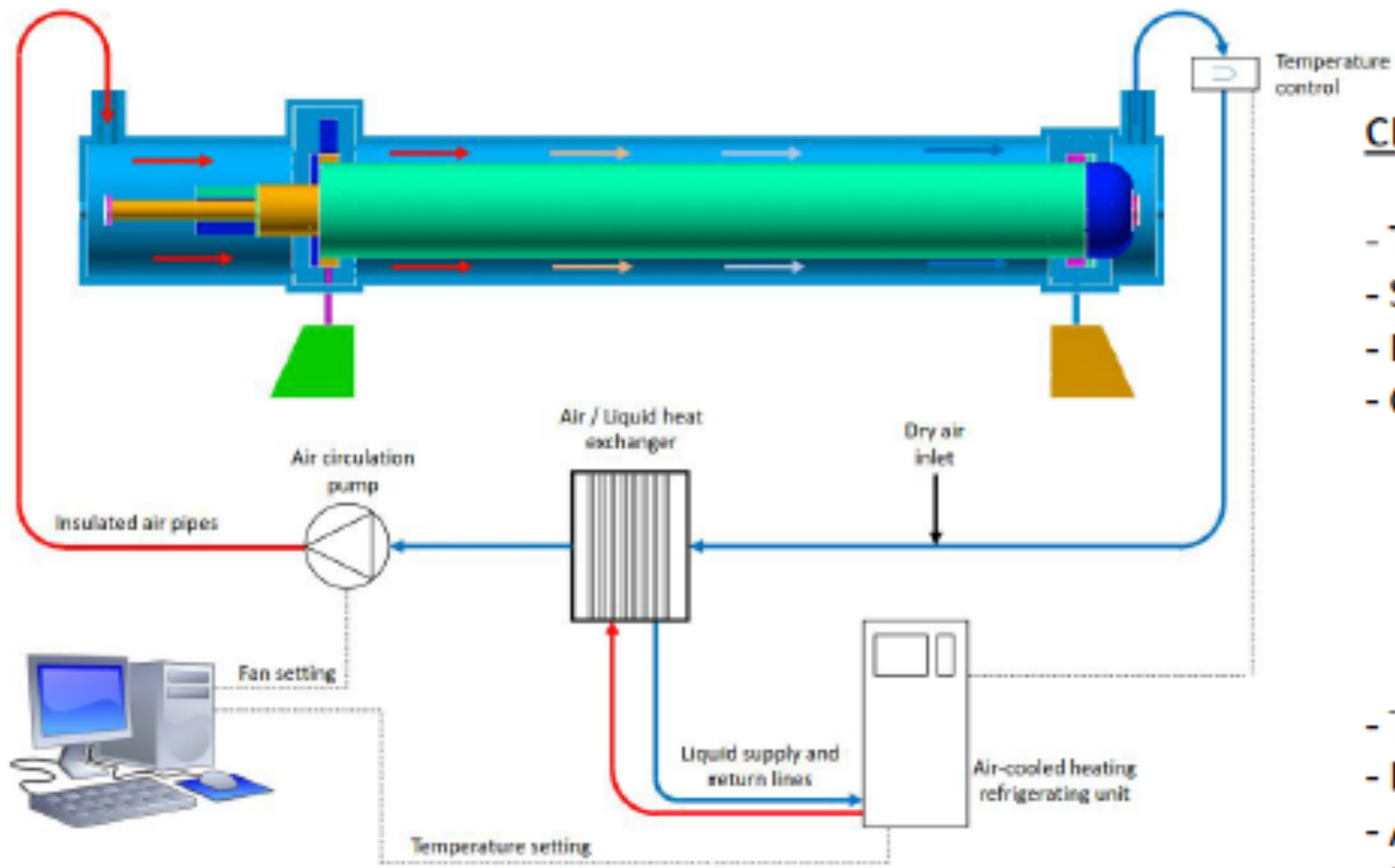
- Built late 1990s, upgraded 2005-06 and 2015-16.
- Large acceptance Cherenkov imaging counter: ±200 mrad in the vertical plane, ±250 mrad in the horizontal plane
- Photon detection
  - central region (25% of surface, higher rate): MAPMTS coupled to individual fused silica lens telescopes
  - peripheral 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)

Notes: proton radius

- Simplest: kink trigger with Silicons
  2 layers before target + 3rd after target. Deviation from straight line?
- SciFi telescopes. Worse spatial resolution, need longer lever arm
  need 2 + 2 layers
- SciFi target: replaced by hydrogen surrounded by SciFi, no problems due to quasi-elastic scattering
- Necessary **(new): active hydrogen target, silicon or SciFi telescopes**, muID, trigger hodoscopes, MW
- Desirable: ECal2, HCal, drift chambers

CEDAR Upgrade

- CEDAR upgrade for better rate and thermal stability, goal: project ready for 03/2018
  - New PMTs, gain monitor, and read-out (COMPASS)
  - New thermalisation (EN-EA / MME / CV)
- S. Mathot is project leader for CERN, M. Ziembicki coordinates Front-end for COMPASS, BE-BI will check compatibility and use this as a pilot project



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 m^2
  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 m^3
- Internal heat load: ~ 50 W

Conventional Beams – Structure

CONVENTIONAL BEAMS WORKING GROUP

Conveners: L.Gatignon, M.Brugger

Members: Experiments, H.Wilkens, G.Lanfranchi, T.Spadaro, EA physicists, HSE, RP, EL, CV, RF, STI

CBWG-ECN3

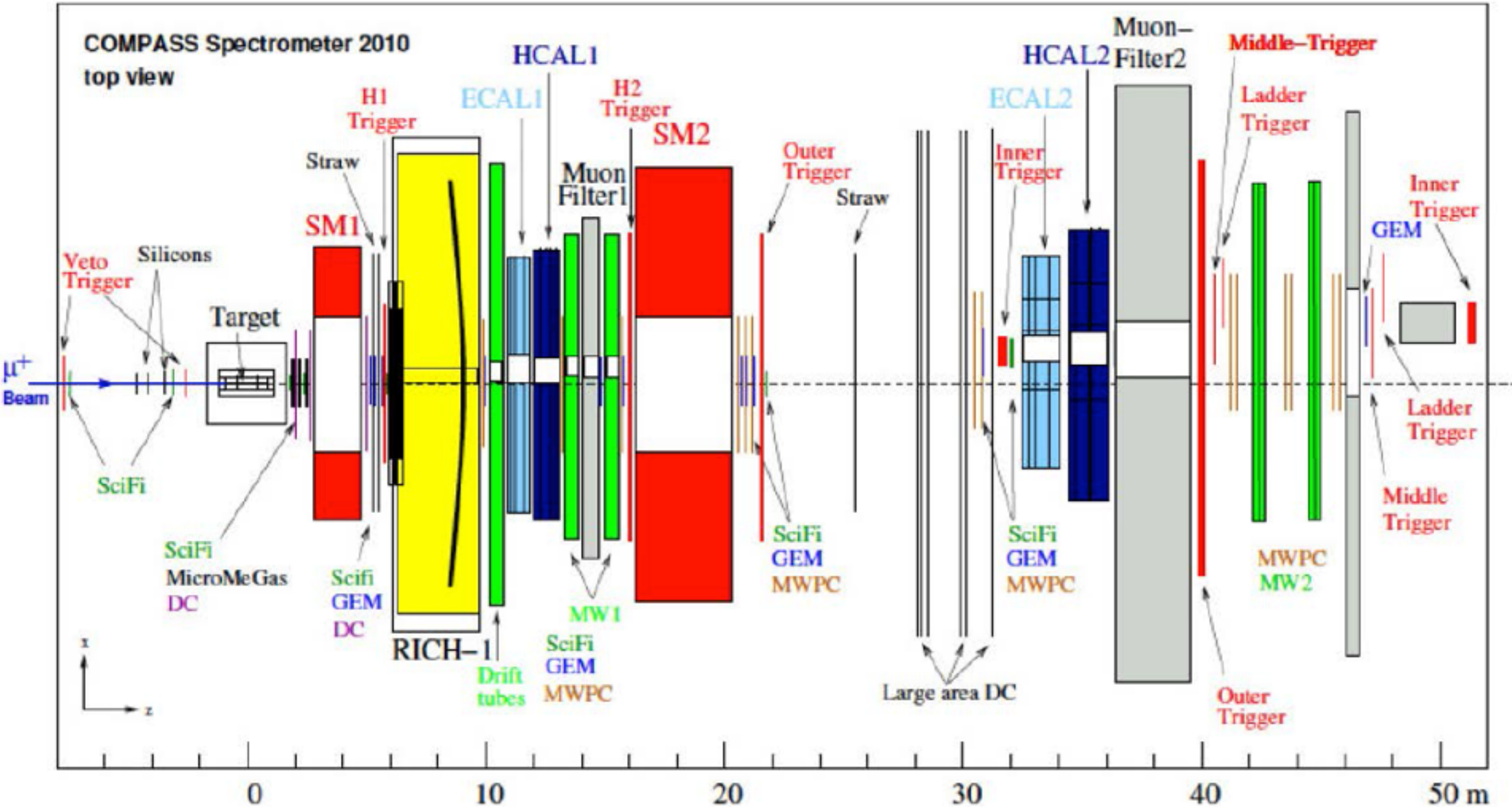
- K_LEVER
- NA62 Dump
- NA60
- DIRAC

CBWG-EHN2

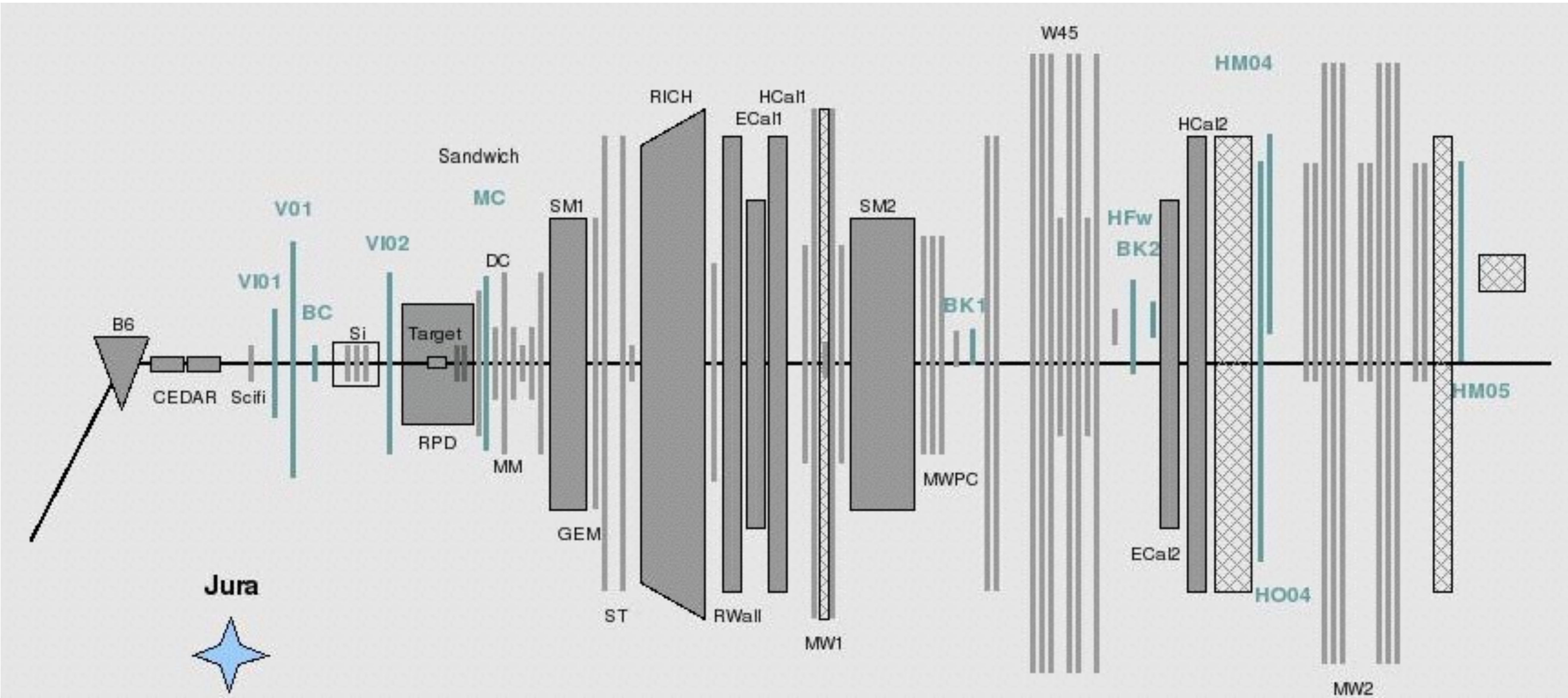
- COMPASS (RF-separated and low energy pbar beams)
- μ-e elastic
- NA64-μ
- CEDAR

CBWG-EHN1

- NA61
- NA64 hadrons



DAQFEET DAQ/FEE/Trigger for COMPASS beyond 2020 Workshop


W45
HM04
RICH
HCal1
ECal1
HCal2
Sandwich
MC
SM1
SM2
HFw
V01
VI02
BK2
DC
VI01
BK1
BC
B6
Si
Target
CEDAR
Scifi
HM05
RPD
MM
MWPC
GEM
ECal2
Jura
HO04
ST
RWall
MW1
MW2

Target region Drell-Yan 2015 & 2018

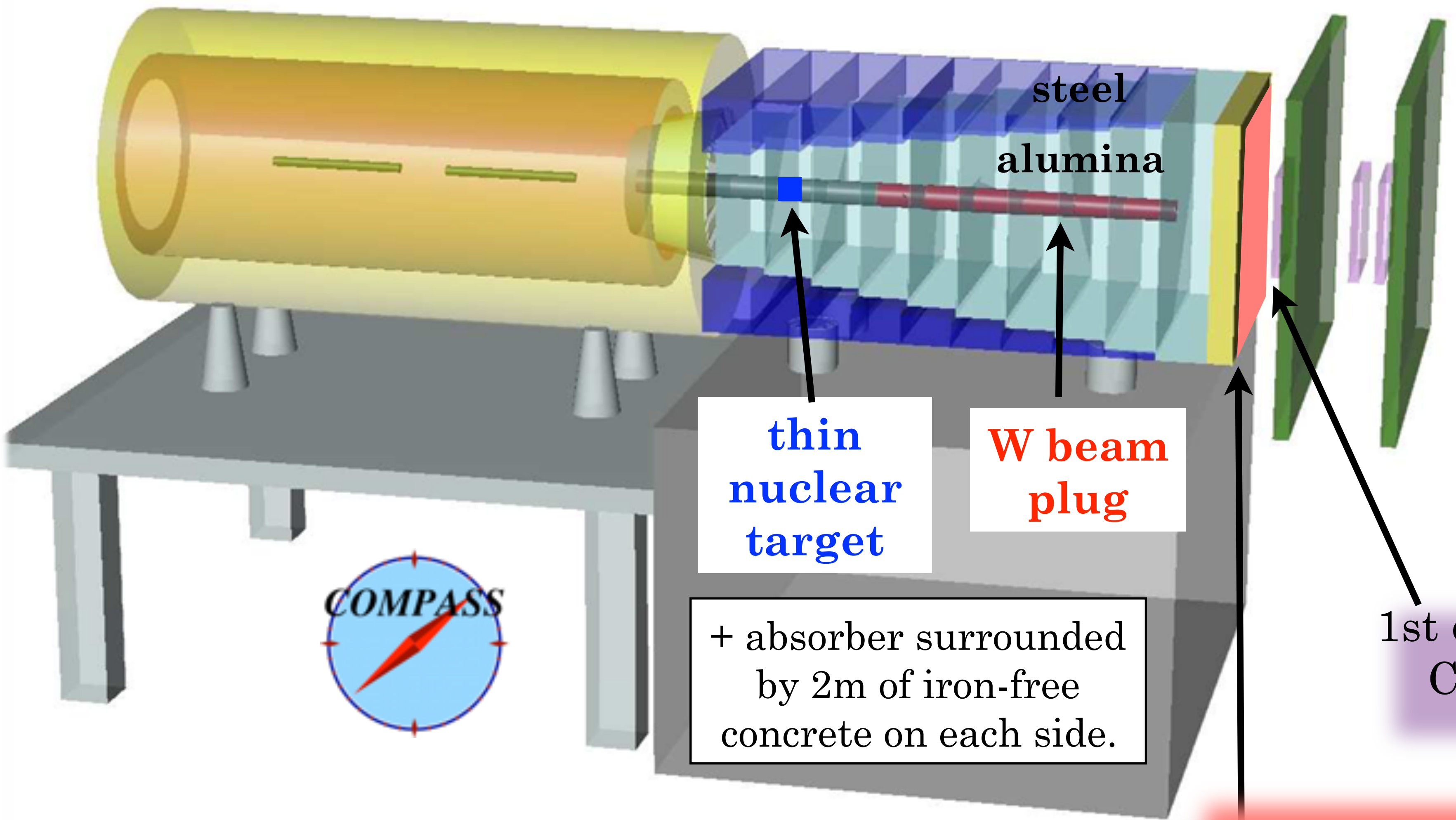
1. Long. pol.: DNP & 2.5T solenoid
2. Trans. pol: 0.6T dipole

Ammonia beads immersed into liquid helium; dilution factor=0.22

Transversely polarized NH3 target

Hadron absorber

To minimize multiple scattering of muons and to maximize stopping power for hadrons.

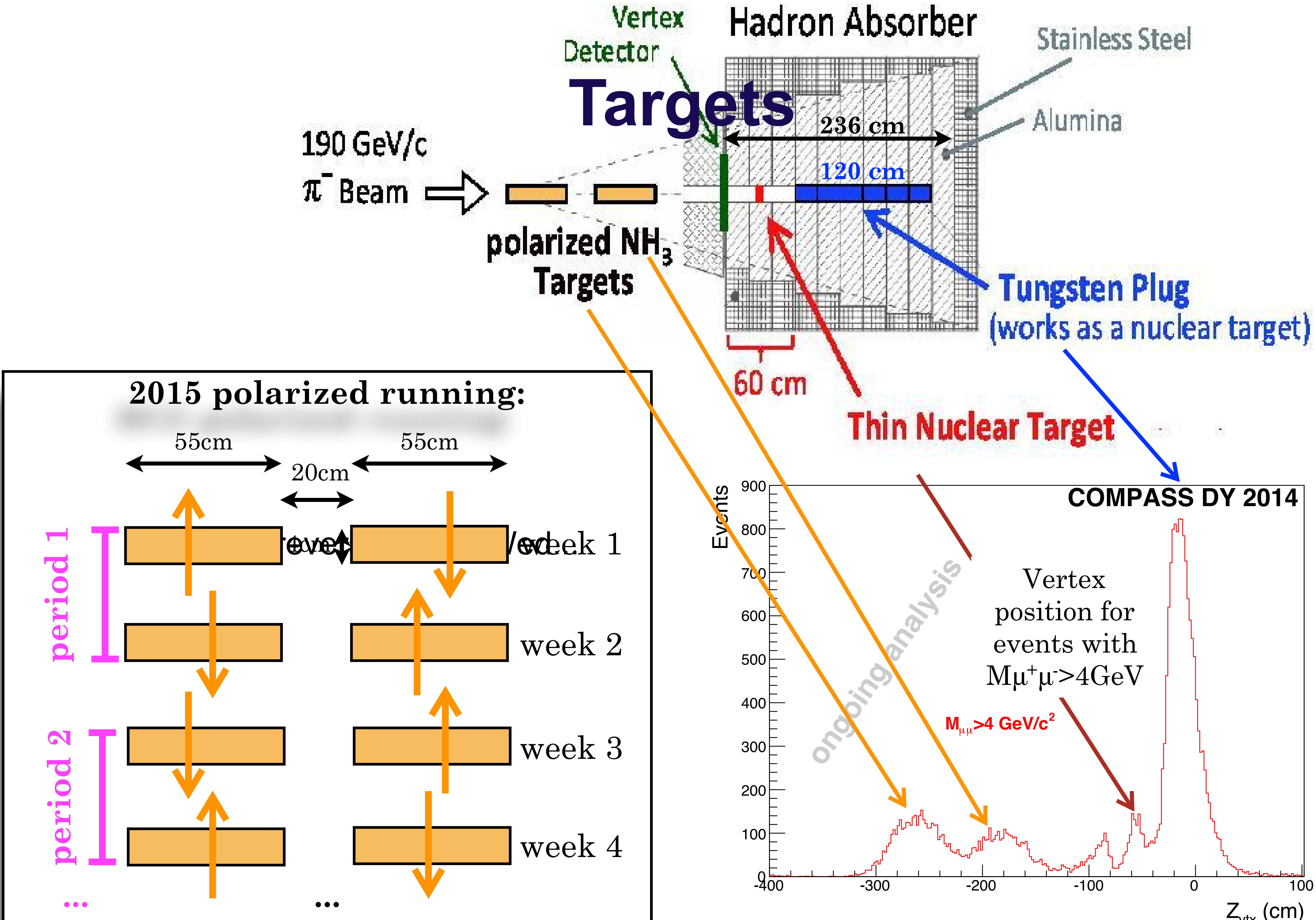


1st downstream COMPASS detector

^{6}Li absorber

to prevent flooding of very upstream detectors with charged particles from capture of spallation neutrons ($\Rightarrow \gamma \Rightarrow e^{+}e^{-}$).

Targets



Vertex Detector
Hadron Absorber
Stainless Steel
Alumina
236 cm
120 cm
190 GeV/c
π⁻ Beam
polarized NH3 Targets
Tungsten Plug
(works as a nuclear target)
60 cm
Thin Nuclear Target
2015 polarized running:
55cm
20cm
55cm
period 1
period 2
week 1
week 2
week 3
week 4
...
...
COMPASS DY 2014
Events
Vertex position for events with Mμ+μ->4GeV
Mμμ>4 GeV/c2
ongoing analysis
Zvtx (cm)
900
800
700
600
500
400
300
200
100
0
-400
-300
-200
-100
0
100