Pion-induced Drell-Yan scattering at

COMPASS

Caroline Riedl
(University of Illinois at Urbana-Champaign)
on behalf of the COMPASS Collaboration

September 13, 2018

Special thanks to Vincent Andrieux, Riccardo Longo, Marco Meyer, Evgenii Mitrofanov, Charles Naim, Bakur Parsamyan, Catarina Quintans

ILLINOIS

BLUE WATERS

Transverse Momentum Dependent PDFs

legend *nucleon moves to the right.*

nucleon (**N**) — nucleon spin

unpolarized quark (**Q**) — quark spin

quark k_T

TMDs surviving integration over k_T. "Collinear analysis"

naive time-reversal odd TMDs

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

chiral odd TMDs

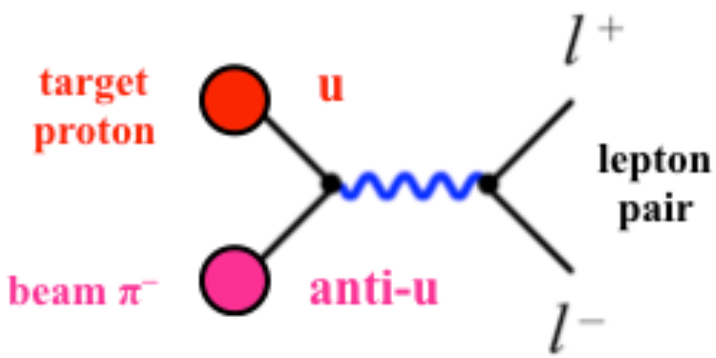
→ **Chiral symmetry breaking** of the QCD nucleon wave function

8 **TMD(PDF)s** needed at leading twist description.
Fragmentation functions (not shown here) are denoted by capital symbols.

Flavor indices and kinematic dependences skipped for simplicity.

Spin-dependent Drell-Yan measurement at COMPASS

Drell-Yan

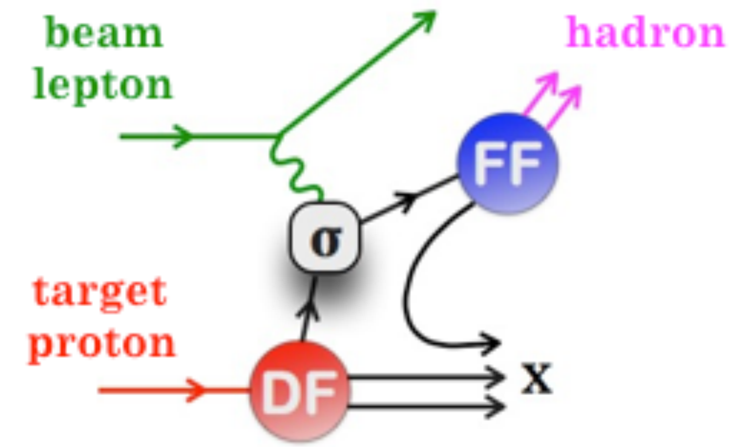


Sivers (proton) ⊗ unpolarized distribution function (pion)

The **Sivers** TMD is expected to have the **same magnitude**, but **opposite sign** in SIDIS vs. DY. The same applies to the **Boer-Mulders** function.

Crucial test of TMD framework.

Semi-Inclusive Deep-Inelastic Scattering



Sivers (proton) ⊗ unpolarized fragmentation function

Drell-Yan cross section for transversely polarized proton target (simplified):

$$d\sigma(\pi^- p^\uparrow \to \mu^+\mu^- X) \sim 1 + \boxed{\overline{h}_1^\perp} \otimes \boxed{h_1^\perp} \cos(2\phi)$$

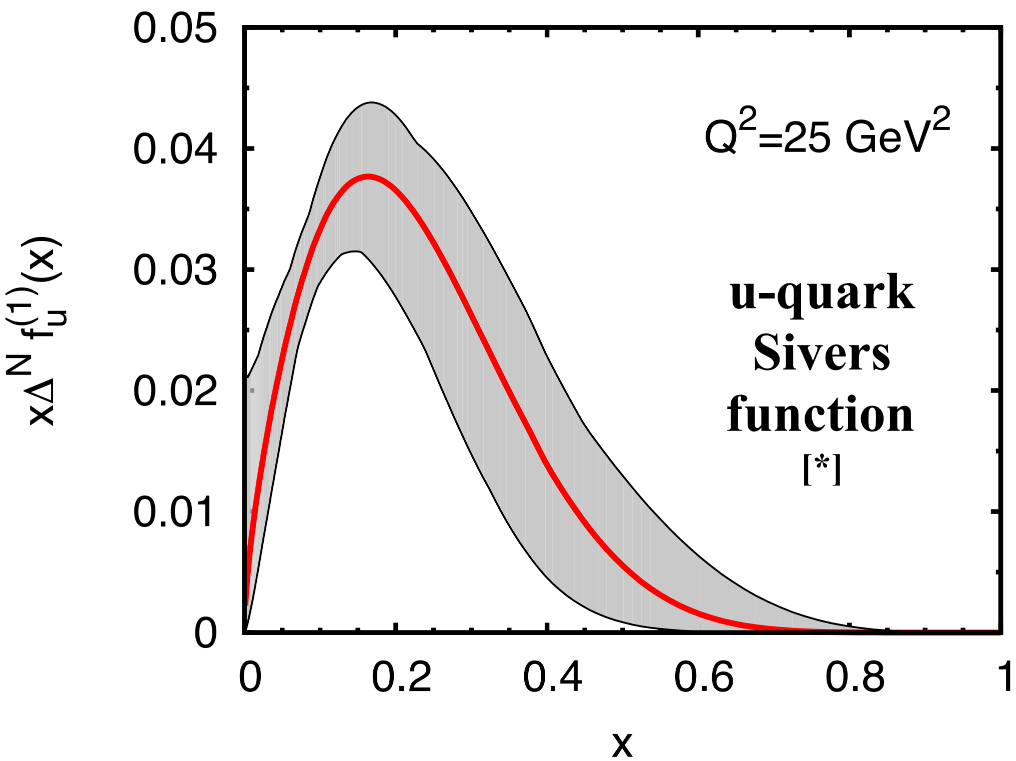
$$+|S_T| \boxed{\overline{f}_1} \otimes \boxed{\overline{f}_{1T}^\perp} \sin\phi_S$$

$$+|S_T| \boxed{\overline{h}_1^\perp} \otimes \boxed{h_{1T}^\perp} \sin(2\phi + \phi_S)$$

$$+|S_T| \boxed{\overline{h}_1^\perp} \otimes \boxed{h_1} \sin(2\phi - \phi_S)$$

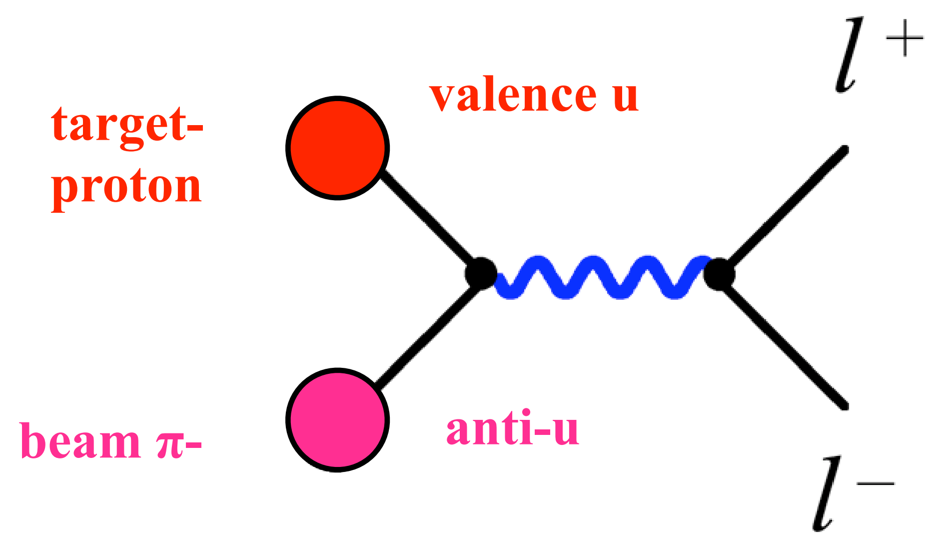
beam		target
(BM)	⊗	(BM)
(f_1)	⊗	(Sivers)
(BM)	⊗	(Pretzelosity)
(BM)	⊗	(Transversity)

COMPASS pion-induced Drell-Yan $\pi^- p^\uparrow \rightarrow \mu^+ \mu^- X$

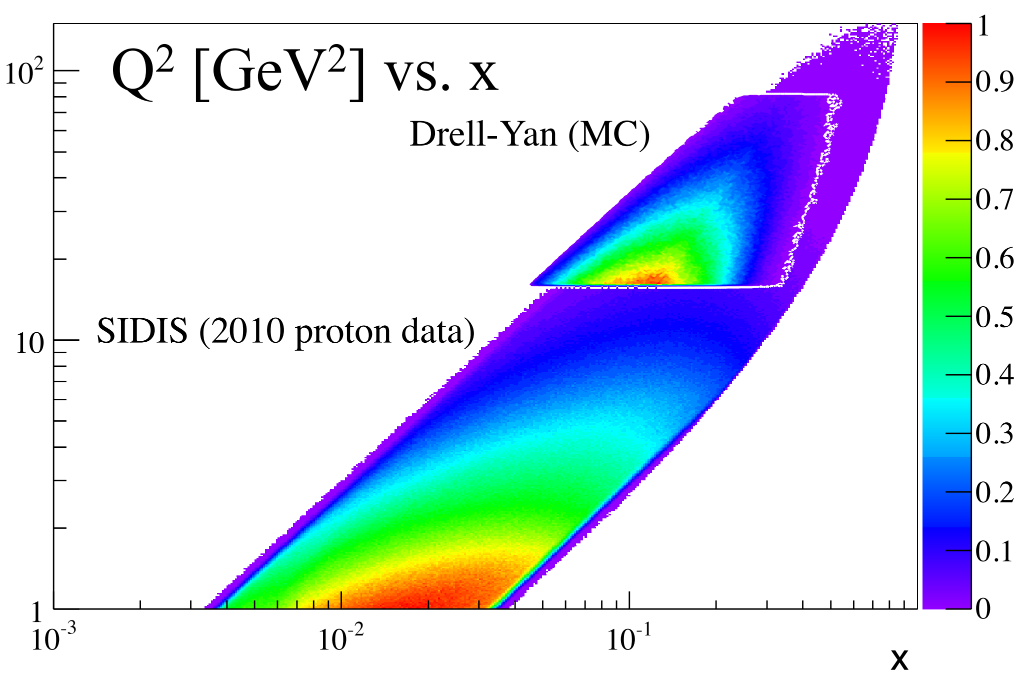


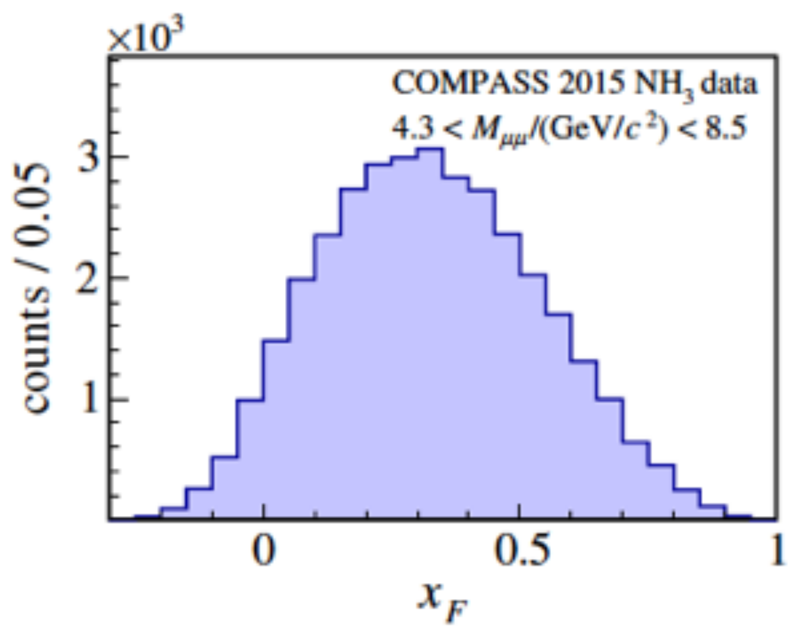
[*] calculated from: M. Anselmino et al., EPJ A39 (2009) 89.

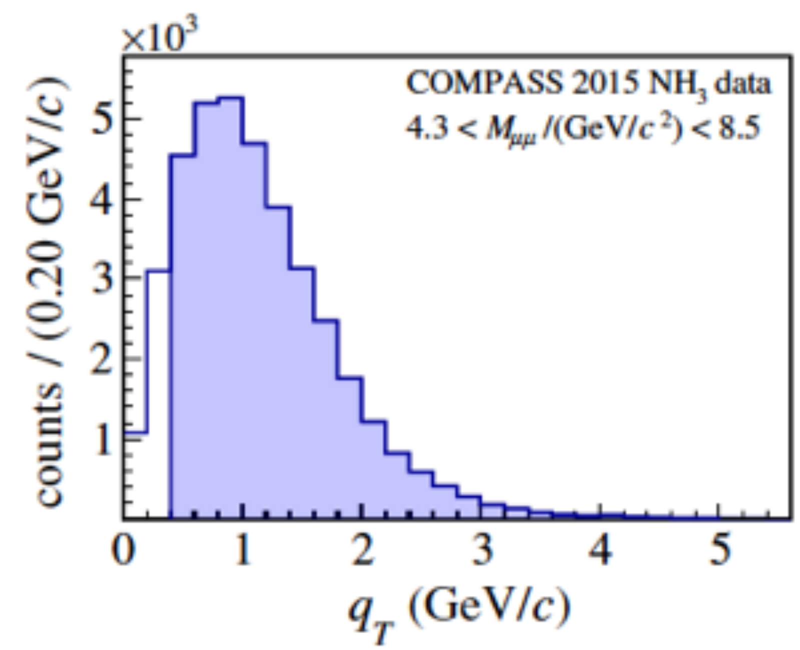
$$\sigma^{\mathrm{DY}} \propto f_{\bar{u}|\pi} \otimes f_{u|p}$$



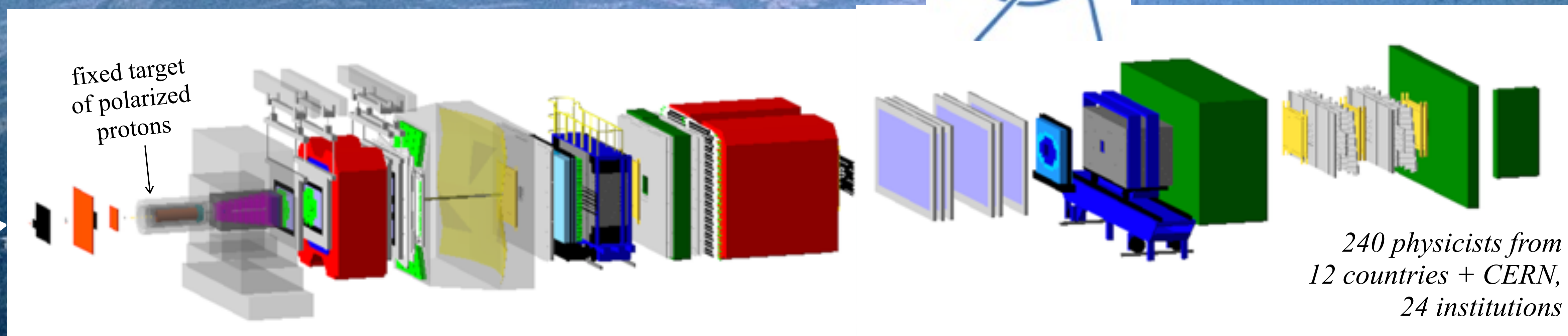
COMPASS DY / SIDIS data

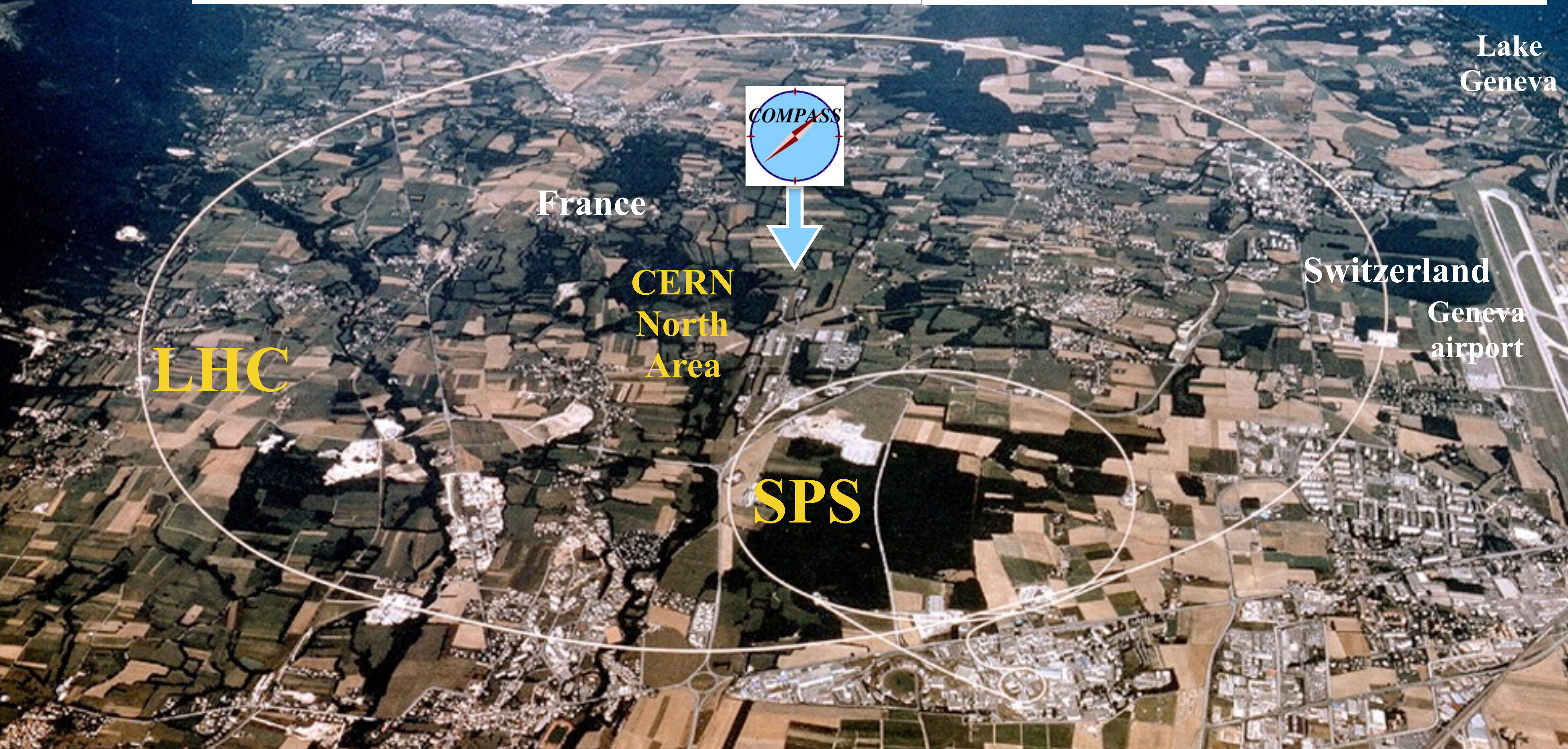






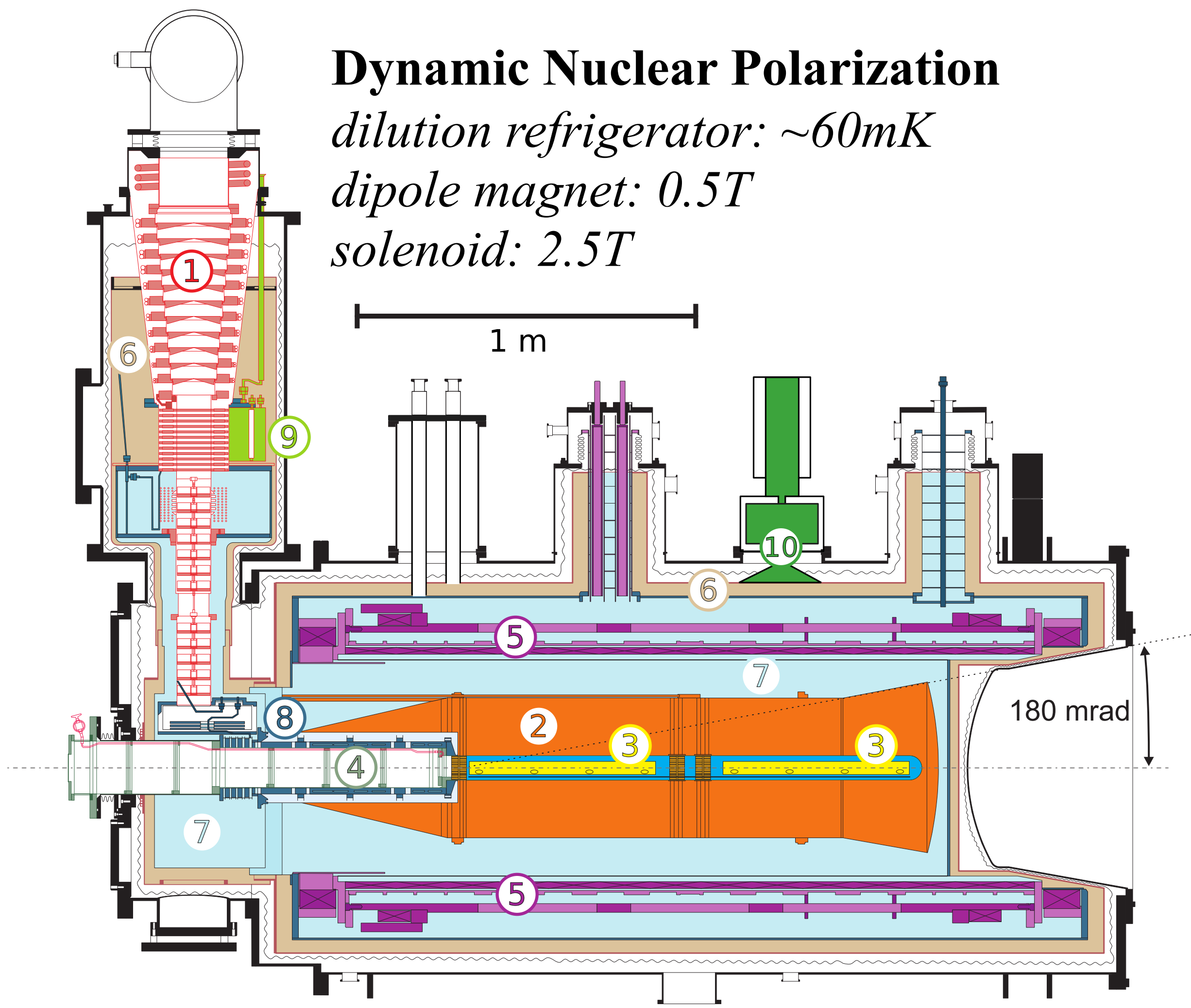
COMPASS @ CERN



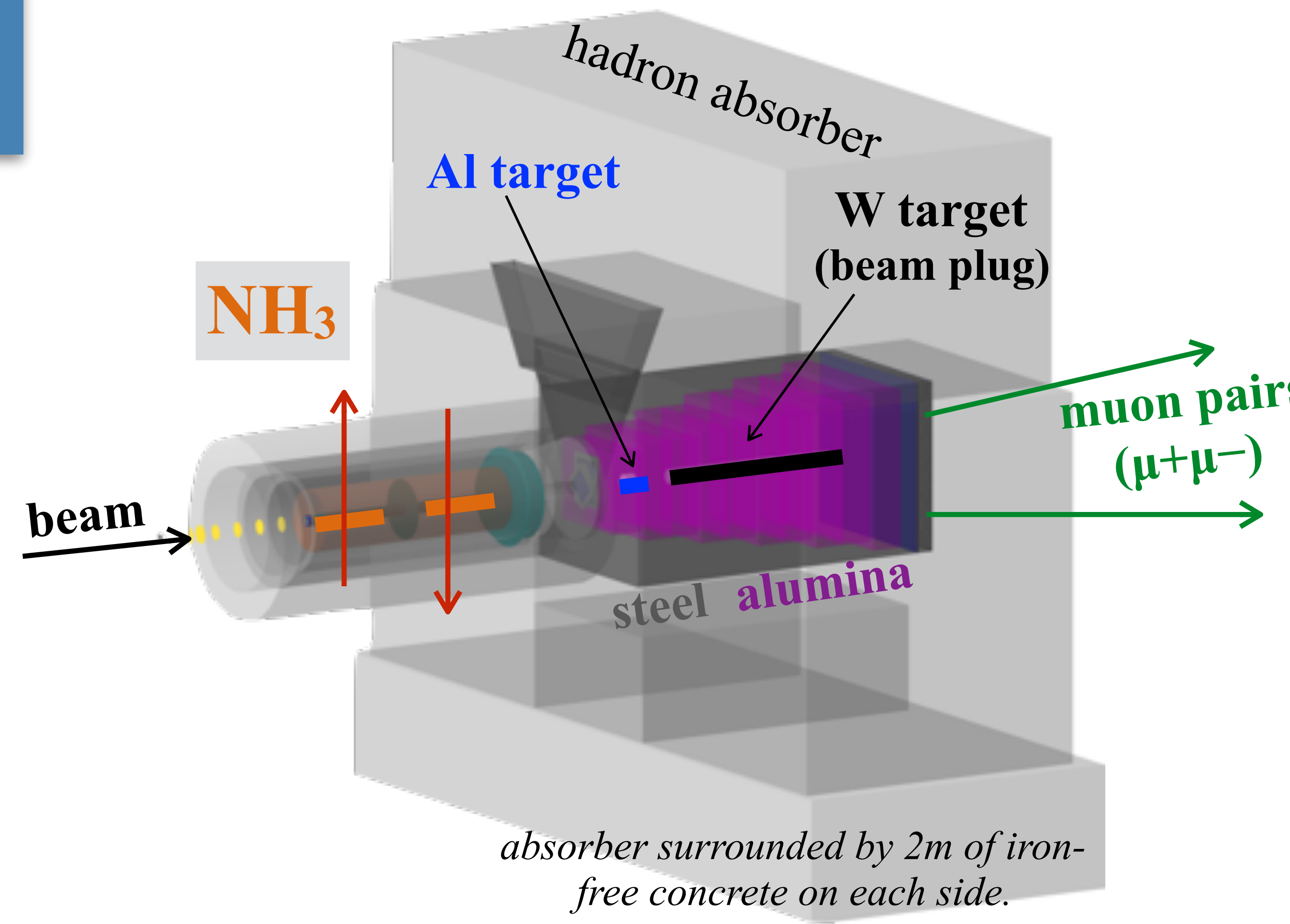


COMPASS target

COMPASS polarized target 2015, 2018 (NH_3);
ammonia beads immersed into liquid helium;
dilution factor ~ 0.22

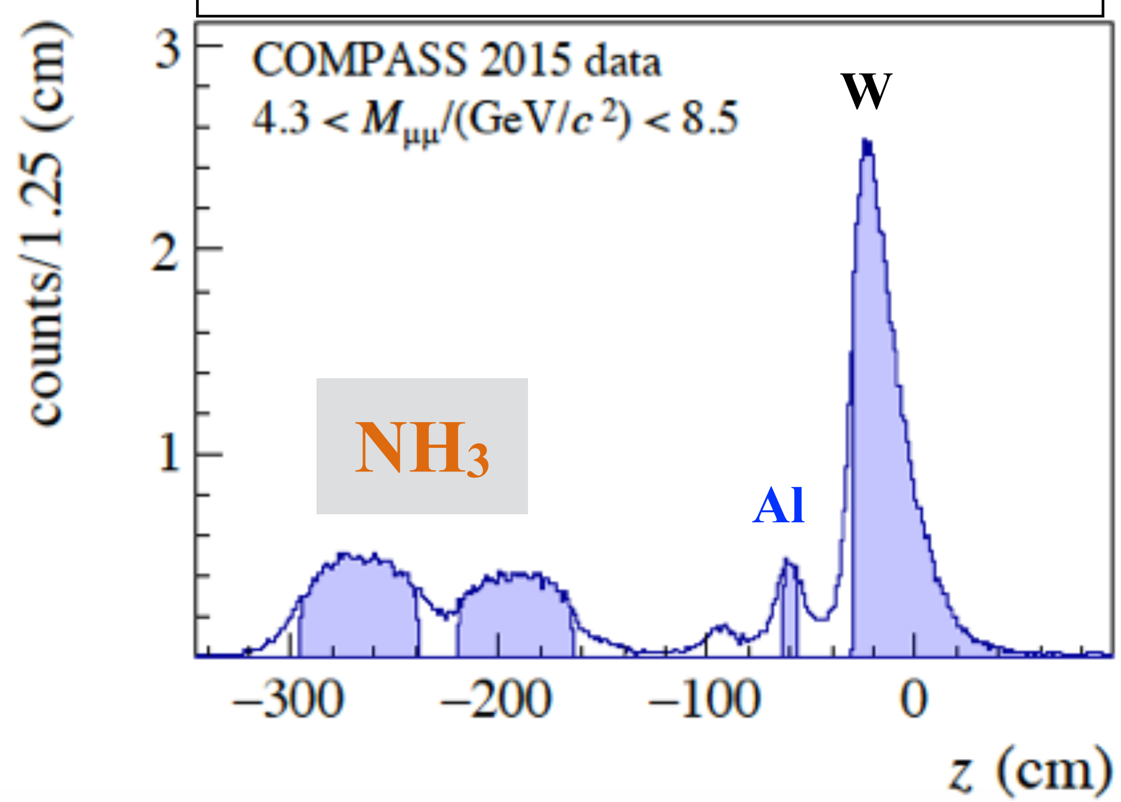


Dynamic Nuclear Polarization
dilution refrigerator: ~60mK
dipole magnet: 0.5T
solenoid: 2.5T



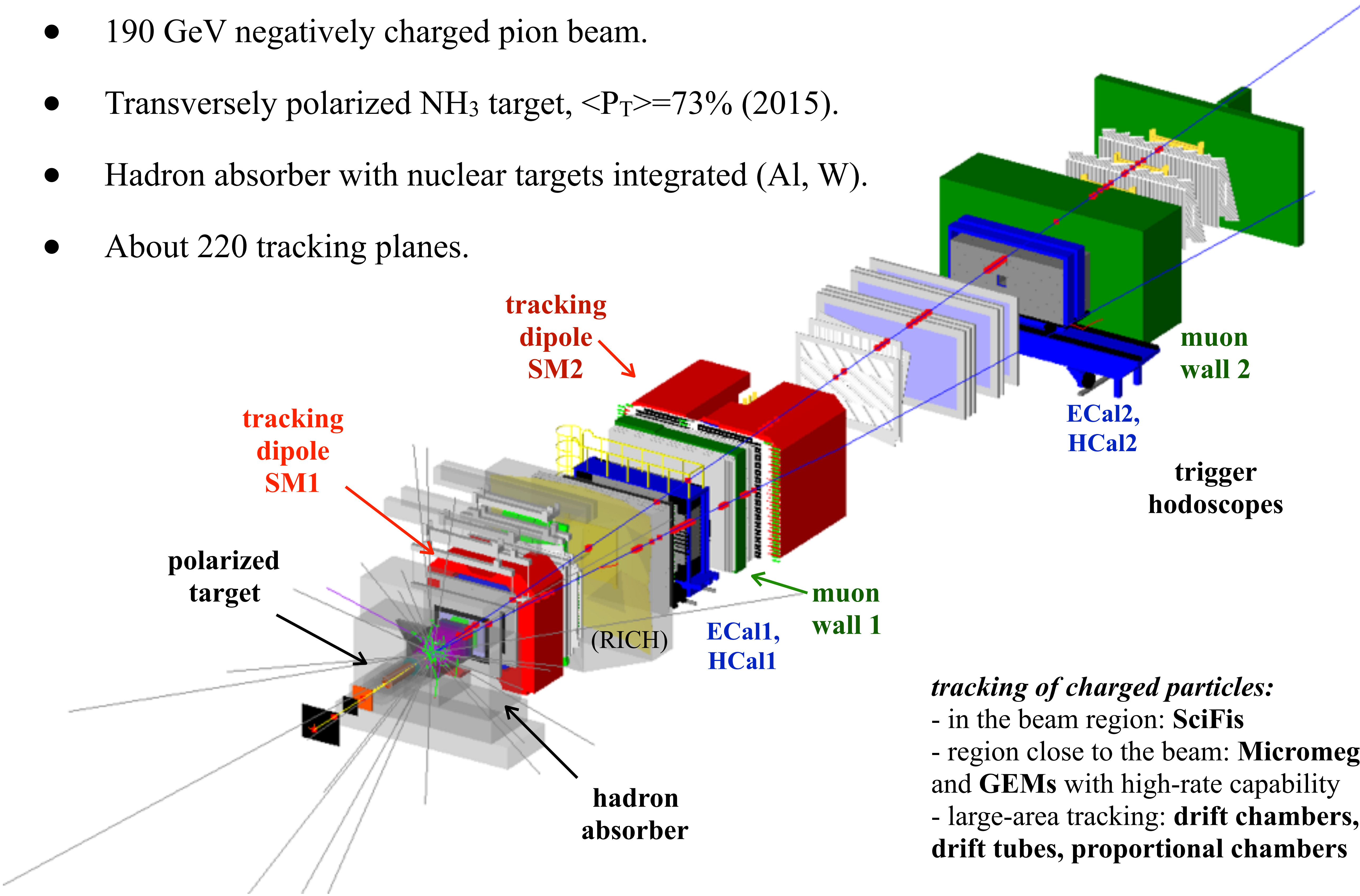
absorber surrounded by 2m of iron-free concrete on each side.

track vertex distribution along beam direction



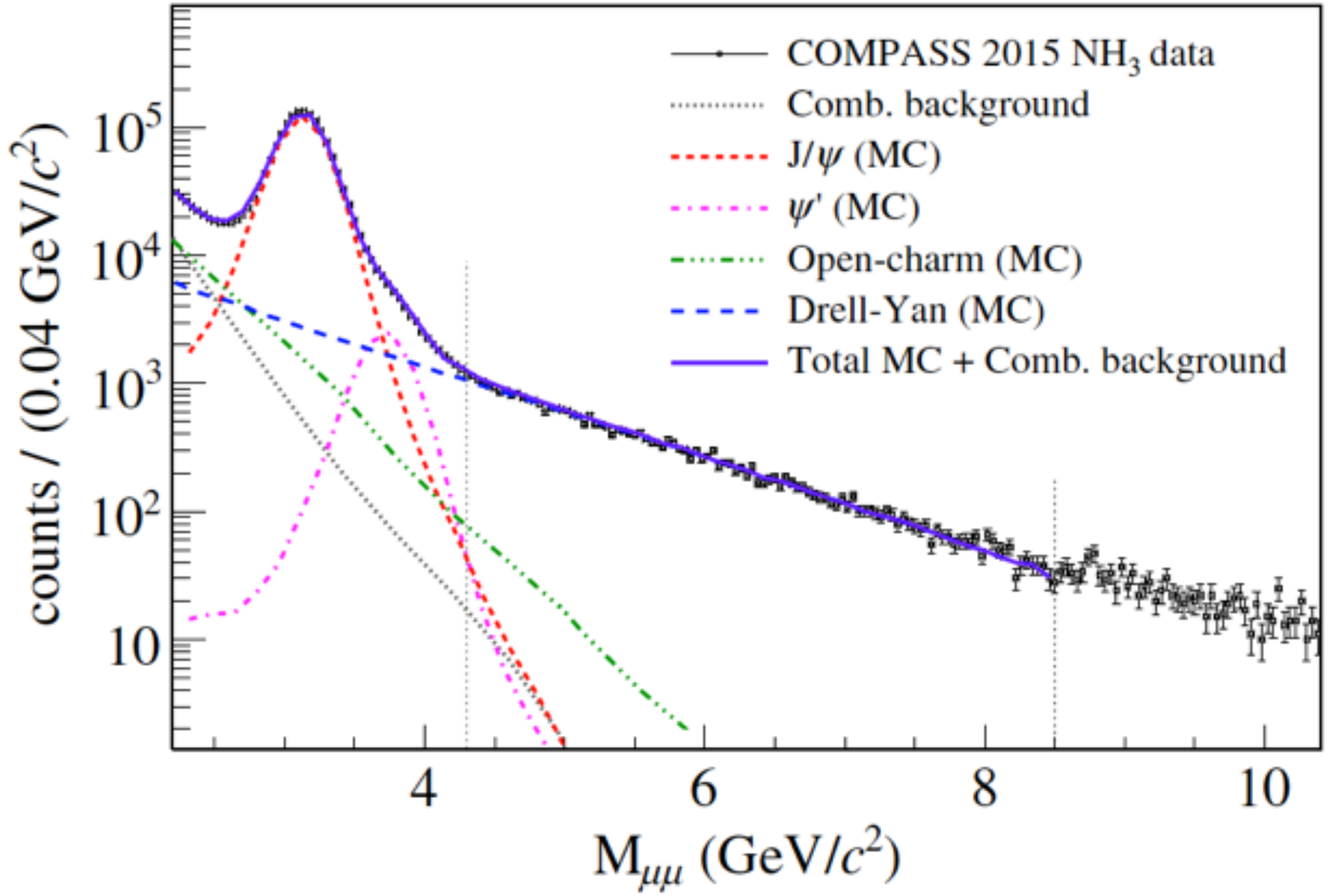
COMPASS Drell-Yan setup 2015 & 2018

- 190 GeV negatively charged pion beam.
- Transversely polarized NH_3 target, $\langle P_T \rangle$=73% (2015).
- Hadron absorber with nuclear targets integrated (Al, W).
- About 220 tracking planes.



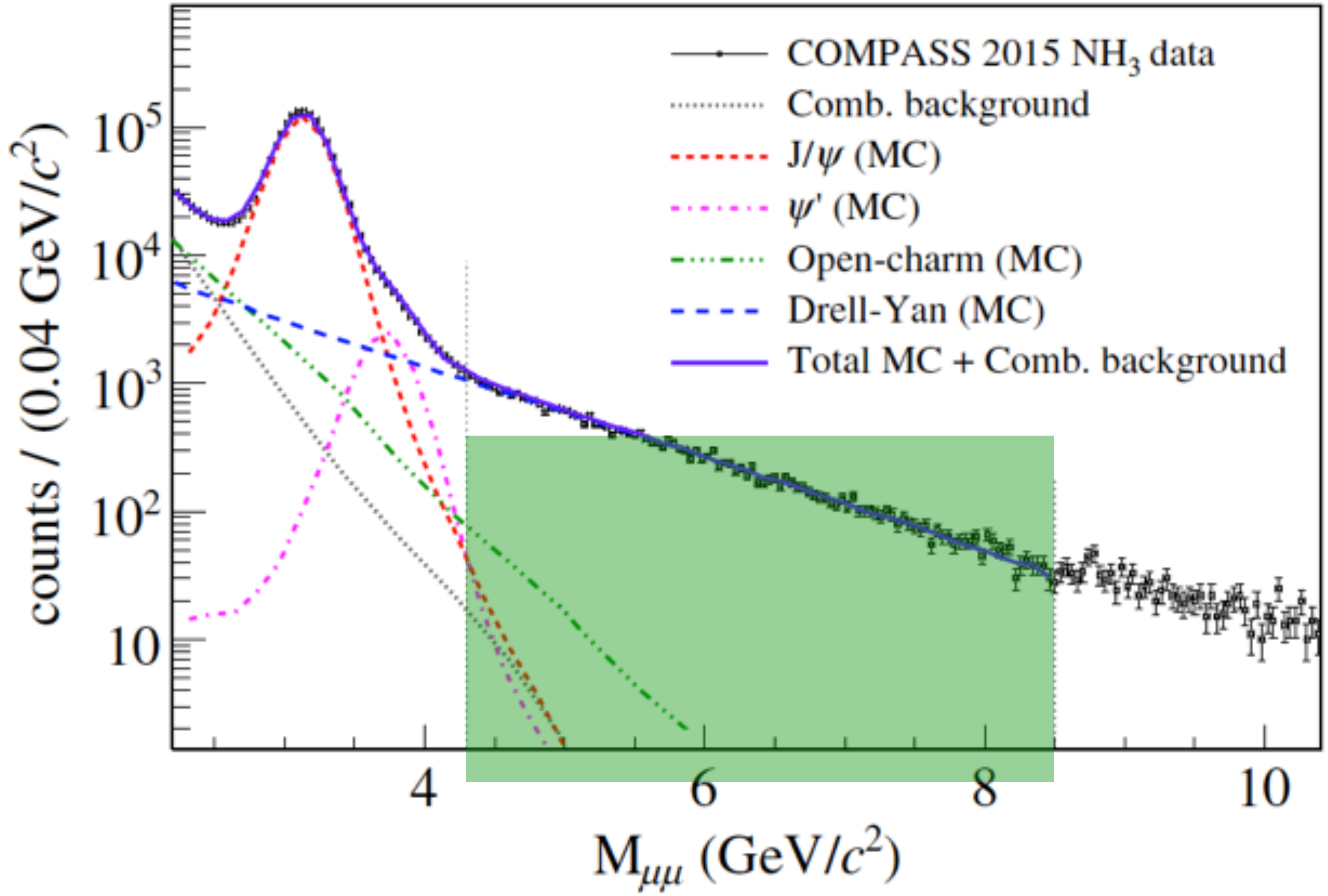
tracking of charged particles:
- in the beam region: **SciFis**
- region close to the beam: **Micromegas** and **GEMs** with high-rate capability
- large-area tracking: **drift chambers, drift tubes, proportional chambers**

Di-muon kinematics



Mμμ [GeV]	<2	2-2.5	2.5-4.3		4.3-8.5
Q^2 [GeV^2]	1-4	4-6.25	6.25-19		19-72
Region	**"DY low mass"**	**"DY medium mass"**	**"DY J/ψ"**	**"J/ψ"**	**"DY high mass"**
clean?	✗✗ >50% bg	✗	✗ ✗	✗✗	✔ ✔ <4% bg
large DY x-section?	✔ ✔	✔	✔	-	✗
large Sivers?	✗	✗	✗	-	✔

Di-muon kinematics



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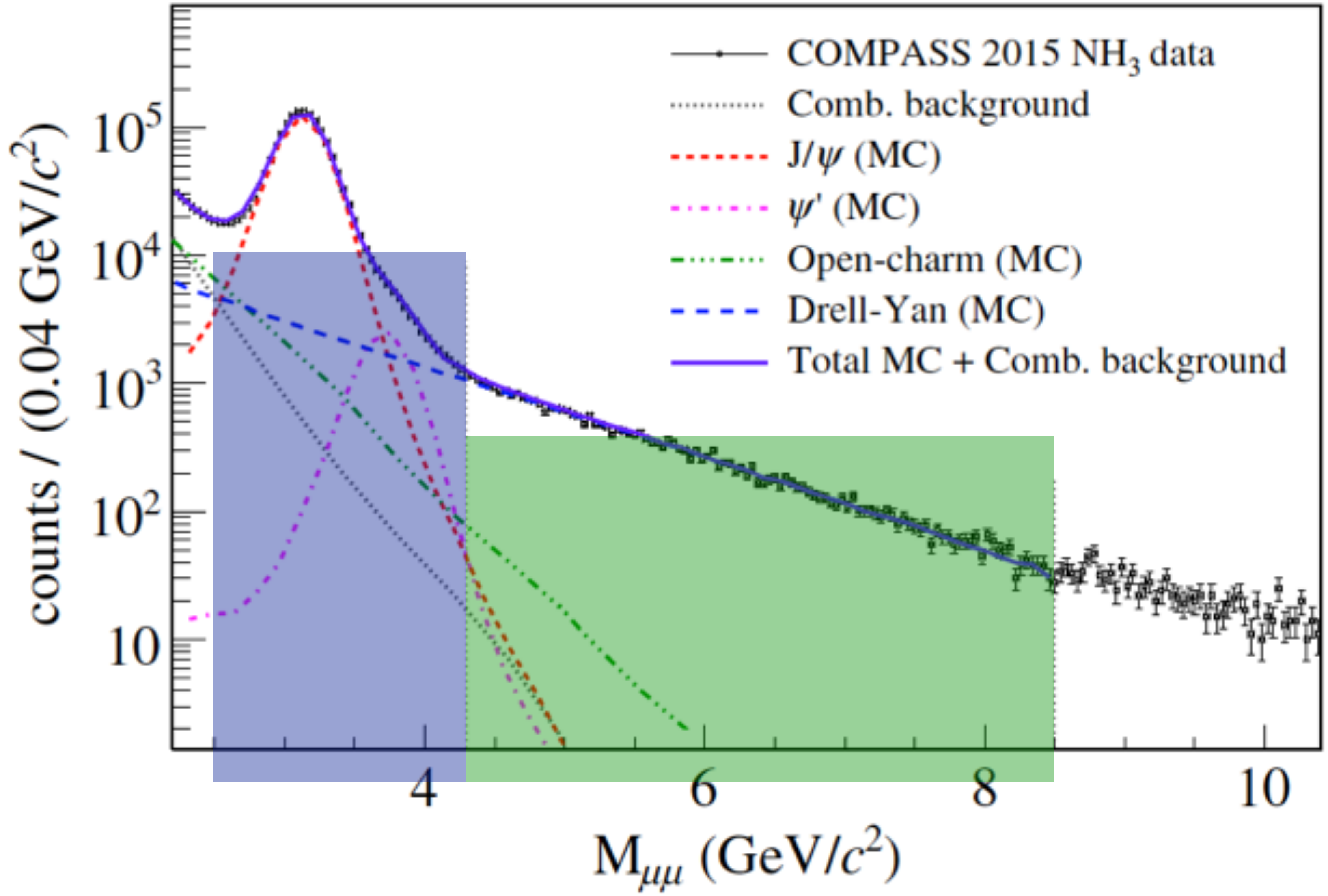
large DY x-section?	✔ ✔	✔	✔	-	✘
large Sivers?	✘	✘	✘	-	✔

Di-muon kinematics



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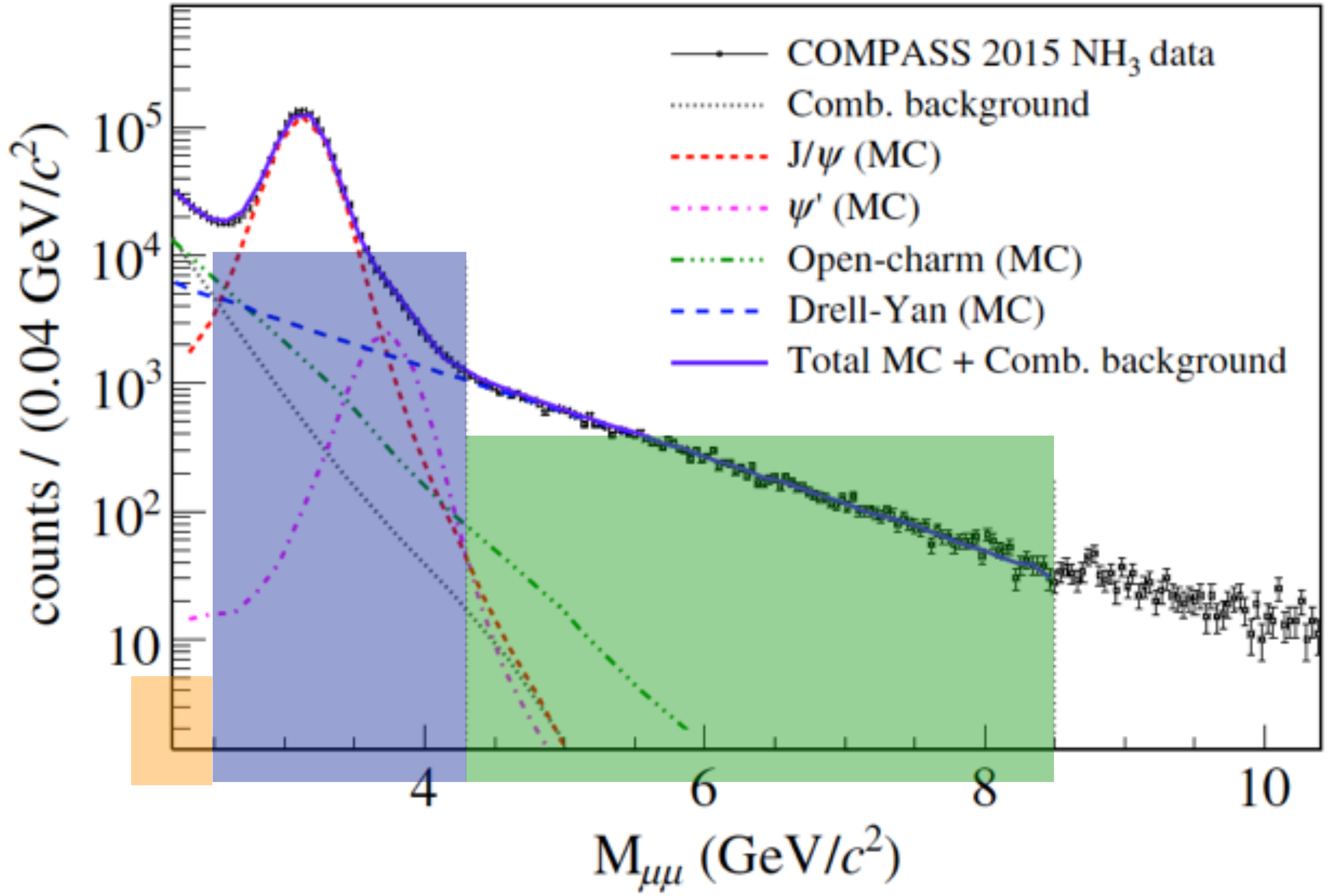
large DY x-section?	✔ ✔	✔	✔	-	✘
large Sivers?	✘	✘	✘	-	✔

Di-muon kinematics



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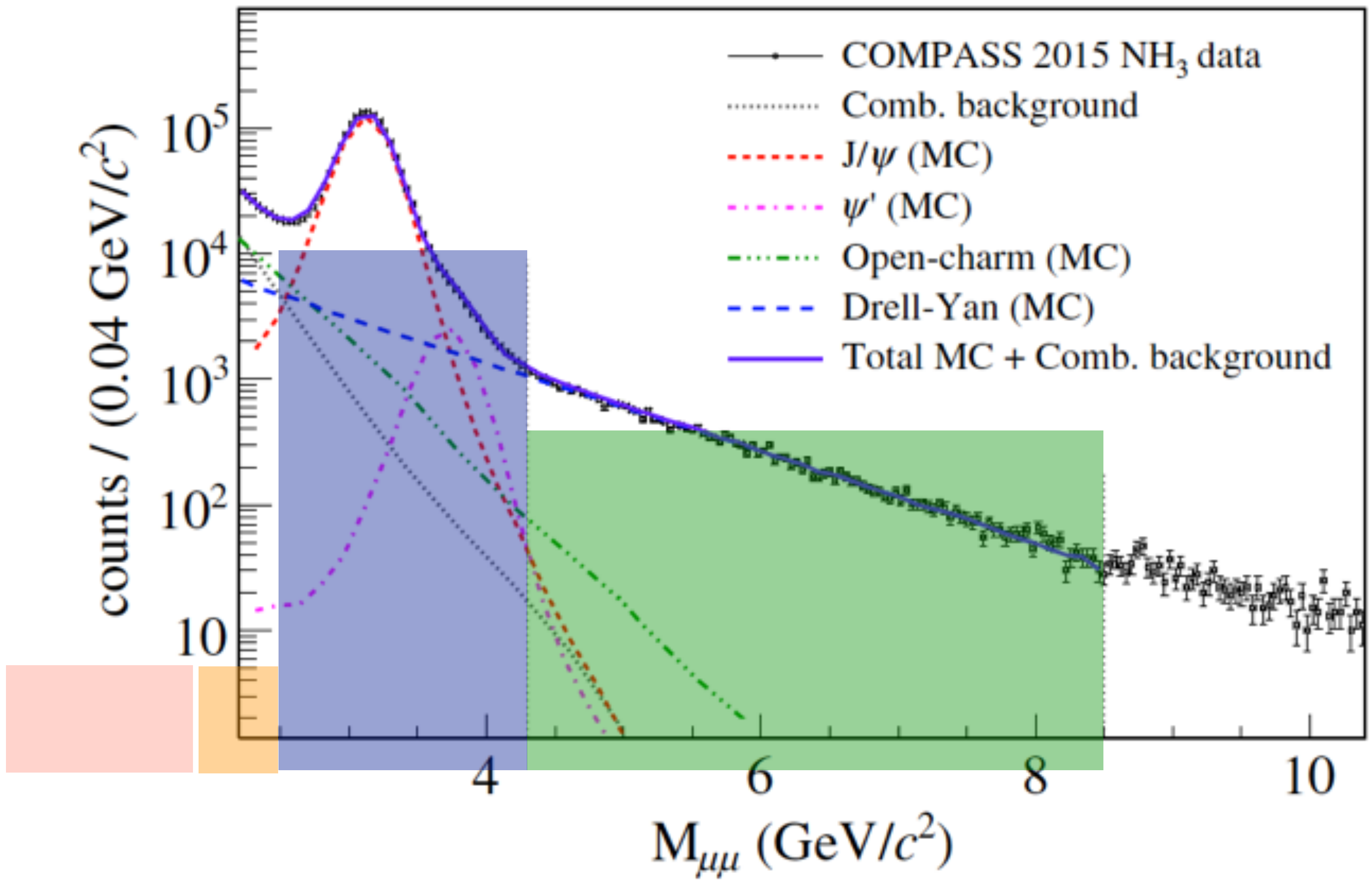
clean?	✗✗ >50% bg	✗	✗ ✗	✗✗	✔ ✔ <4% bg
large DY x-section?	✔ ✔	✔	✔	-	✗
large Sivers?	✗	✗	✗	-	✔

Di-muon kinematics



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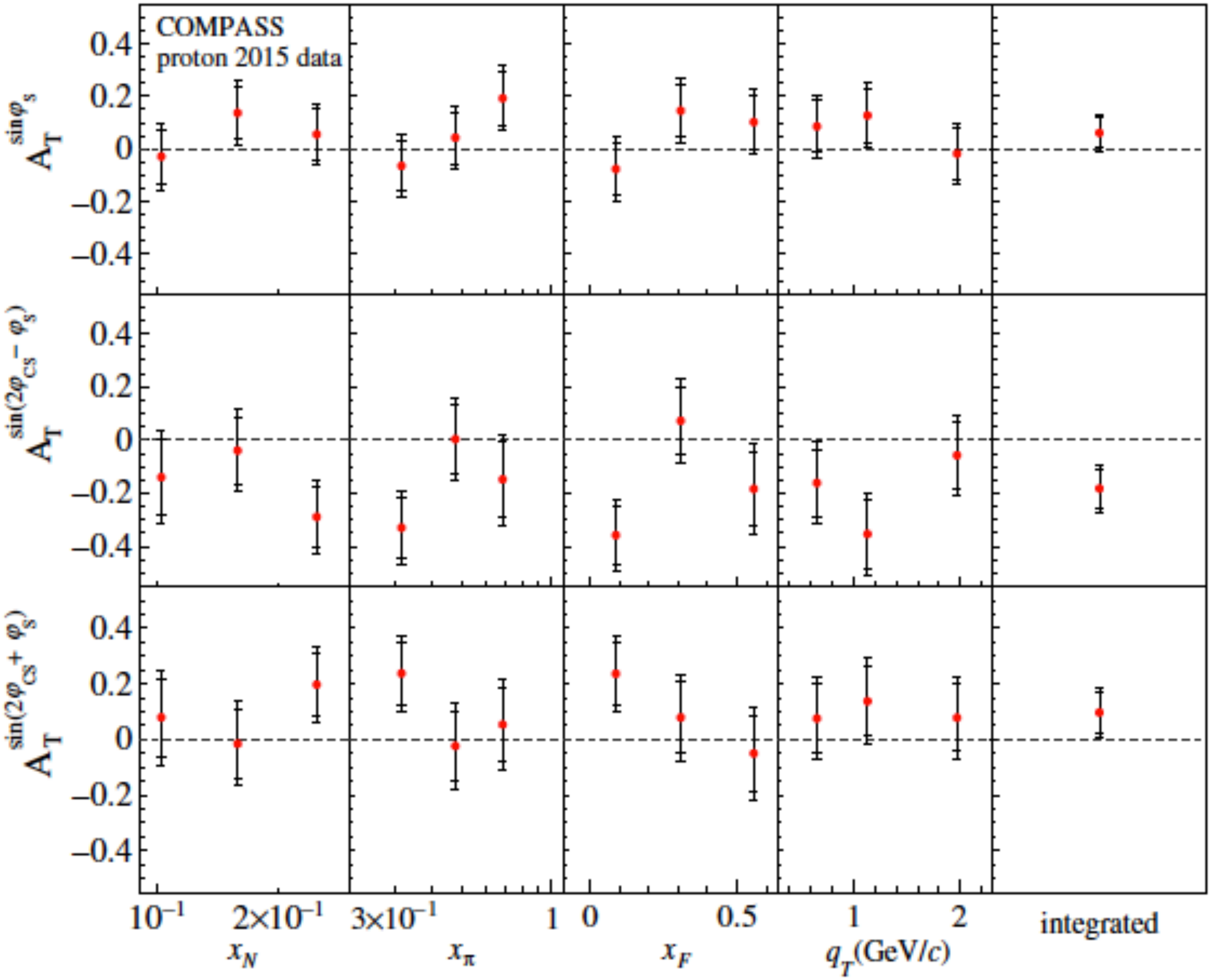
large DY x-section?	✔ ✔	✔	✔	-	✘
large Sivers?	✘	✘	✘	-	✔

COMPASS Drell-Yan spin-dependent asymmetry amplitudes

DY PRL 119 (2017) 112002



Sivers

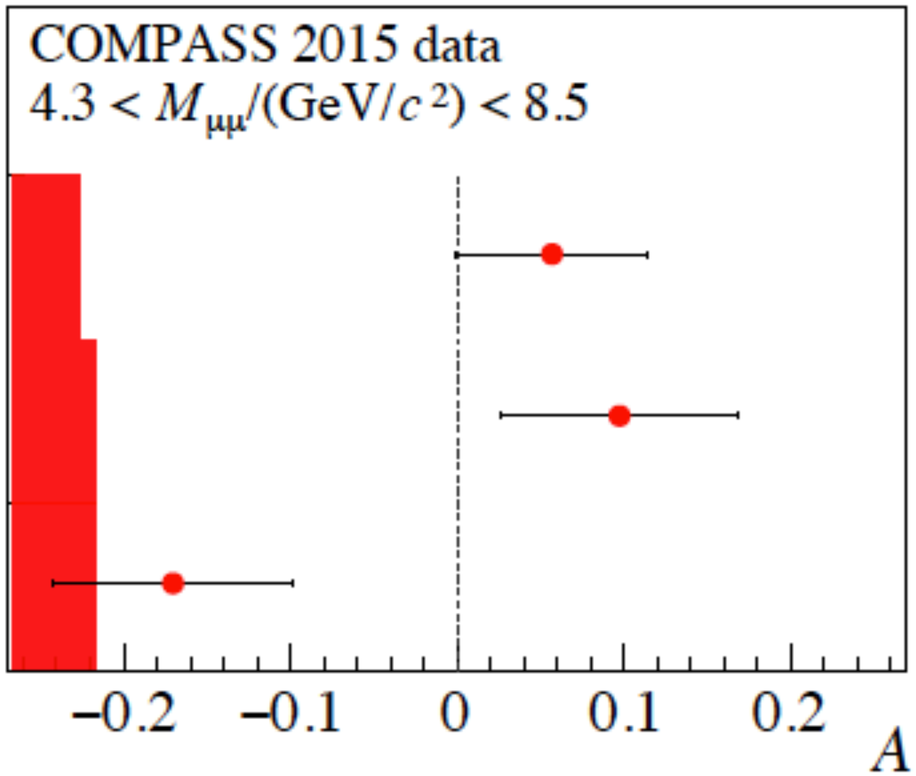
transversity

pretzelosity

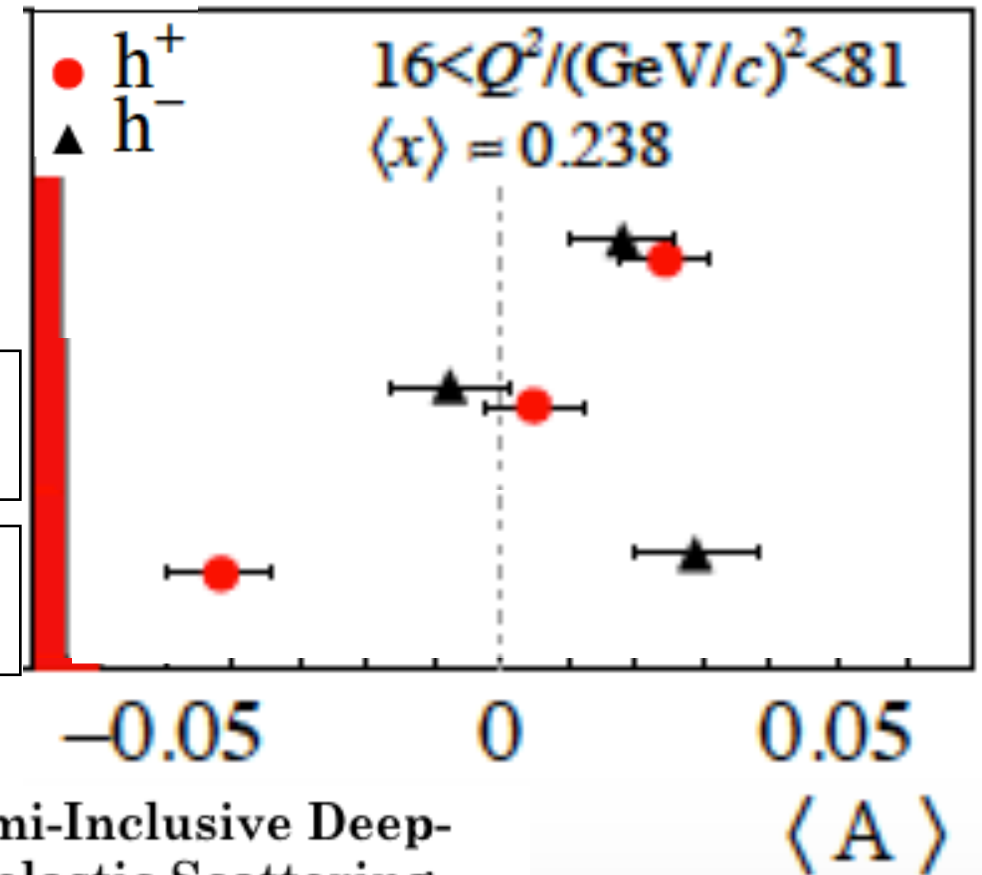
scale uncertainty due to target polarization (5%) & target dilution factor (8%) not shown.

COMPASS Drell-Yan vs. SIDIS: spin-dependent asymmetry amplitudes

DY PRL 119 (2017) 112002

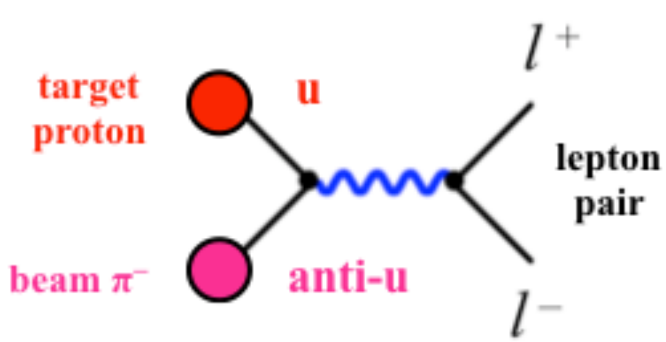


SIDIS PLB 770 (2017) 138



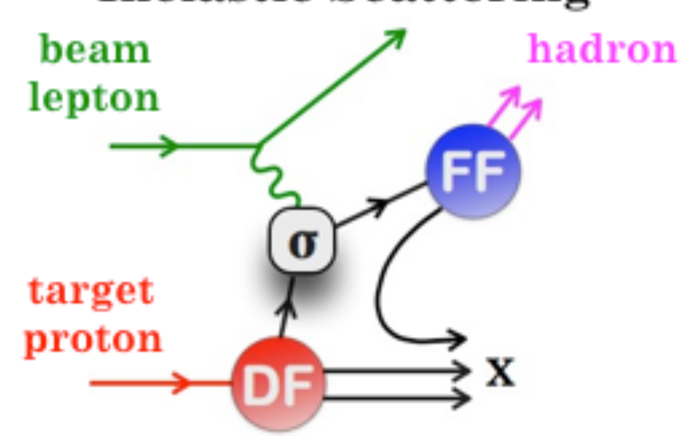
$(\mathrm{Sivers})_p \otimes (f_1)_\pi$	Sivers $\otimes$ D1
$(\mathrm{Pretzelosity})_p \otimes (\mathrm{BM})_\pi$	Pretzelosity $\otimes$ Collins
$(\mathrm{Transversity})_p \otimes (\mathrm{BM})_\pi$	Transversity $\otimes$ Collins

Drell-Yan



Sivers (proton) $\otimes$ unpolarized distribution function (pion)

Semi-Inclusive Deep-Inelastic Scattering



Sivers (proton) $\otimes$ unpolarized fragmentation function

COMPASS Sivers Drell-Yan result 2015

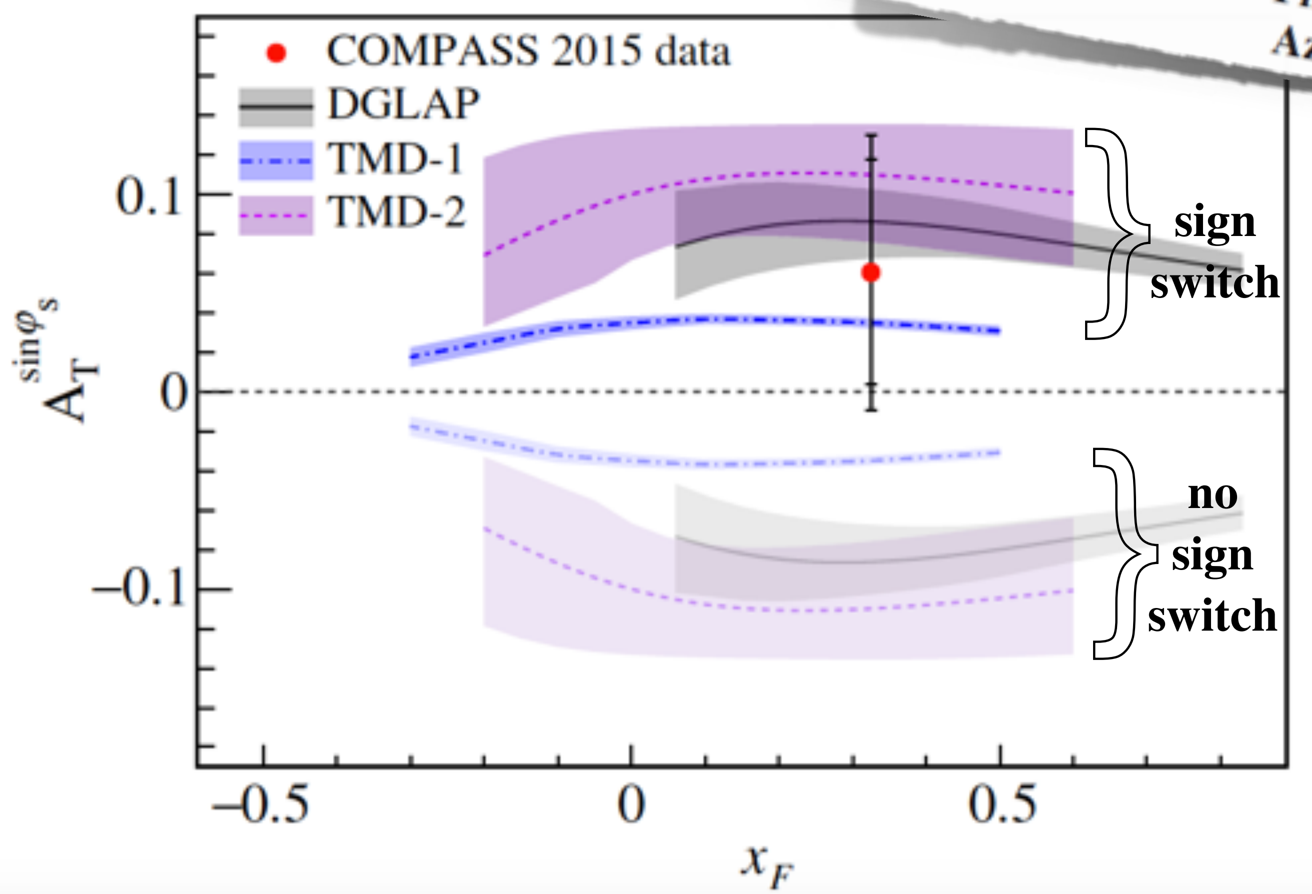

PRL **119**, 112002 (2017)

PHYSICAL REVIEW LETTERS

week ending 15 SEPTEMBER 2017

First Measurement of Transverse-Spin-Dependent Azimuthal Asymmetries in the Drell-Yan Process

(COMPASS Collaboration)



- $\langle A_T^{\sin\varphi_S} \rangle = 0.060 \pm 0.057(\text{stat}) \pm 0.040(\text{sys})$ (~ 1 sigma)
- 2018 (ongoing run): factor of at least 1.5 more statistics expected, as compared to 2015

“**DGLAP**” M. Anselmino, M. Boglione, U. D’Alesio, F. Murgia, and A. Prokudin, J. High Energy Phys. 04 (2017) 046.
“**TMD 1**” M. G. Echevarria, A. Idilbi, Z.-B. Kang, and I. Vitev, Phys. Rev. D 89, 074013 (2014).
“**TMD 2**” P. Sun and F. Yuan, Phys. Rev. D 88, 114012 (2013).

Weighted transverse spin asymmetries in 2015 COMPASS Drell-Yan data:

☞ Jan Matousek, Monday TMD 15:20

- Direct measurement of TMD k_T^2 moments
- Products instead of convolutions of TMDs

More COMPASS DY results to come

- Unpolarized Drell-Yan angular distributions from π- on NH_3.
- Absolute Drell-Yan cross-sections of pion collisions on NH_3 and W targets.
- Nuclear effects from the ratio of Drell-Yan on W to NH_3.

Spin-averaged Drell-Yan cross section

COMPASS results to come

- For DY, J/ψ, ψ'
- For NH3 &W targets

$$\boxed{\sigma_{\mu^+\mu^-} = \frac{N_{\mu^+\mu^-}}{\mathcal{L}} \times \frac{1}{A_{cc}} \times \frac{1}{\mathcal{E}_{tot}}}$$

(trigger, reconstruction, detector) Efficiencies

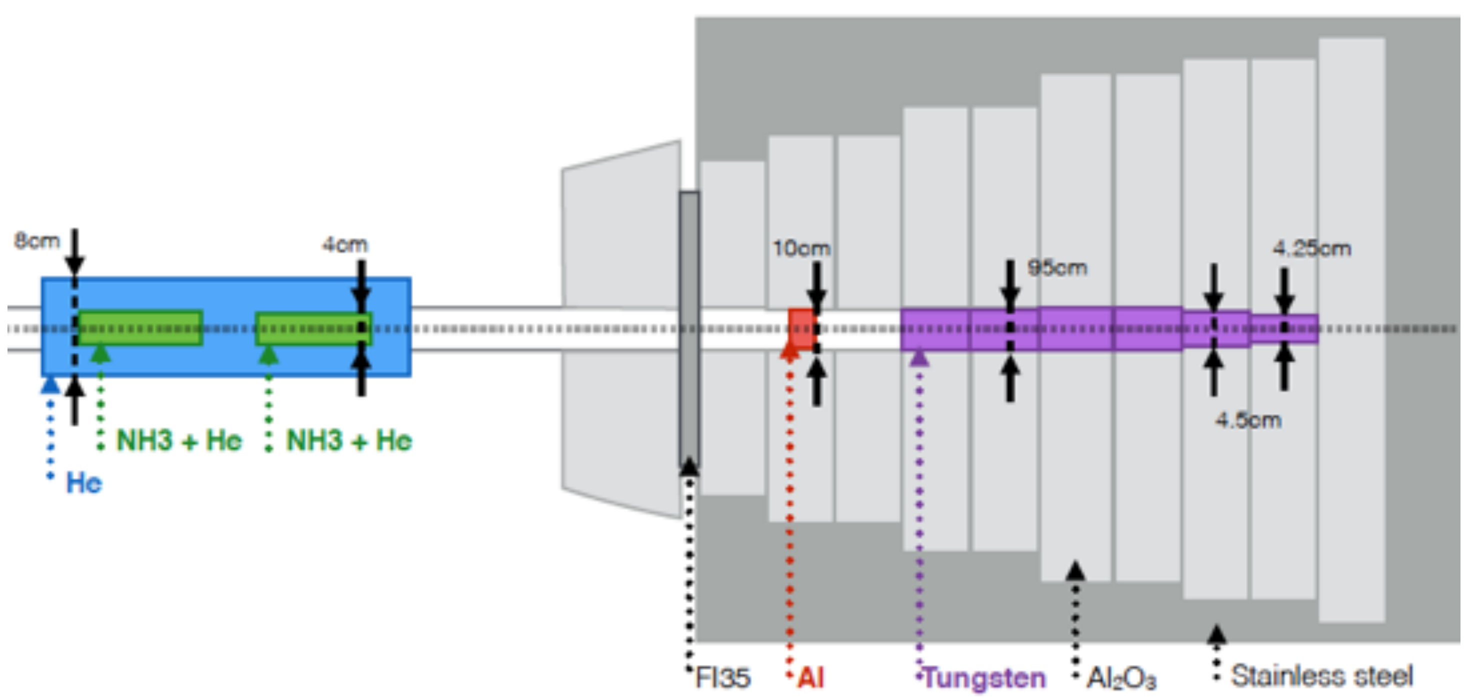
$$\boxed{\mathcal{L} = \mathcal{F} \times \varrho_T}$$

Luminosity

Acceptance

Multi-dimensional analysis (M, xF, qT, Zvtx)

Flux stability vs. time



Angular dependence of the Drell-Yan cross section

COMPASS results to come

$$d\sigma(\pi^- p^\uparrow \to \mu^+\mu^- X \sim 1 + \boxed{\bar{h}_1^\perp} \otimes \boxed{h_1^\perp} \cos(2\phi)$$

beam target

(BM) ⊗ (BM)

$$+ |S_T| \boxed{\bar{f}_1} \otimes \boxed{\bar{f}_{1T}^\perp} \sin\phi_S$$

(f_1) ⊗ (Sivers)

$$+ |S_T| \boxed{\bar{h}_1^\perp} \otimes \boxed{h_{1T}^\perp} \sin(2\phi + \phi_S)$$

(BM) ⊗ (Pretzelosity)

$$+ |S_T| \boxed{\bar{h}_1^\perp} \otimes \boxed{h_1} \sin(2\phi - \phi_S)$$

(BM) ⊗ (Transversity)

Φ_S: angle related to direction of target spin
Φ, θ: angles in Collins-Soper frame

$$1 - \lambda = 2\nu$$

Lam-Tung relation

C.S. Lam and W.K. Tung, PRD 18 (1978) 2447

- If intrinsic transverse motion & QCD radiative effects: $\lambda \neq 1$, $\mu \neq 0$, $\nu \neq 0$
- Collider [CMS PLB 750 (2015)] and pion-induced DY [NA10 Z.Phys.C 31, 513 (1986)] violation of Lam-Tung relations
- NNLO QCD corrections can explain these findings [M. Vogelsang, M. Lambertsen, Phys.Rev.D93 (2016)].

Angular dependence of the Drell-Yan cross section

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$$d\sigma(\pi^- p^\uparrow \rightarrow \mu^+\mu^- X \sim 1 + \boxed{\bar{h}_1^\perp} \otimes \boxed{h_1^\perp} \cos(2\phi)$$

$$\cancel{+|S_T| \boxed{\bar{f}_1} \otimes \boxed{\bar{f}_{1T}^\perp} \sin\phi_S}$$

$$\cancel{+|S_T| \boxed{\bar{h}_1^\perp} \otimes \boxed{h_{1T}^\perp} \sin(2\phi + \phi_S)}$$

$$\cancel{+|S_T| \boxed{\bar{h}_1^\perp} \otimes \boxed{h_1} \sin(2\phi - \phi_S)}$$

beam		target
(BM)	⊗	(BM)
~~(f_1)~~	~~⊗~~	~~(Sivers)~~
~~(BM)~~	~~⊗~~	~~(Pretzelosity)~~
~~(BM)~~	~~⊗~~	~~(Transversity)~~

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$$\boxed{1 - \lambda = 2\nu}$$

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Angular dependence of the Drell-Yan cross section

COMPASS results to come

$$d\sigma(\pi^- p^\uparrow \to \mu^+\mu^- X \sim \boxed{1 + \boxed{\bar{h}_1^\perp} \otimes \boxed{h_1^\perp} \cos(2\phi)}$$

beam target

(BM) ⊗ (BM)

$$\frac{d\sigma}{d\Omega} \propto 1 + \lambda \cos^2\theta + \mu \sin(2\theta)\cos\phi + \boxed{\frac{\nu}{2}\sin^2\theta}\cos(2\phi)$$

<u>Boer and Mulders 1998</u>: distribution function of the unpolarized nucleon with intrinsic k_T dependence.
Describes correlation between **quark transverse spin & momentum**.

Φ_S: angle related to direction of target spin
Φ, θ: angles in Collins-Soper frame

$$1 - \lambda = 2\nu$$

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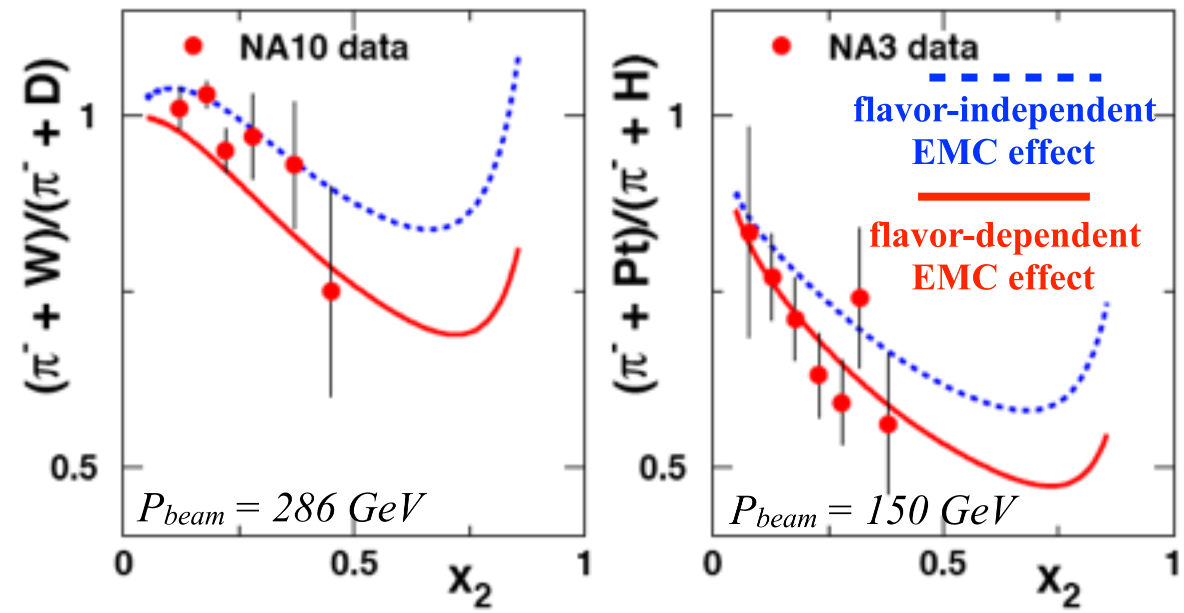
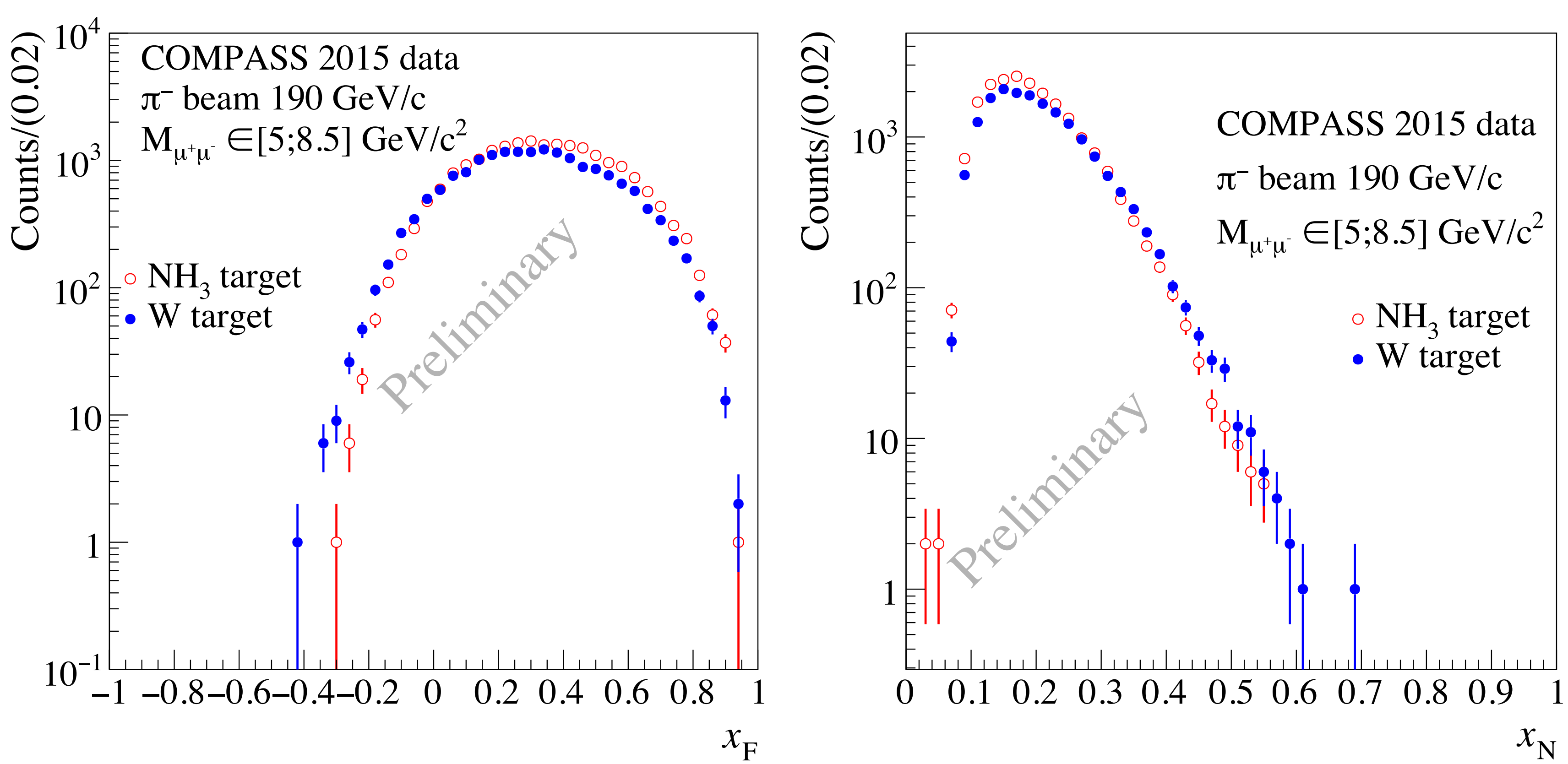
Flavor-dependent EMC effect & parton energy loss

- EMC effect in DIS: nuclear PDFs found to be modified with respect to proton PDFs ("shadowing", etc.)
- Pion-induced Drell-Yan: Cloet, Bentz, Thomas (CBT) model: isovector mean field in a N≠Z nucleus causes different modification for u- and d-quarks.



- **COMPASS** data do not only probe the **EMC effect** but also **parton energy loss effects** via soft gluon radiation in the cold nuclear medium through multiple scattering.

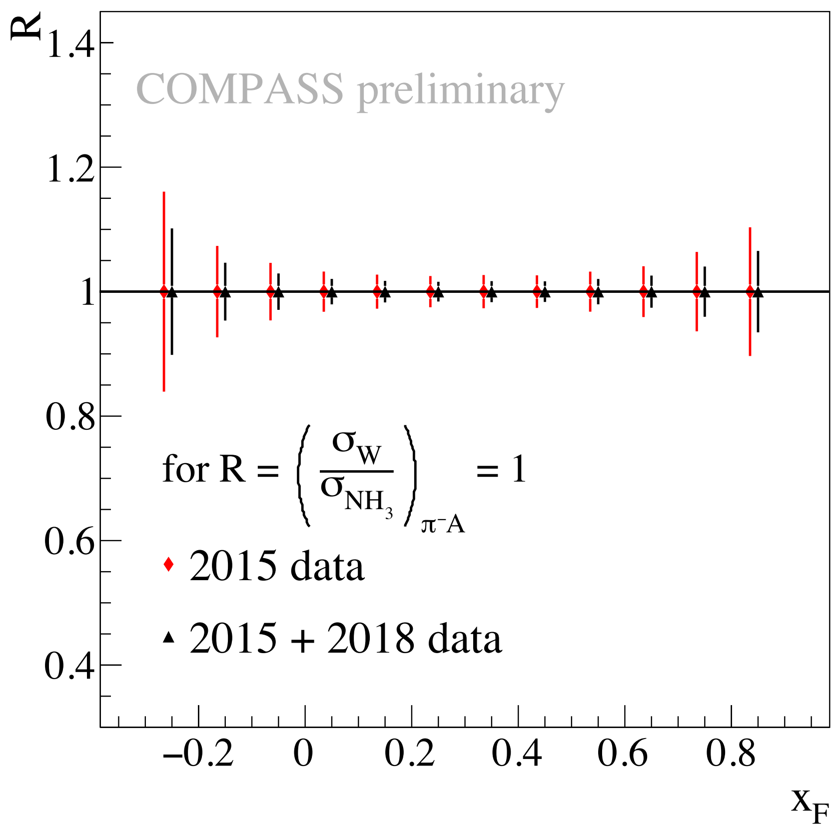
$$R = \frac{\sigma^{DY}(\pi^- + A)}{\sigma^{DY}(\pi^- + D)} \approx \frac{u_A(x)}{u_D(x)}$$

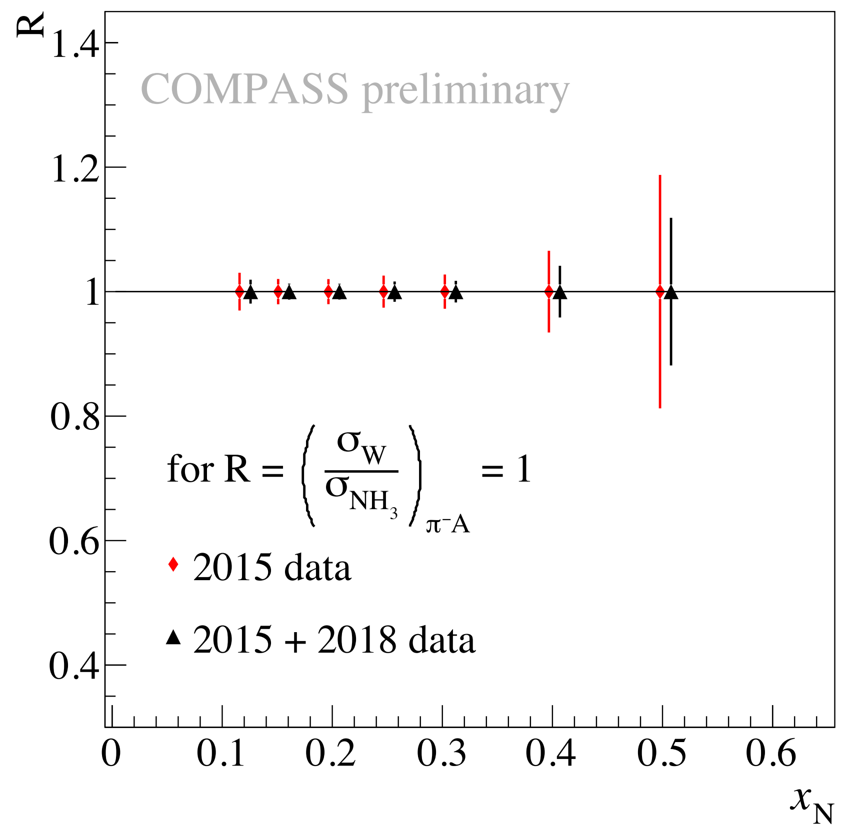


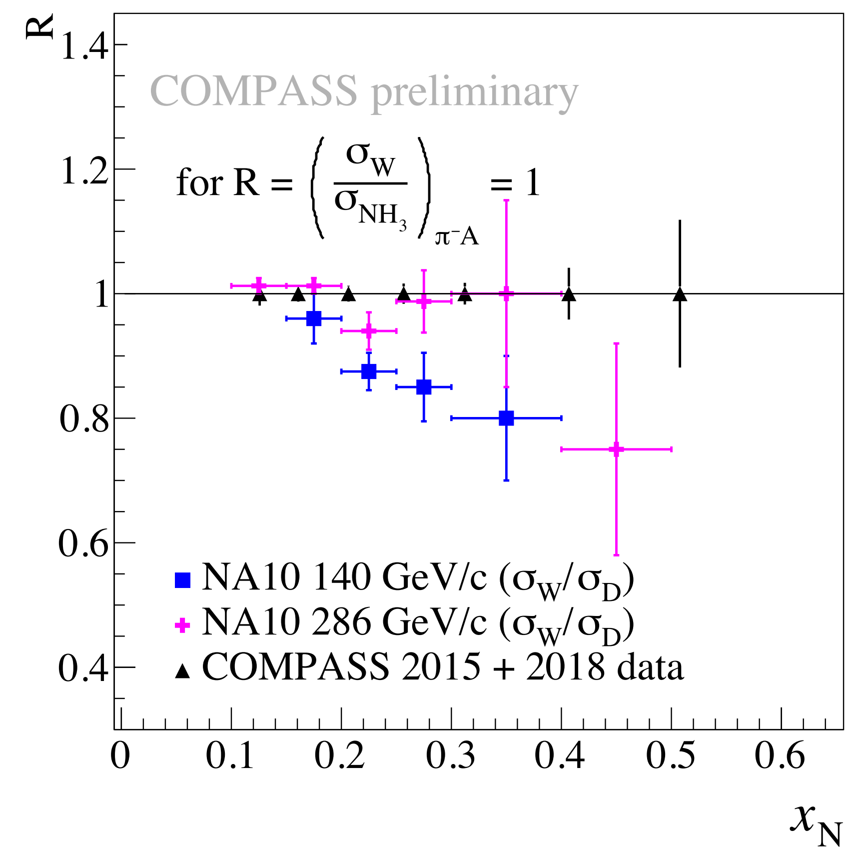
Cloet et al, Phys.Lett.B 642, 210 (2006)
D. Dutta et al, Phys.Rev. C 83 042201 (2011)

NA3, Phys.Lett.B 104, 335 (1981)
NA10, Phys.Lett.B 193, 368 (1987)

2015 & 2018 COMPASS W/NH3 Drell Yan data: projected uncertainties







NA10 data: Phys. Lett. B193 (1987) 368

- Assuming no nuclear effects at all.
- Only statistical uncertainties shown.
- Expected DY statistics for 2018 assumed to be 1.5x that of 2015.
- Next: J/Psi production; gg-fusion vs. qqbar-fusion production mechanisms.

BLUE WATERS at NCSA

https://bluewaters.ncsa.illinois.edu

- Petascale supercomputer at the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign.

- The NSF awarded $208 million for the Blue Waters project, installation 2012.

Memory	**Disk storage**	**Tape storage**	**Speed**
1.5 petabytes	26 petabytes	380 petabytes	13.3 petaFLOPS

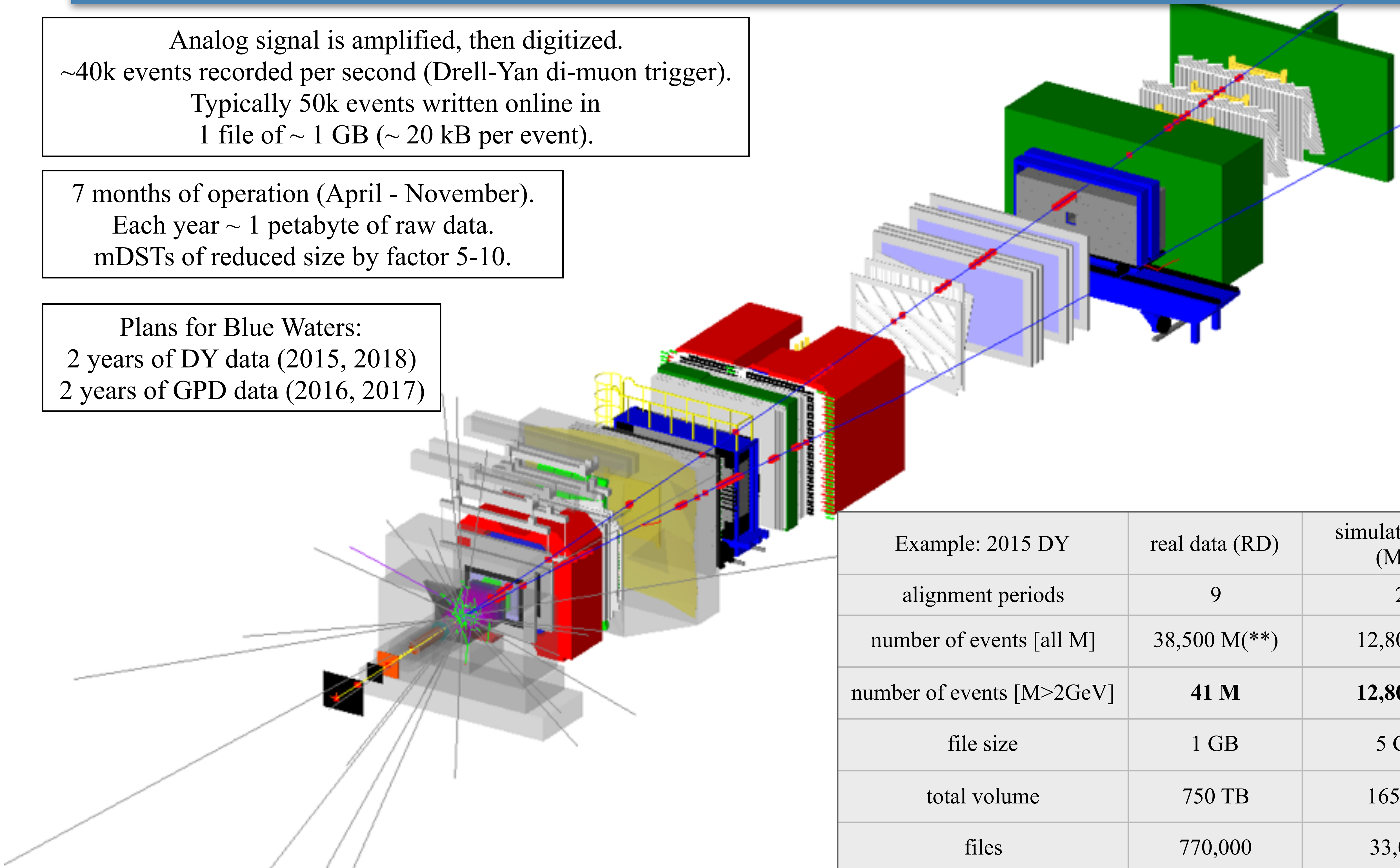
Cray inc. node	remark	CPUs per node	memory per node [GB]	memory per CPU [GB]	total number of nodes
XE6	**dual CPU x86 processor**	**32**	**64**	**2**	**22,640**
XK7	heterogeneous x86 CPU & (“accelerated”) GPU	16	32	2	4,228

Data taking conditions at COMPASS - Drell Yan

Analog signal is amplified, then digitized.
~40k events recorded per second (Drell-Yan di-muon trigger).
Typically 50k events written online in
1 file of ~ 1 GB (~ 20 kB per event).

7 months of operation (April - November).
Each year ~ 1 petabyte of raw data.
mDSTs of reduced size by factor 5-10.

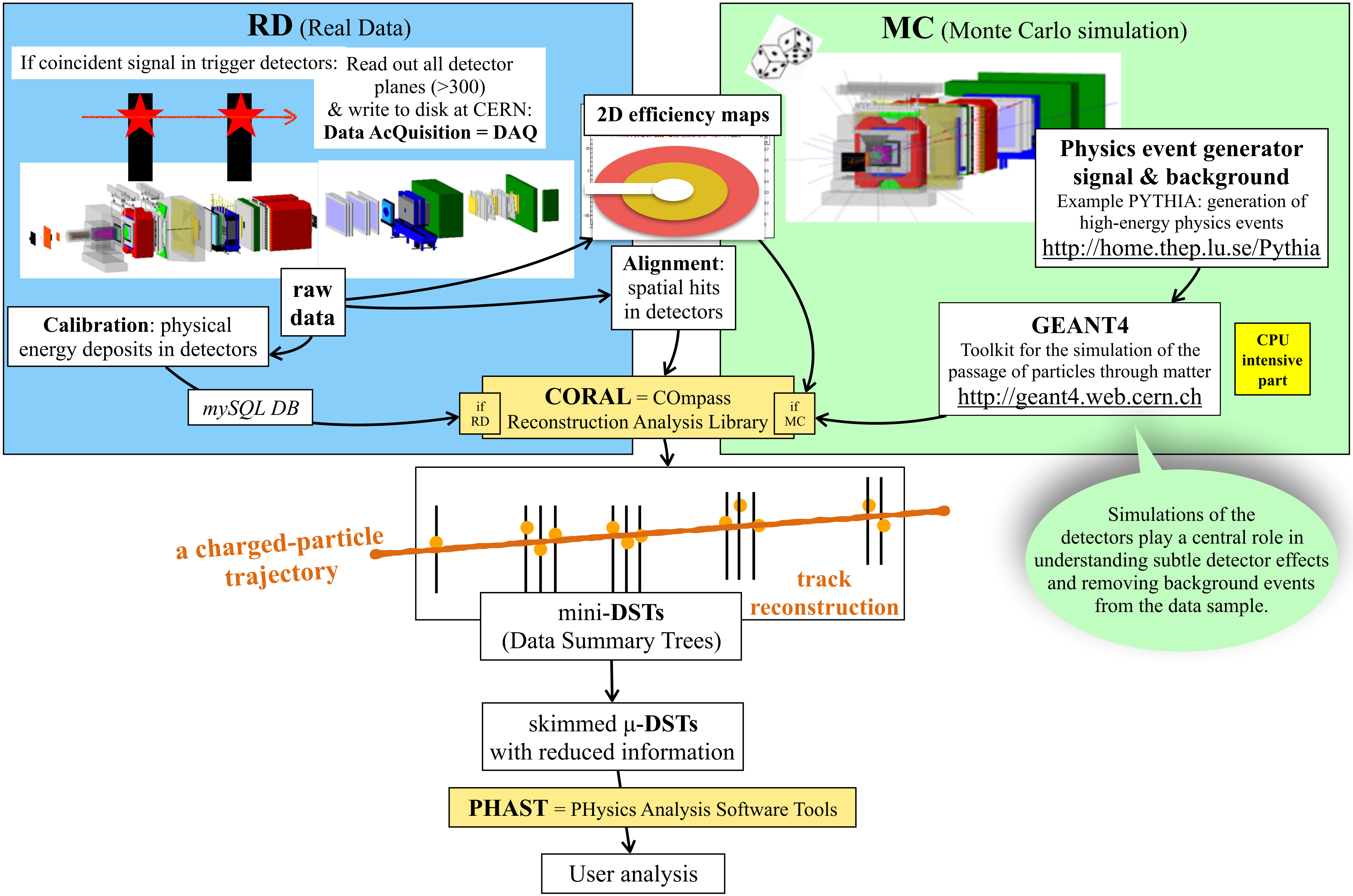
Plans for Blue Waters:
2 years of DY data (2015, 2018)
2 years of GPD data (2016, 2017)



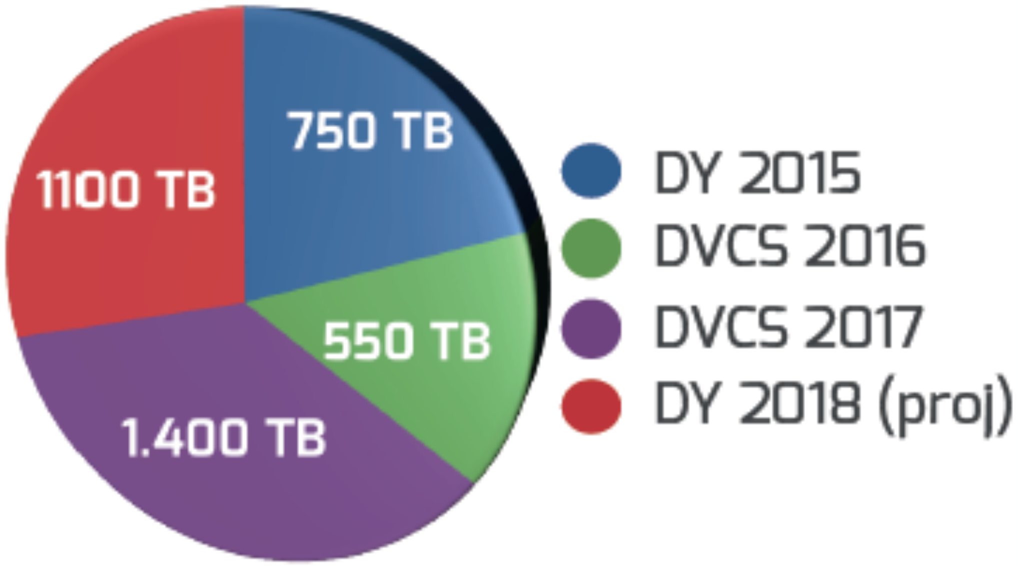
Example: 2015 DY	real data (RD)	simulated data (MC)
alignment periods	9	2
number of events [all M]	38,500 M(**)	12,800 M
number of events [M>2GeV]	**41 M**	**12,800 M**
file size	1 GB	5 GB
total volume	750 TB	165 TB
files	770,000	33,000
file type	raw	GEANT

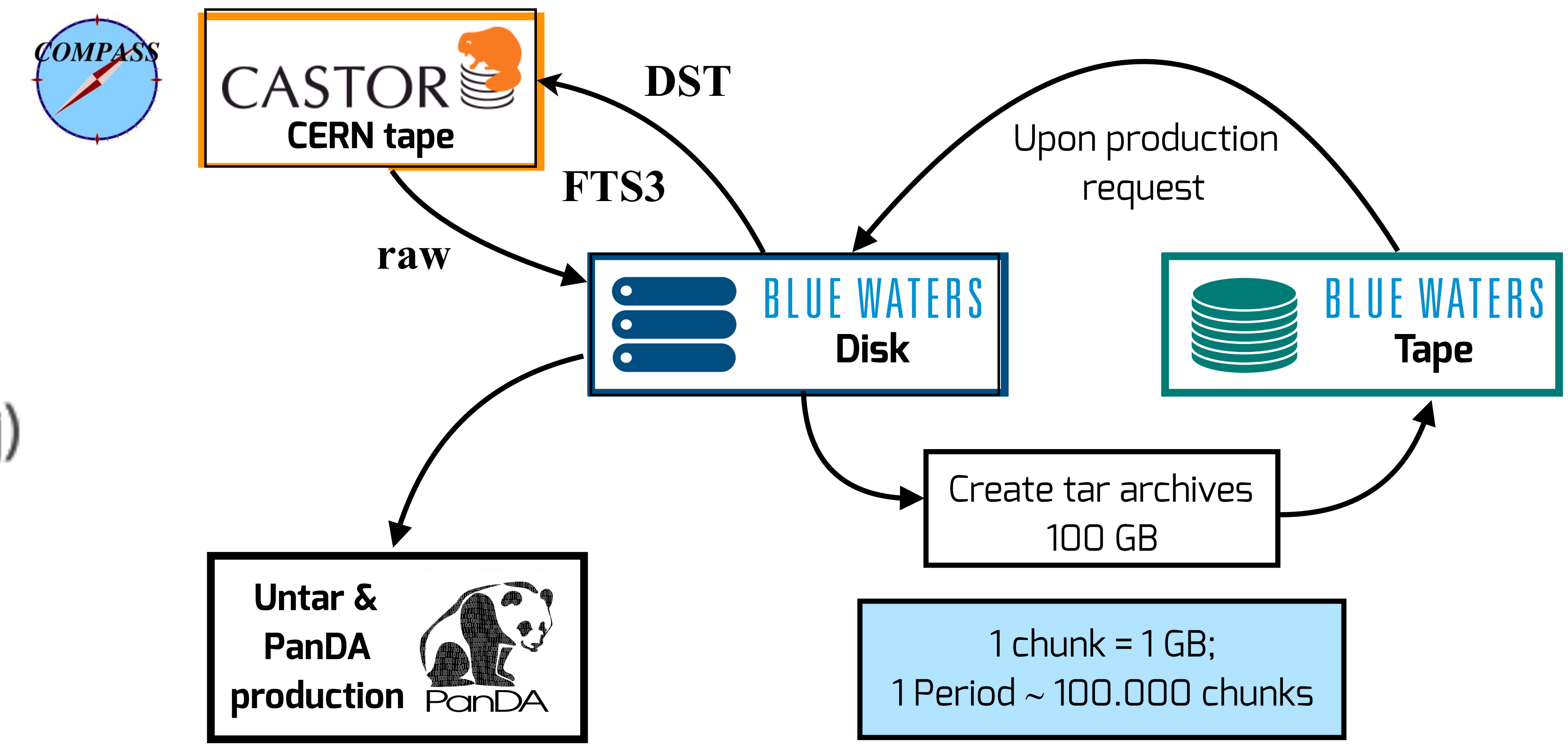
(**) containing many low-mass combinatorial background events absent in the MC because of the generator cut M>2GeV

COMPASS data productions - the principle



Experimental data productions on Blue Waters





- PanDA harvests and exploits processing resources via autonomous pilot jobs.

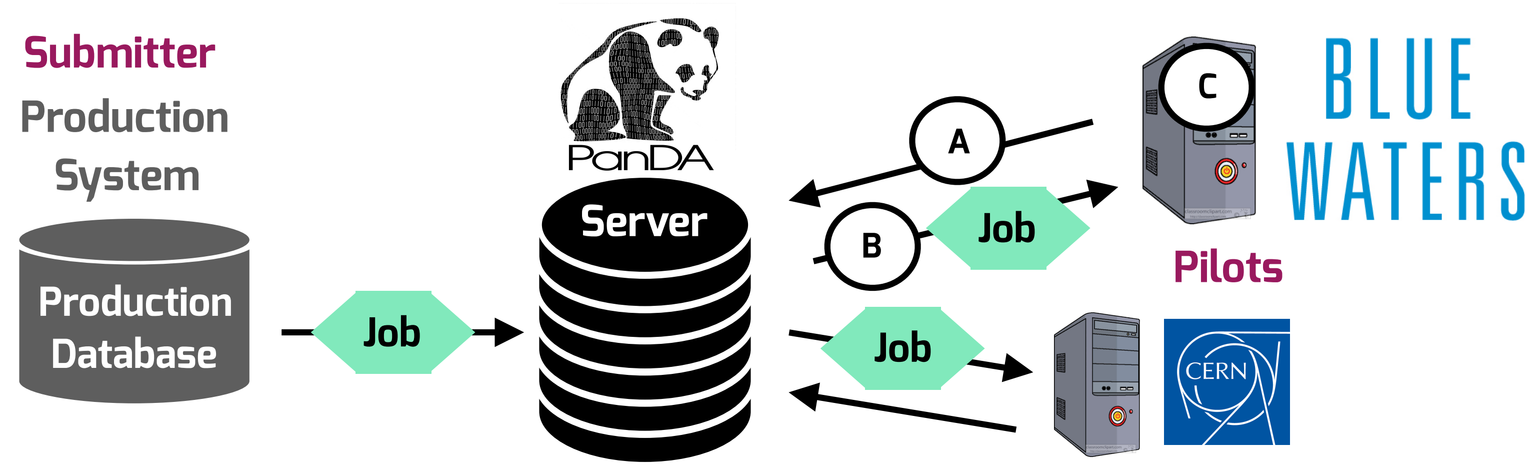
- Tasks manageable on different sites by central interface.

- Framework recently integrated with BW run COMPASS data-productions.

- Each pilot runs on a worker node:
  A. Send a request —>
  B. Receives a Job —>
  C. Runs the Job.

FTS3 (File transfer system): bulk data mover created to globally distribute LHC data.

PanDA = **Production ANd Distributed Analysis** = data production and monitoring system developed for ATLAS-LHC.

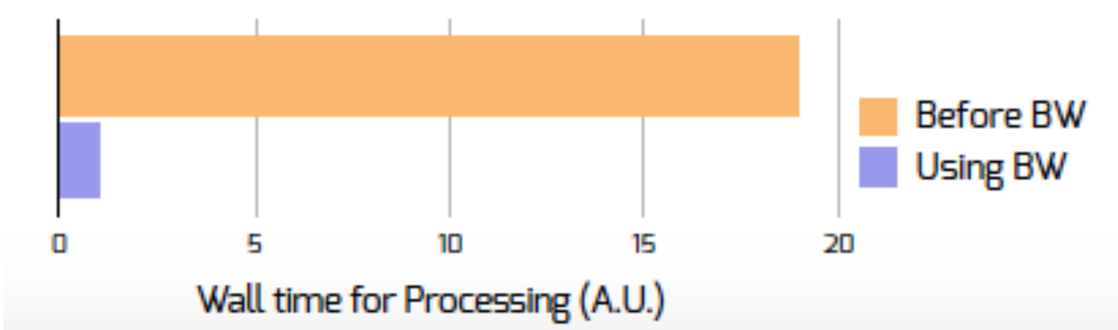


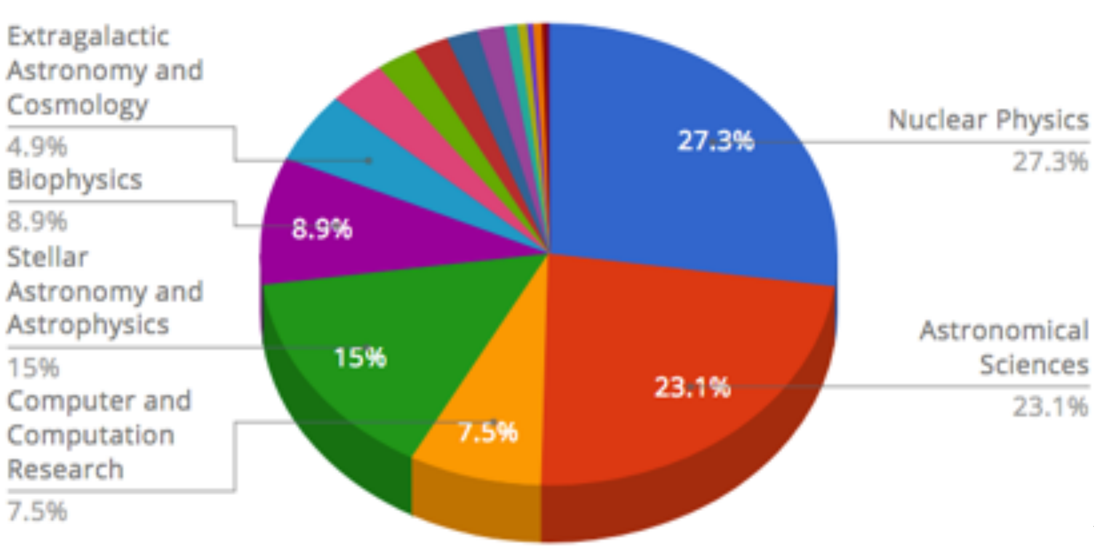
Using a supercomputer in experimental nuclear physics

The scope of the project:

NSF grant (award #1713684)
Allocation "PRAC_balh"

- Monte Carlo productions
- Real data productions
- 2D efficiency maps
- Physics analysis





The advantages, compared to the standard computing clusters:

- (Much) faster data production due to parallel processing
- Minimization of systematic uncertainties due to possibility of
  - applying multi-dimensional acceptance corrections;
  - simulating high realistic pile-up;
  - generating with minimum-bias trigger.
- Unprecedented precision determination of detector efficiencies
- More disk space for fast access available (in general)

These are examples.
They might not apply in general.

BLUE WATERS

https://bluewaters.ncsa.illinois.edu/usage-project-details?project=balh

Outlook: Letter of Intent

CERN
A new QCD facility
at the M2 beam line of the CERN SPS

- **LoI (Draft 1.0)** : https://arxiv.org/abs/1808.00848

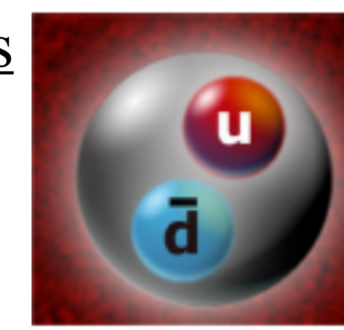
- We are looking for new collaborators!
  Sign up here: https://nqf-m2.web.cern.ch

- Drell-Yan related:

  - *phase 1*: Drell-Yan and charmonium production with conventional hadron beams

>2021

  * Separation of valence and sea contributions in the pion
  * Gluon distribution in the pion
  * Nuclear dependence: Flavor-dependent valence modifications

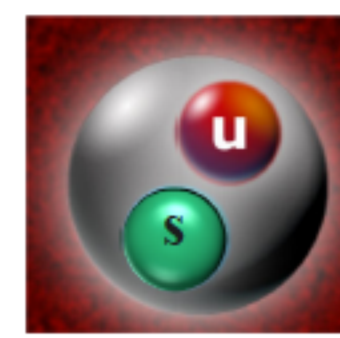


  - *phase 2*: Drell-Yan physics with high-intensity kaon and antiproton beams

> LS3

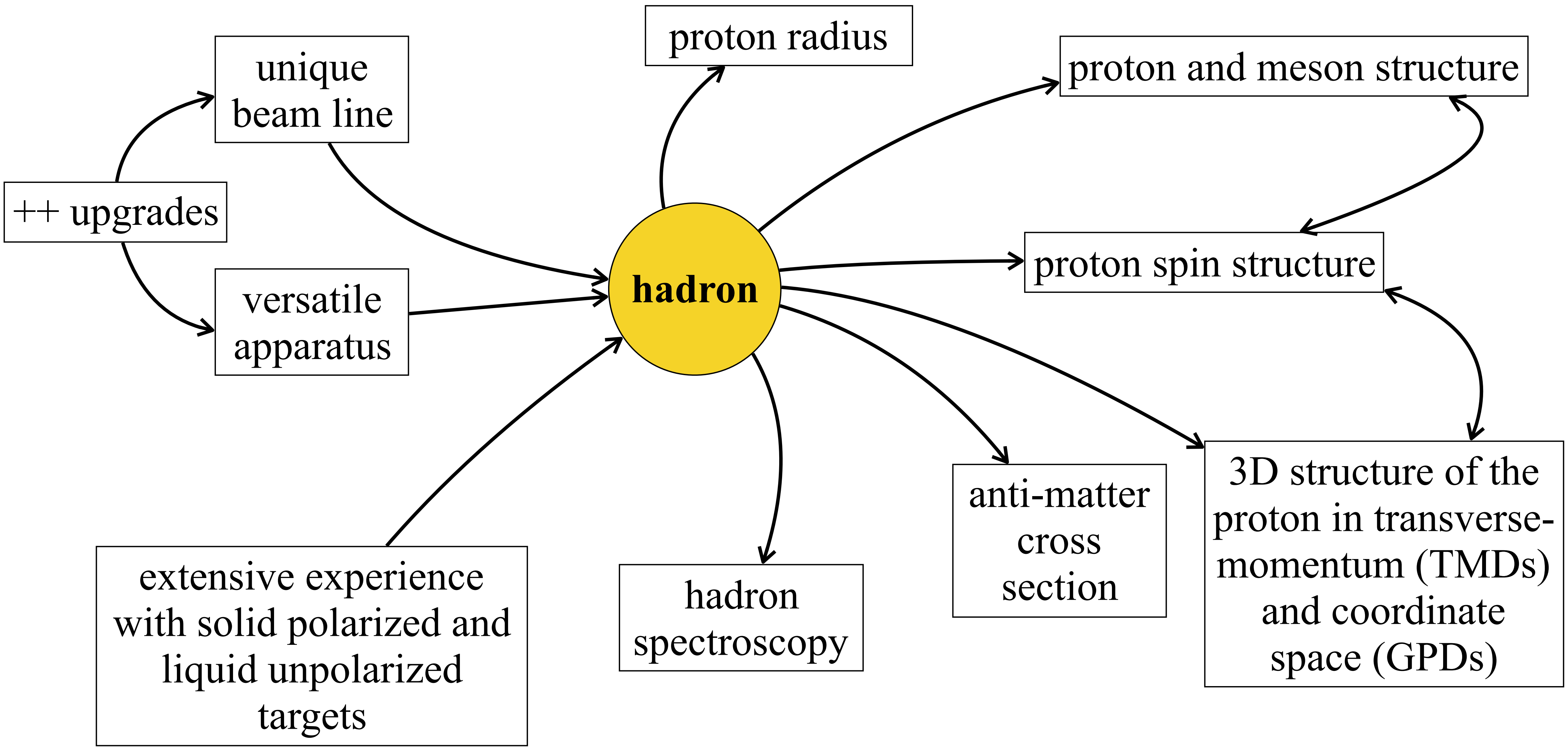
RF-separated hadron beams

  * Nucleon spin structure with antiproton beam
  * Valence quark distribution in the kaon
  * Separation of valence and sea contributions in the kaon
  * Gluon distribution in the kaon



Exploring hadron structure at CERN North Area's EHN2

A new QCD facility
at the M2 beam line of the CERN SPS



Letter of Intent: programs

A new QCD facility at the M2 beam line of the CERN SPS

https://arxiv.org/abs/1808.00848

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	$K^\pm, \overline{p}$	$NH_3^\uparrow$, C/W	2026 2-3 years	"active absorber", vertex det.
Primakoff (RF)	Kaon polarisi-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	

Table 6: Requirements for future programs at the M2 beam line after 2021. Standard muon beams are in blue, standard hadron beams in green, and RF-separated hadron beams in red.

Summary: Drell Yan at COMPASS

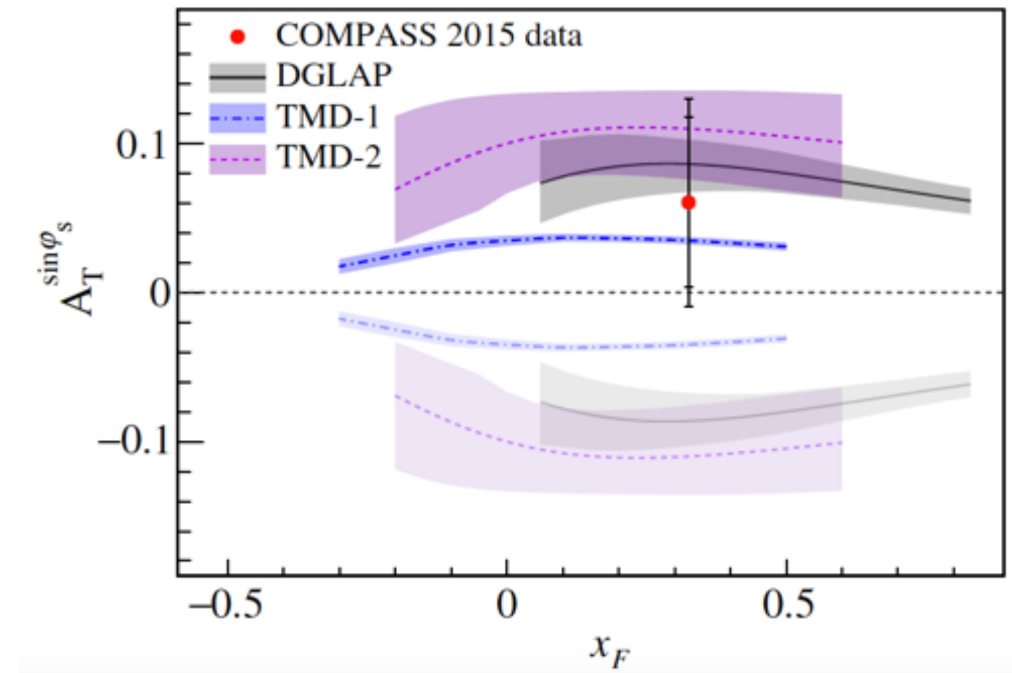
- First spin-dependent Drell-Yan result (2015 data): sign flip of Siver function wrt SIDIS supported, albeit with large experimental uncertainties.

- 2018 run ongoing at this second - expect at least stat(2018) = 1.5 x stat(2015)!

- Soon to come: modulations of spin-averaged cross section; DY cross section; nuclear effects

- Blue Waters speeds up data productions significantly

- A new QCD facility at the M2 beam line of the CERN SPS!
  Letter of Intent v1.0: https://arxiv.org/abs/1808.00848
  Express your interest, no obligations! https://nqf-m2.web.cern.ch



BLUE WATERS

A new QCD facility at the M2 beam line of the CERN SPS

This research is part of the Blue Waters sustained-petascale computing project, which is supported by the National Science Foundation (awards OCI-0725070 and ACI-1238993) and the state of Illinois. Blue Waters is a joint effort of the University of Illinois at Urbana-Champaign and its National Center for Supercomputing Applications. This work is also part of the "Mapping Proton Quark Structure using Petabytes of COMPASS Data" PRAC allocation supported by the National Science Foundation (award number OCI 1713684).

Backup

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

A new QCD facility
at the M2 beam line of the CERN SPS

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

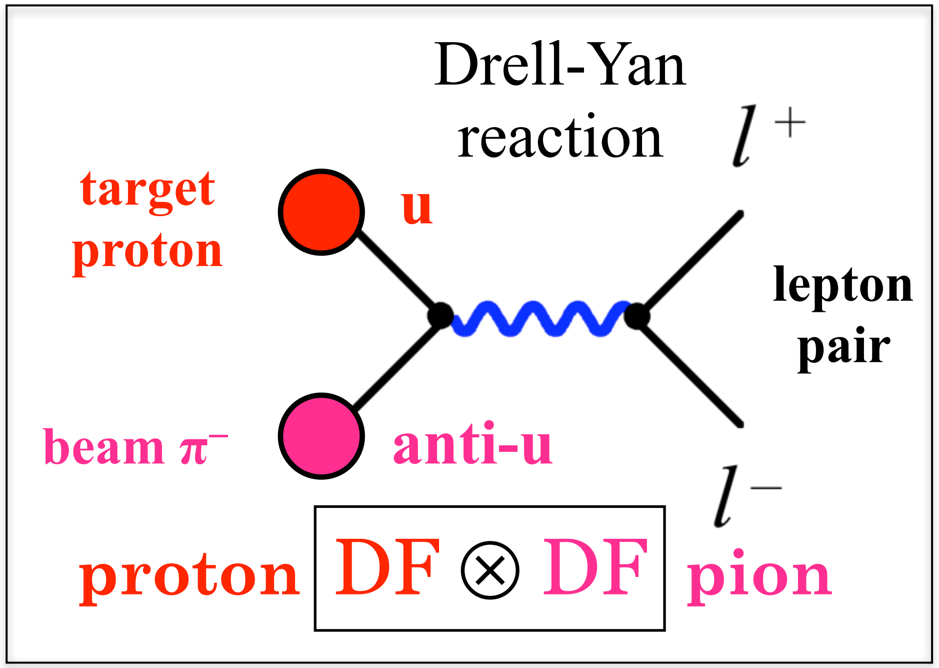
- **Proton quark & gluon structure**: detailed experimental information from (SI)DIS and jet, hadron, and Drell-Yan cross sections in pp / p-anti_p

- **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

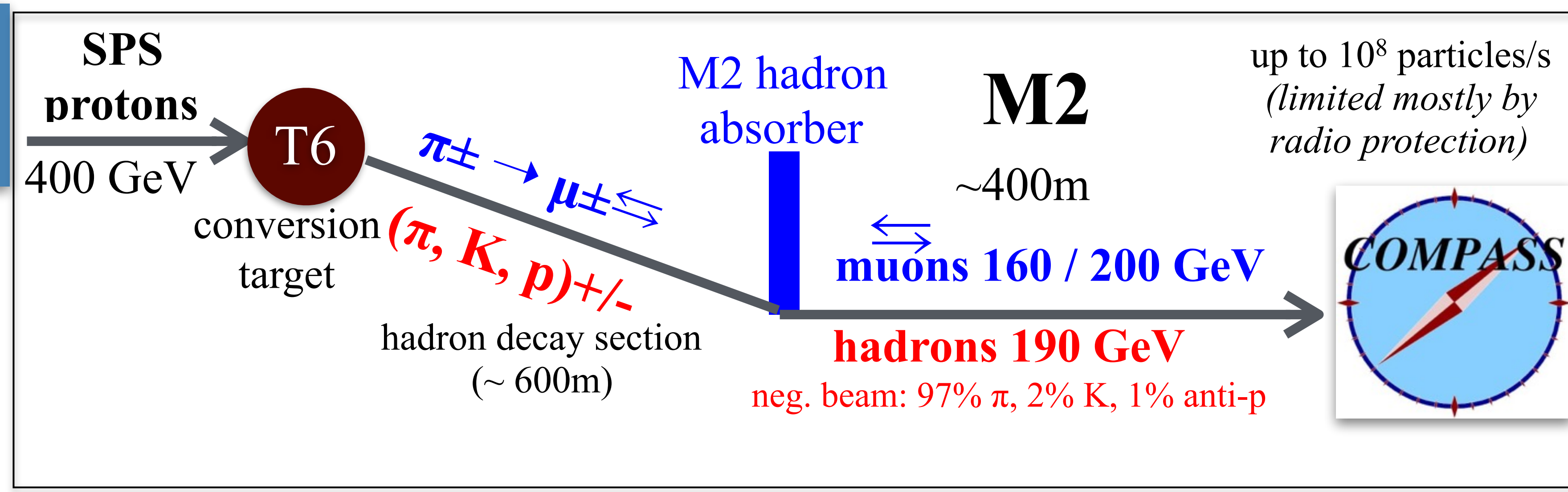
Nuclear medium modifications ("EMC-type" effect)

Drell-Yan with kaon and anti-proton beams

A new QCD facility at the M2 beam line of the CERN SPS

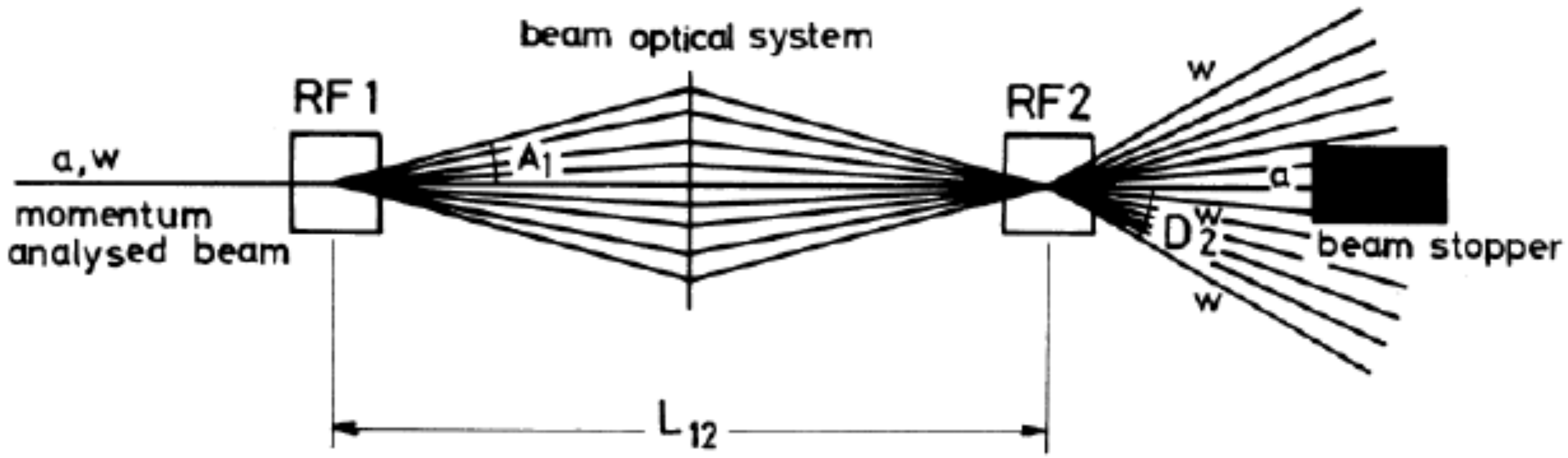
- Pion (*ud*) vs. kaon (*us*): presence of the heavier valence strange-quark might alter kaon properties.
- Kaon s-quark carries larger fraction of kaon momentum:
  ⇒ Valence distributions differ kaon vs. pion.
  ⇒ Less gluons in kaon than in pion (heavier quarks radiate softer gluons).
- Only experimental 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: $(BM)_p \otimes (BM)_\pi$
  anti-p_p scattering: $(BM)_p \otimes (BM)_{anti\text{-}p}$
  ⇒ Access to valence-quark TMDs of the proton only.

CERN M2 beam line



RF-separated beams
(not before LS3):

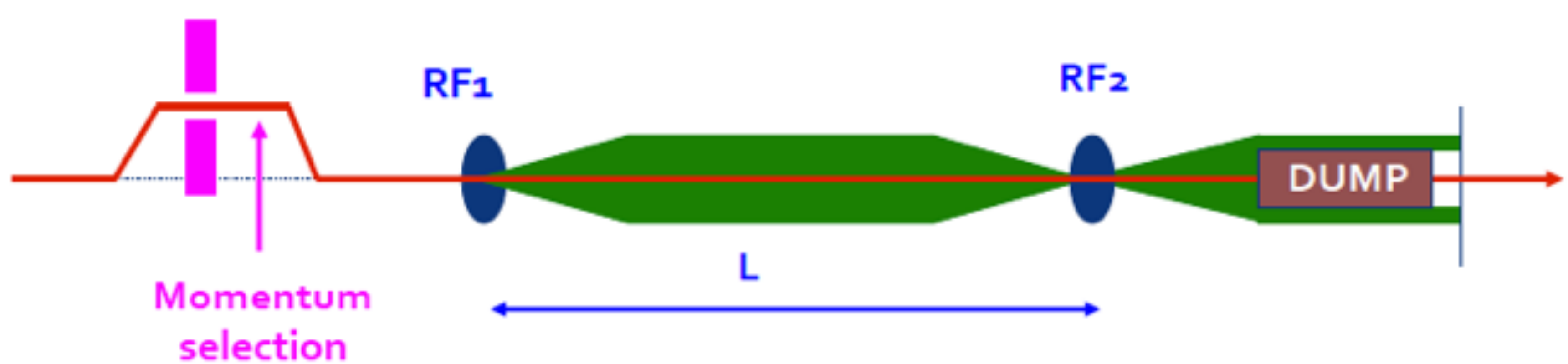
Panofsky-Schnell-System with two cavities (CERN 68-29):



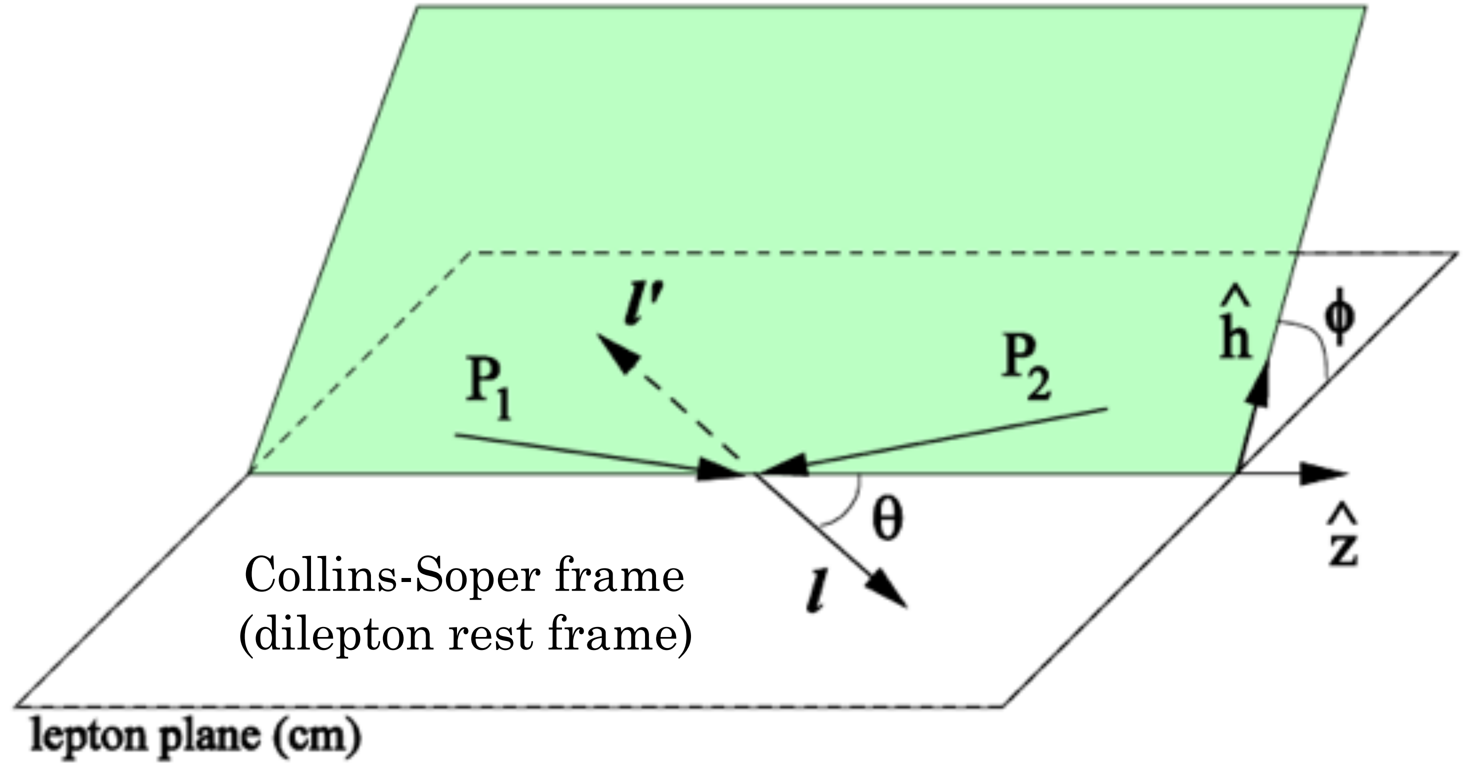
- Particle species have same momenta but different velocities
- Time-dependent transverse kick by RF cavities in dipole mode
- RF1 kick compensated or amplified by RF2
- Selection of particle species by selection of phase difference

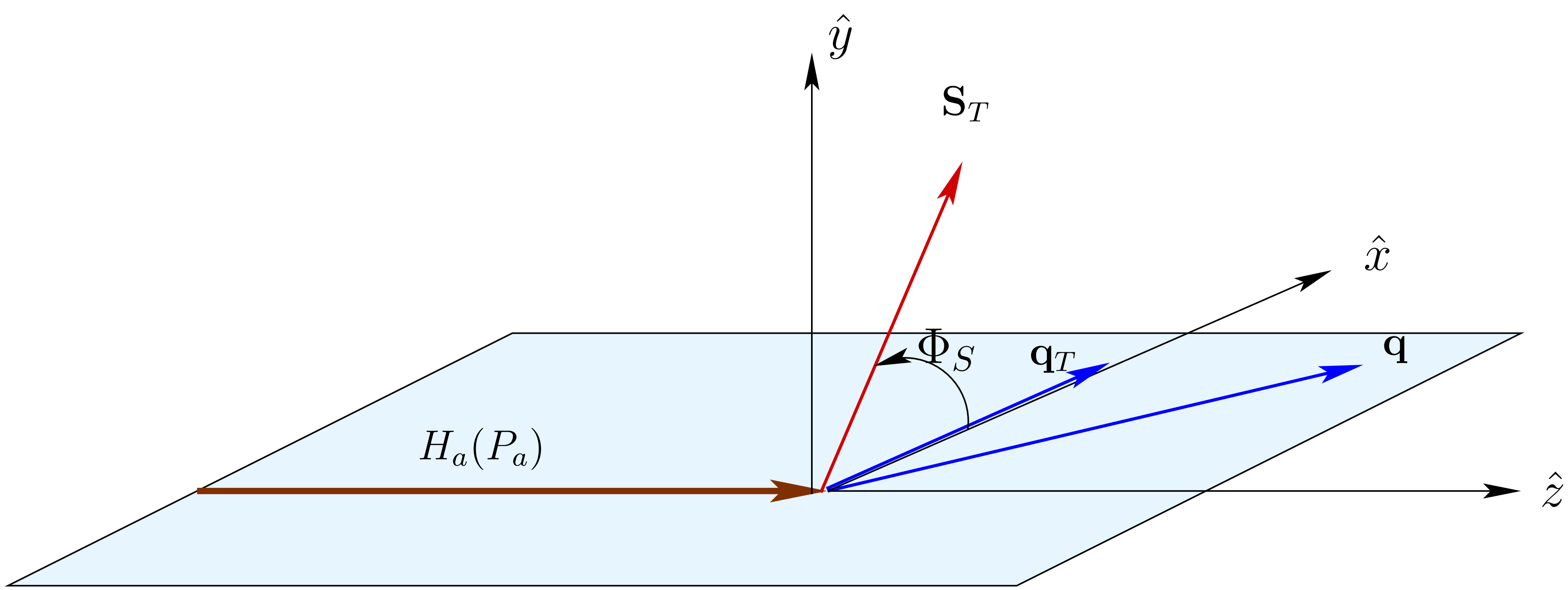
$\Delta\Phi = 2\pi\,(L\,f\,/\,c)\,(\beta_1^{-1} - \beta_2^{-1})$

J.Bernhard

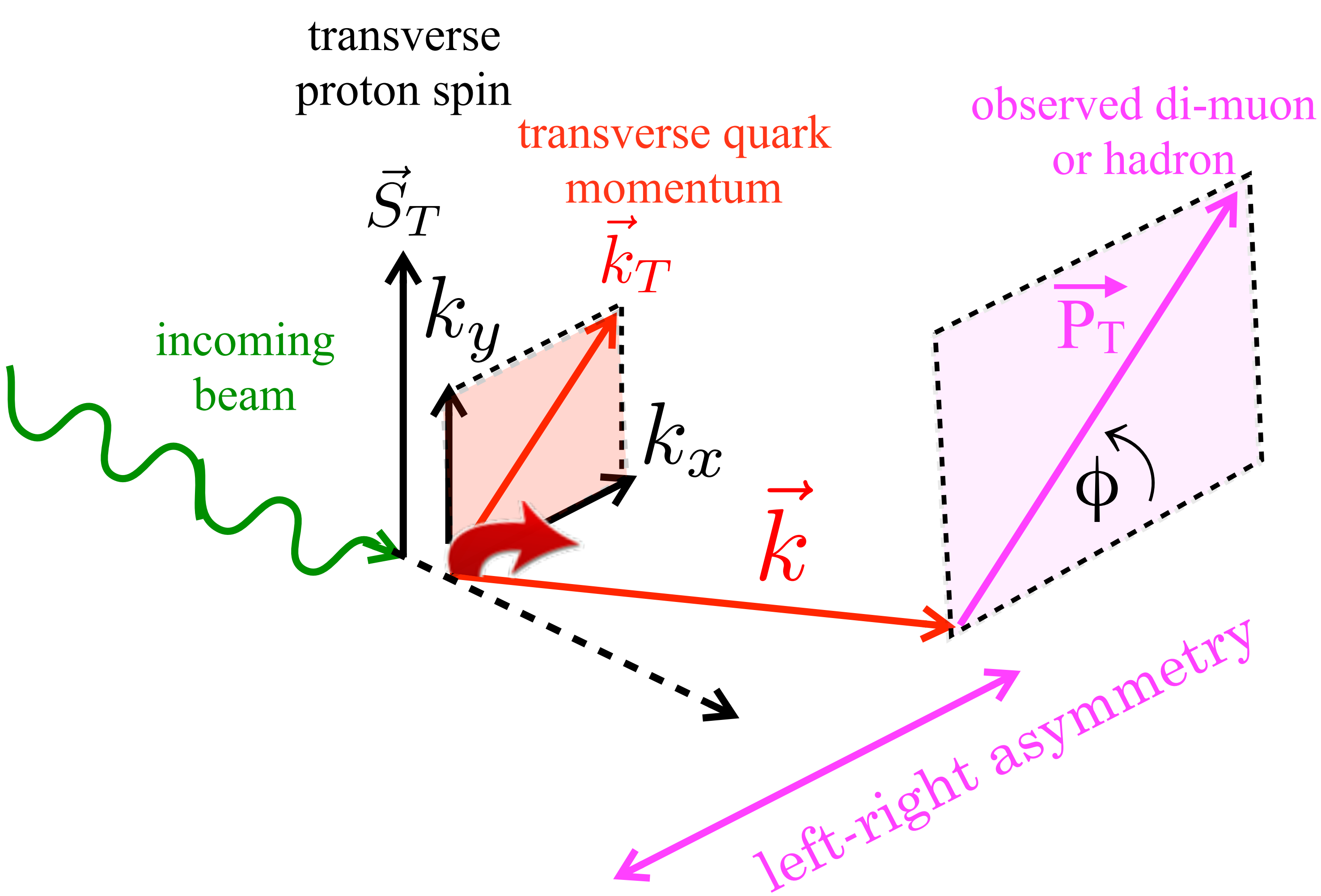


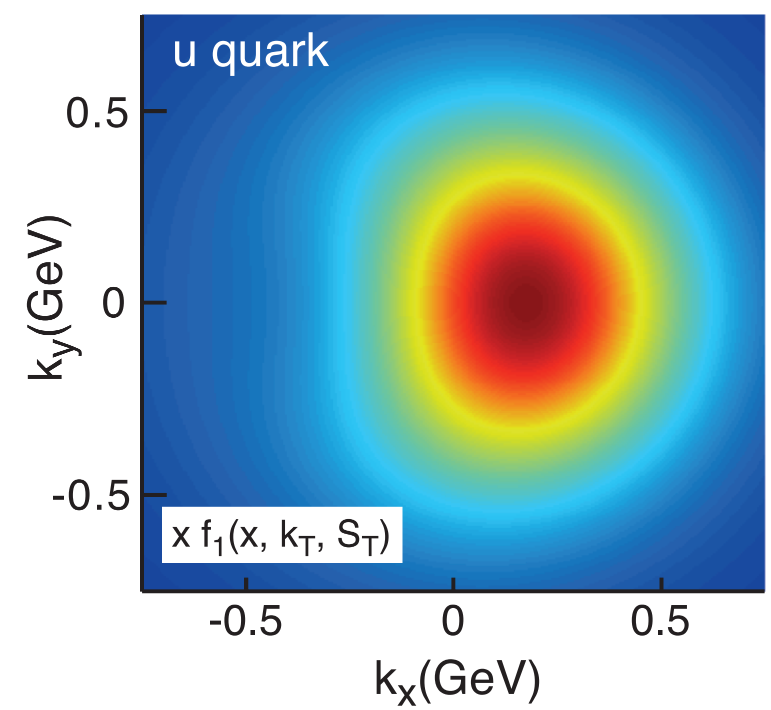
Angles in Drell Yan





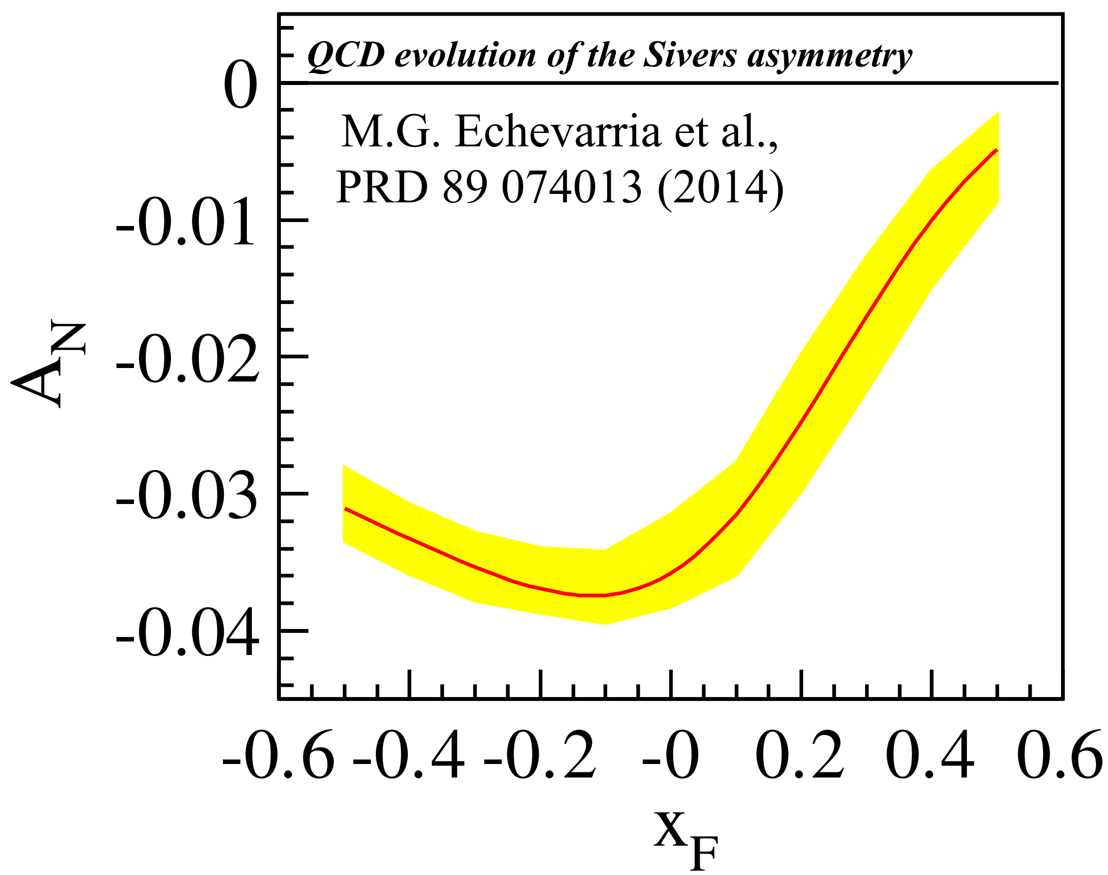
The Sivers effect

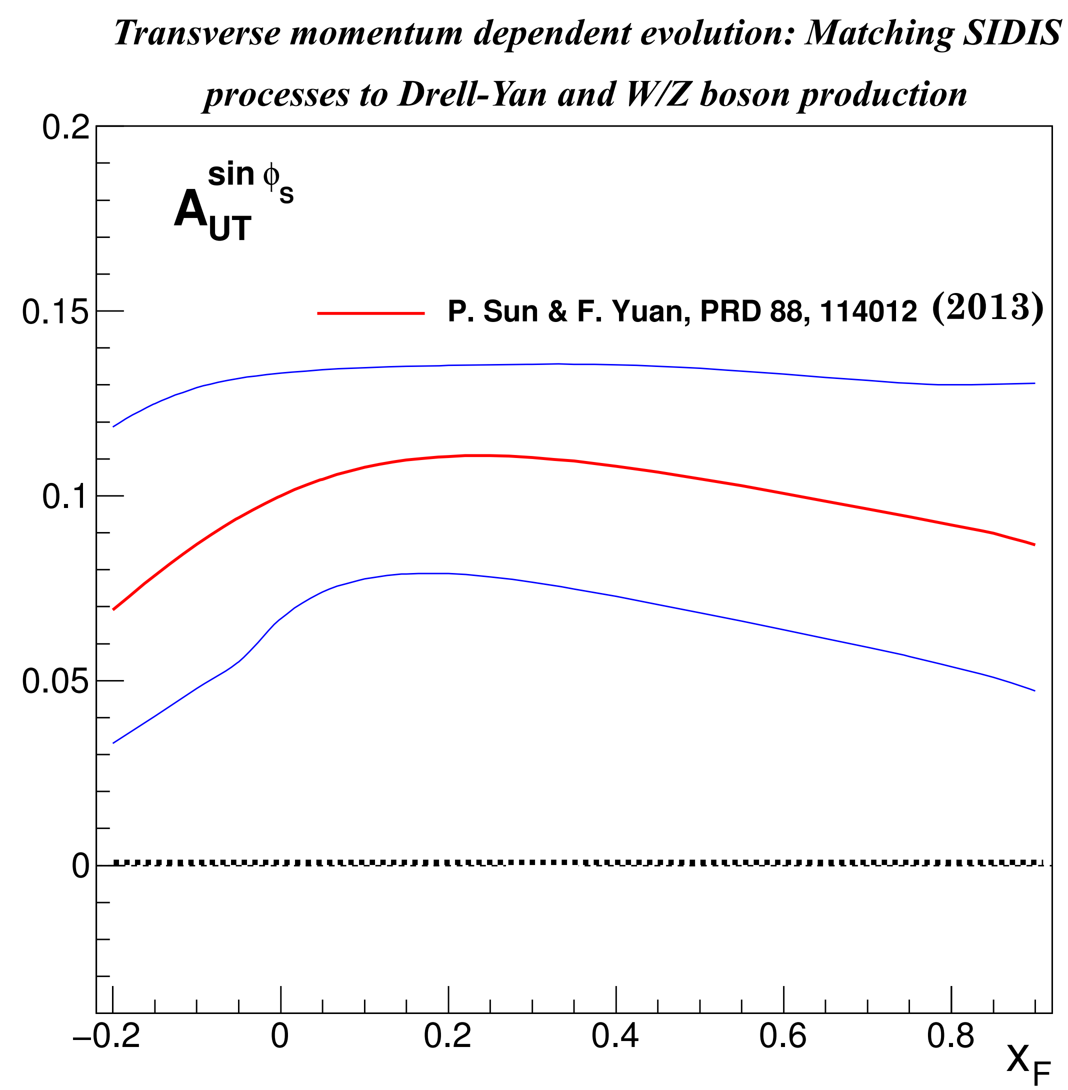




EIC "White Paper" arXiv:1212.1701, based on M. Anselmino et al., J. Phys. Conf. Ser. 295, 012062 (2011), arXiv:1012.3565

Sivers amplitude: predictions for COMPASS DY





The SIDIS cross section: "harmonic(ϕ , ϕ s)·DF ⊗ FF"

Cahn-effect + BM ⊗ Collins

Worm-gear (Kotzinian-Mulders) ⊗ Collins

BM ⊗ Collins

$$\sigma(\phi,\phi_S) \equiv \frac{d^6\sigma}{dx\,dy\,dz\,d\phi\,d\phi_S\,dP_{hT}^2} = \frac{\alpha^2}{xyQ^2}\frac{y^2}{2(1-\epsilon)}\left(1+\frac{\gamma^2}{2x}\right)$$

$$\Big\{ F_{UU,T} + \epsilon F_{UU,L} + \boxed{\sqrt{2\epsilon(1+\epsilon)}\,\cos\phi\, F_{UU}^{\cos\phi}} + \boxed{\epsilon\,\cos(2\phi)\, F_{UU}^{\cos(2\phi)}} + \lambda_e\left[\sqrt{2\epsilon(1-\epsilon)}\,\sin\phi\, F_{LU}^{\sin\phi}\right] +$$

$$+S_L\left[\sqrt{2\epsilon(1+\epsilon)}\,\sin\phi\, F_{UL}^{\sin\phi} + \boxed{\epsilon\,\sin(2\phi)\, F_{UL}^{\sin(2\phi)}}\right] + S_L\lambda_e\left[\sqrt{1-\epsilon^2}\, F_{LL} + \sqrt{2\epsilon(1-\epsilon)}\,\cos\phi\, F_{LL}^{\cos\phi}\right]$$

$$+|S_T|\left[\boxed{\sin(\phi-\phi_S)\left(F_{UT,T}^{\sin(\phi-\phi_S)} + \epsilon F_{UT,L}^{\sin(\phi-\phi_S)}\right)} + \boxed{\epsilon\,\sin(\phi+\phi_S)\, F_{UT}^{\sin(\phi+\phi_S)}} + \boxed{\epsilon\,\sin(3\phi-\phi_S)\, F_{UT}^{\sin(3\phi-\phi_S)}}\right.$$

$$\left.+\sqrt{2\epsilon(1+\epsilon)}\,\sin\phi_S\, F_{UT}^{\sin\phi_S} + \sqrt{2\epsilon(1+\epsilon)}\,\sin(2\phi-\phi_S)\, F_{UT}^{\sin(2\phi-\phi_S)}\right]$$

$$+|S_T|\lambda_e\left[\boxed{\sqrt{1-\epsilon^2}\,\cos(\phi-\phi_S)\, F_{LT}^{\cos(\phi-\phi_S)}} + \sqrt{2\epsilon(1-\epsilon)}\,\cos\phi_S\, F_{LT}^{\cos\phi_S} + \sqrt{2\epsilon(1-\epsilon)}\,\cos(2\phi-\phi_S)\, F_{LT}^{\cos(2\phi-\phi_S)}\right]\Big\},$$

Sivers ⊗ D1

Worm-gear ⊗ D1

Transversity ⊗ Collins

Pretzelosity ⊗ Collins

- $F_{XY[Z]}$ = structure function. X=beam, Y= target polarization, [Z= virtual-photon polarization]. X, Y ∈ {U, L, T}

Unpolarized
Longitudinally
Transversely

- λ_e = helicity of the lepton beam
- S_L and S_T = longitudinal and transverse target polarization
- ε = ratio of longitudinal and transverse photon fluxes

Bacchetta et al., JHEP 02, 093 (2007)

COMPASS Blue Waters: project time line

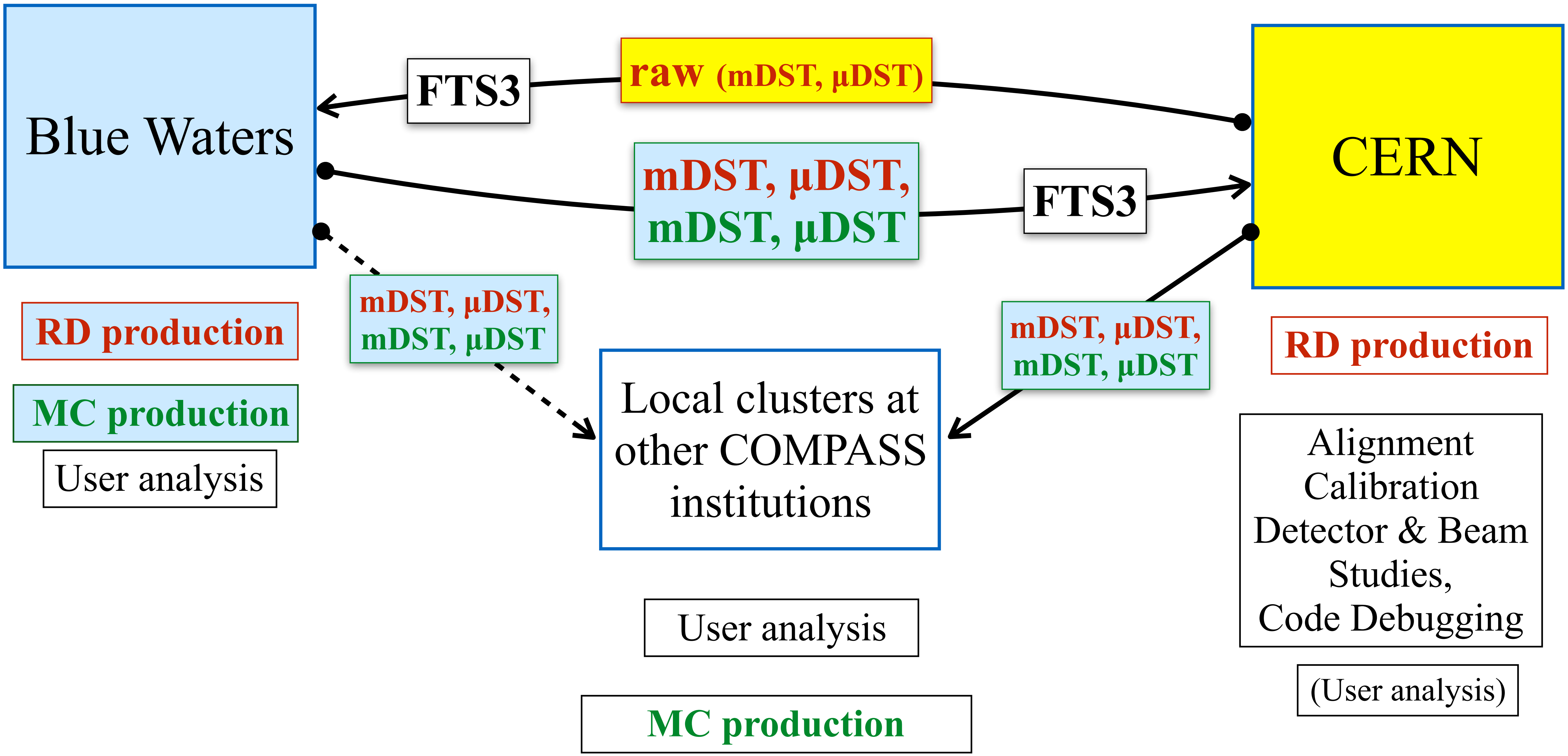
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
2016												
2017												
2018									NOW			
2019												

node hours (~~used up~~) ~~40,000~~ ~~200,000~~ ~~(9,440,000)~~ 9,440,000

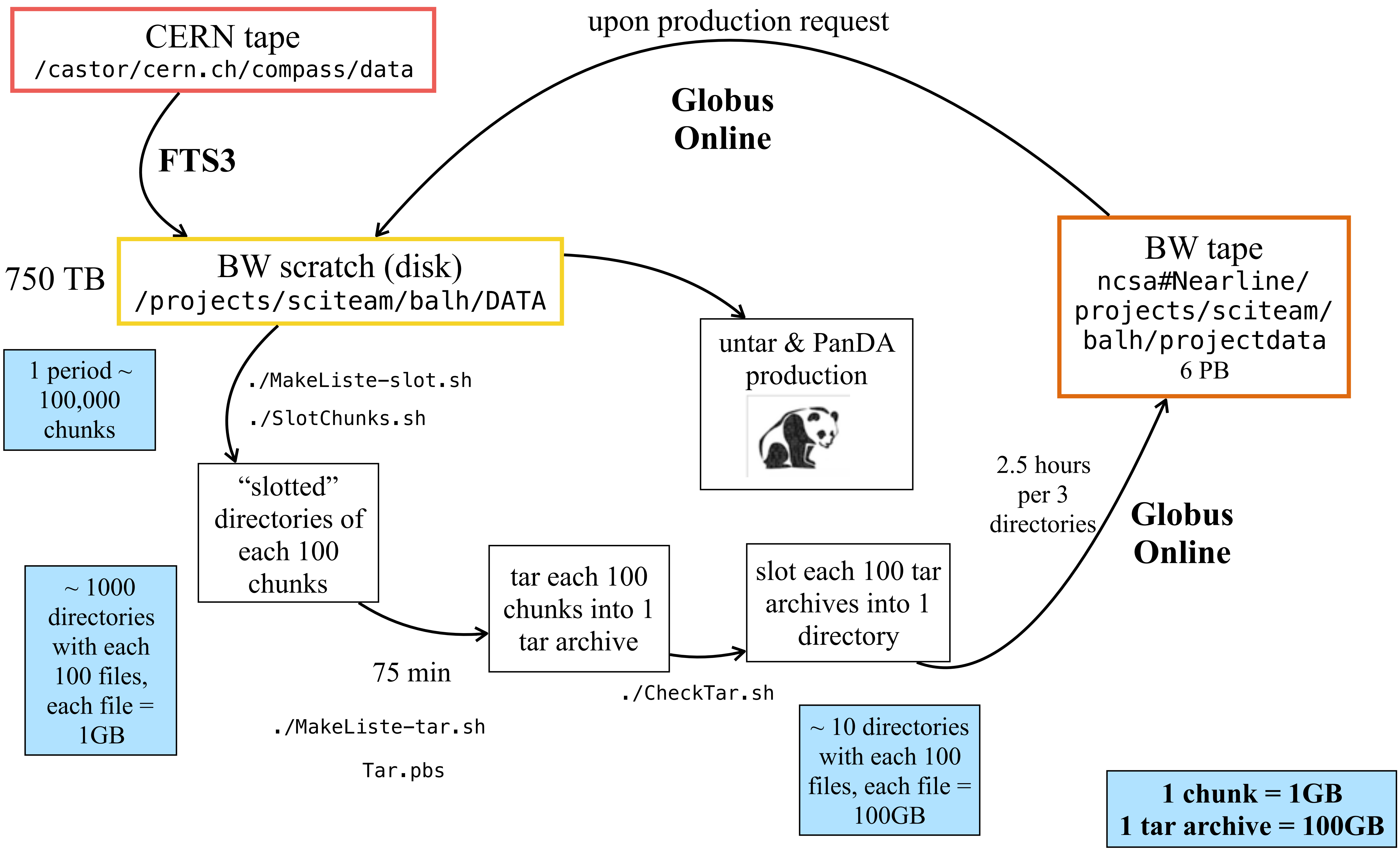
proposal submission

Exploratory **Campus** **PRAC-A** **PRAC-B** allocations

COMPASS Blue Waters computing model



Raw data management on Blue Waters



PanDA production interface

Cloud, Sites	Status	nJobs	defined	waiting	assigned	throttled	activated	sent	starting	running	holding	merging	transferring	finished	failed	cancelled	% failed
all sites including MCP		77418	0	0	0	0	39	196	16	898	252	0	0	52576	23441	0	30
BW_COMPASS_MCORE	online	3112	0	0	0	0	39	32	16	48	0	0	0	256	2721	0	91
CERN_COMPASS_PROD	online	74306	0	0	0	0	0	164	0	850	252	0	0	52320	20720	0	28

COMPASS PanDA | Dash | Productions | Tasks | Jobs | Errors | Users | Sites | Search | COMPASS | Help

The summary for the **dy2015W12t5BWtest** production started on 03 Apr 2018. The total number of chunks is 968. The average walltime of a finished job is 1234 minutes. Built 10:42

Tasks for dy2015W12t5BWtest | Jobs for dy2015W12t5BWtest | Show settings path for dy2015W12t5BWtest

Show 50 entries Search:

Run	Number of events	Total number of chunks	Staged	Sent	Running	Failed	Finished	Status of mDST merging	X-checked mDST	mDST migration	Status of histogram merging	Histogram migration	Status of event dump merging	X-checked event dump	Event dump migration
263293	22373350	466	-	40	9	-	417	-	no	-	-	-	-	no	-
263330	24204064	502	-	47	39	-	416	-	no	-	-	-	-	no	-

Showing 1 to 2 of 2 entries Previous 1 Next

Brought to you by the PanDA team.
All times are in UTC. Page may be cached; check the build time above.
PanDA home

- The PanDA pilot receives jobs from remote PanDA server, requests jobs by preparing PBS jobs and sending them to PBS MOM nodes
- The pilot checks if jobs are OK, sends monitoring callback to PanDA and, once jobs are finished, performs stage-out of result files to the target directories.