Drell-Yan programme and requirements

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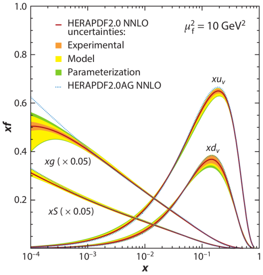
COMPASS Front-end, Trigger and DAQ workshop
March 2nd-3rd

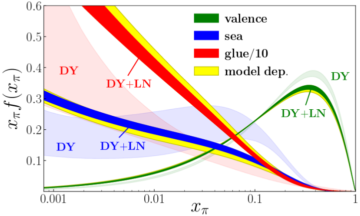
Emergence of the hadronic mass

How to explain the origin of the mass of composite hadrons?



$M_p \sim 940 MeV/c^2$
3 light valence quarks

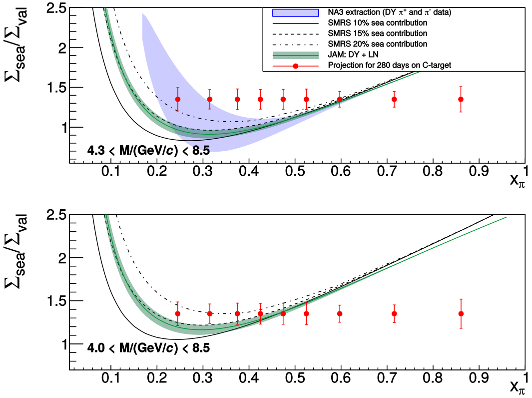
P. C. Barry *et al.* arXiv:1804.01965v1



$M_\pi \sim 130 MeV/c^2$
2 light valence quarks

Knowledge of the nucleon and the **pion PDFs**
are **fundamental to understand the hadrons mass budget.**
Let us study their structure!

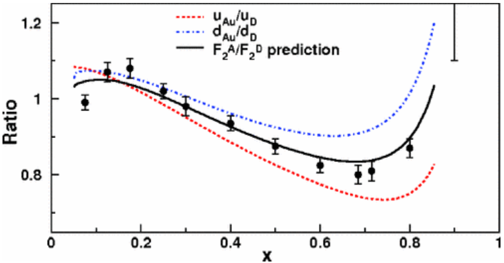
Measure of Pions structure



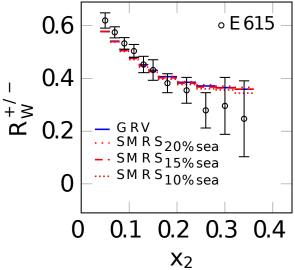
$$\Sigma_{val} = \sigma^{\pi^- C} - \sigma^{\pi^+ C}\text{: only valence-valence}$$
$$\Sigma_{sea} = 4\sigma^{\pi^+ C} - \sigma^{\pi^- C}\text{: no valence-valence}$$

- Aim at the first precise direct measurement of the pion sea contribution
- Collect at least a **factor 10 more statistics** than presently available

Study nuclear effects



P. Paakkinen *et al.* PLB 768 (2017) 7

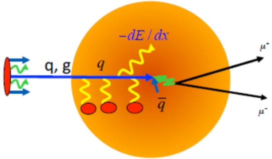


Nuclear PDFs:

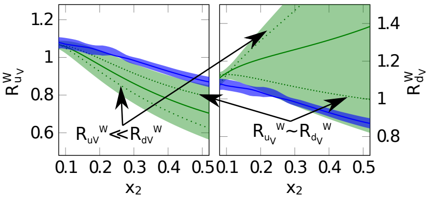
- Flavour dependence of nPDF (unconstrained by DIS data)
- Applicability of pion-induced DY data validated

Parton energy loss:

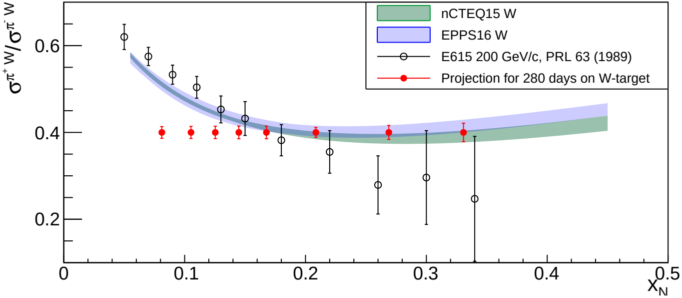
- Particularly important for low $\sqrt{s} \rightarrow$ fixed target
- Important input also to interpret heavy ion data



EMC effects

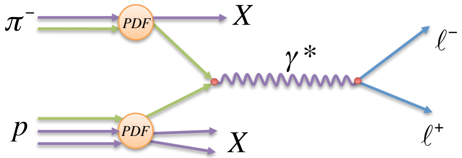


Using two π beam charges and two targets, one can add constraints on the EMC effect and flavour dependence



How do we do it?

<u>Process</u>: Drell-Yan lepton pair (and Charmonia) productions

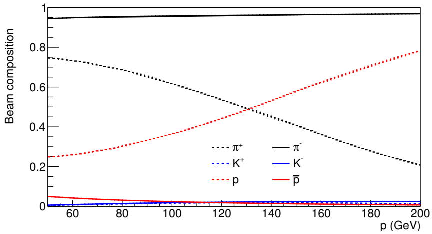


- Theory well known
- Access quarks structure of both projectiles

Caveat:

- Low cross-section
- Limited range of pure contribution

<u>Beam</u>: M2 Beam line



- High intensities available (limited by RP)
- Almost pure π^- beam (97% @ 190 GeV)
- Reasonable contribution of π^+ (24% @ 190 GeV)

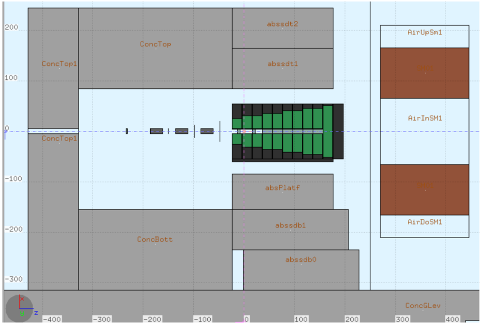
Choice of targets and shielding

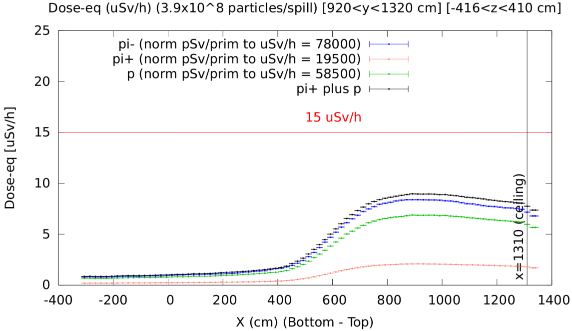
Targets:

Carbon:
- 3×25 cm
- λ_I=52 cm

Tungsten:
- 2 cm and 2×6 cm
- λ_I =11 cm

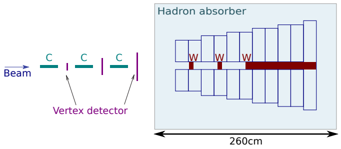
Embedded in a bunker:





Expected intensity: $1.8\times10^{8}s^{-1}$

Apparatus



3 carbon targets of 25cm length

2 tungsten targets of 6cm length

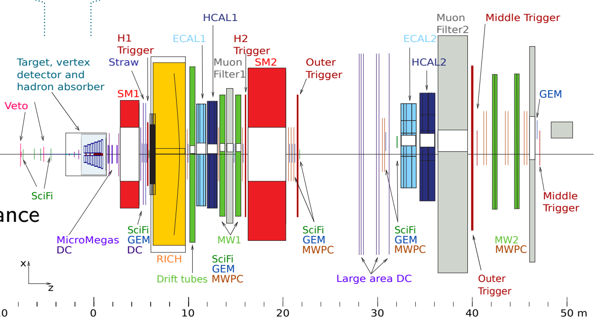
(alternative 2cm length W upstream)

2024 Drell-Yan setup

Hadron absorber for high intensity

Vertex detectors for Mass resolution

Two CEDAR detectors for beam PID

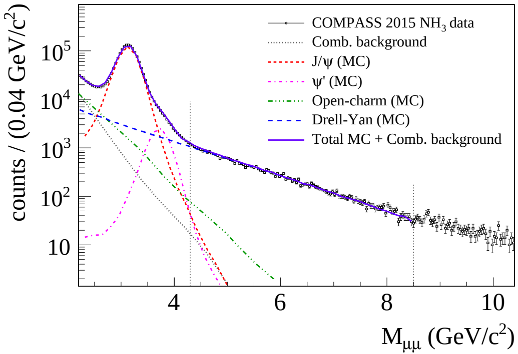


COMPASS-like spectrometer for acceptance

$8 \lesssim \theta^{\mu^{\pm}}/(mrad) \lesssim 140$

Motivation for a vertex detector system

M. Aghasyan *et al.* PRL 119, 112002 (2017)

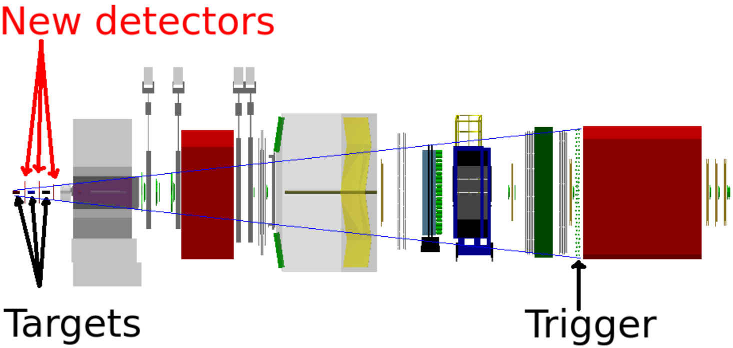


Degradation of spectrometer resolution due to the absorber

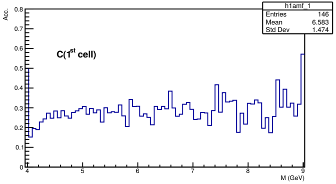
→ Loss of Drell-Yan events

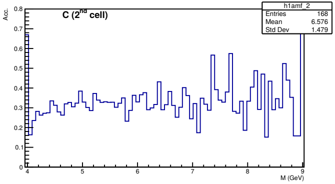
→ ψ' signal un-exploitable

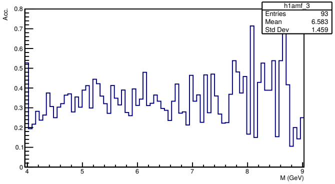
Restore the performances with a system of vertex detectors to cancel the effect of multi-scattering



- Size: from 10×10 cm^2 to 40×40 cm^2
- Ideally also cover beam area (luminosity)
- Rough acceptance flat *vs* $M_{\mu\mu}$ and around 30%







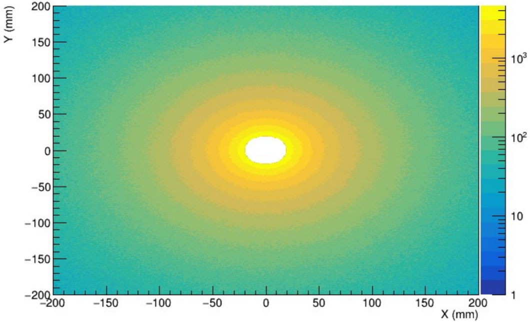
Required performance

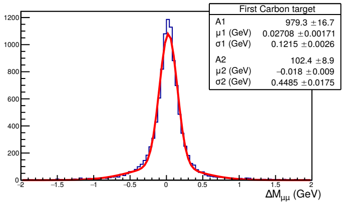
Main difficulty for the reconstruction is the multiplicity: $\sim$20 tracks/events

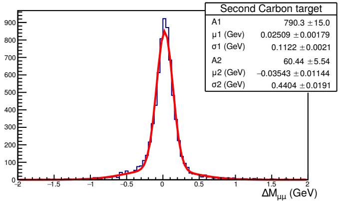
- Hit rates: $\sim$ 10 kHz/mm^2
- Time resolution: a few ns
- Spacial resolution $< 200\mu$m
  Due to small level arm
- Ideally, no dead-zone

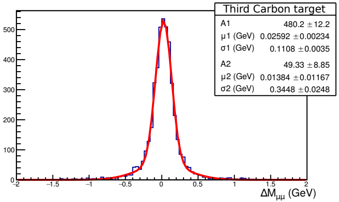
$\rightarrow$ Goal: $\delta M_{\mu\mu} < 100$ MeV

Hit rate (Hz/mm^2)

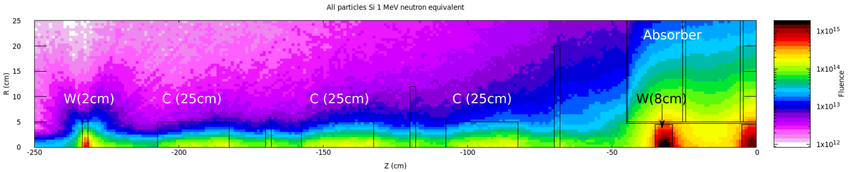


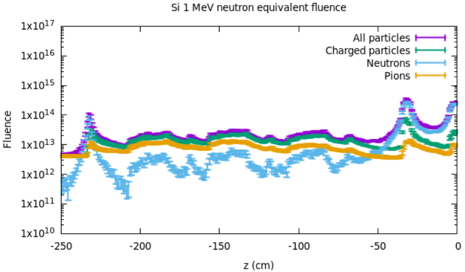


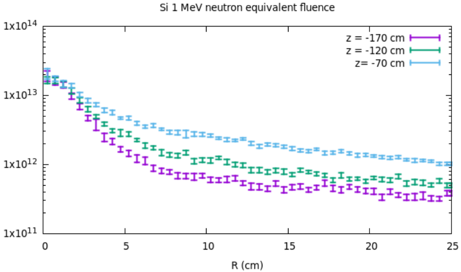




Radiation environment for the vertex detectors







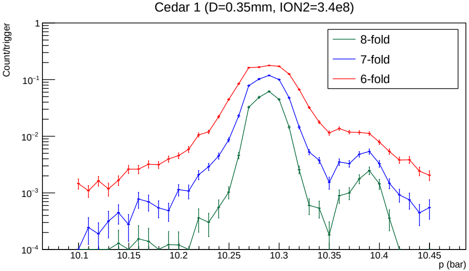
- Estimate for 40×10^{13} pions, *i.e.* 1 year of data taking with $I = 1.8 \times 10^{8} s^{-1}$
- Environment hostile but not incompatible with Silicon technology: ALPIDE, RD50
- Solution to the vertex detection system will be a combination of different technology

Beam PID

Need to tag Pions @ 190 GeV:

- discriminate K and p for h^- beam
- Identify π (24%) in h^+ beam

Idea: use 2 CEDARs of 8 MAPMTs each



Challenge:

- up to 40 MHz particles to tag
- Efficiency larger than 90%

COMPASS 2018 with $\sim$ 70 MHz beam intensity:

- Operational but low efficiency based on majority signal (beam divergence)

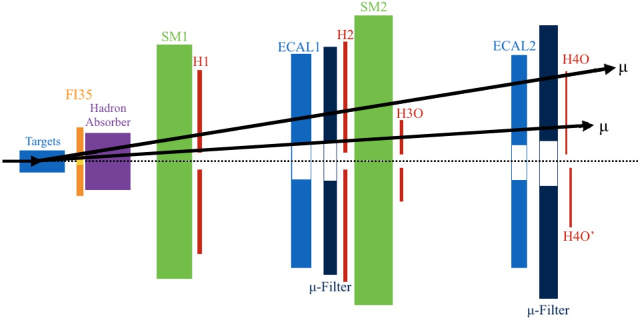
$\rightarrow$ Require a low material budget detector upstream of CEDARs

Trigger requirement and expected rates for the DAQ

Trigger: Horizontal slabs of scintillator for target pointing as in COMPASS . . .

- 1 system in LAS (H1 & H2)
- 2 systems in SAS
  - Outer (H3 & H4)
  - Middle (not shown)

. . . + some tracking information
and no veto system



Trigger (COMPASS 2018)	LASLAS	OLAS	MLAS
w. Veto (kHz)	22.9	1.5	0.7
w/o. Veto (kHz)	52.0	33.3	10.4

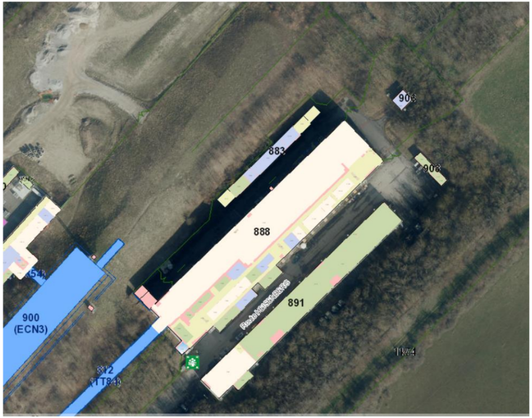
First estimate $\sim$ **150 kHz** and without DAQ dead-time

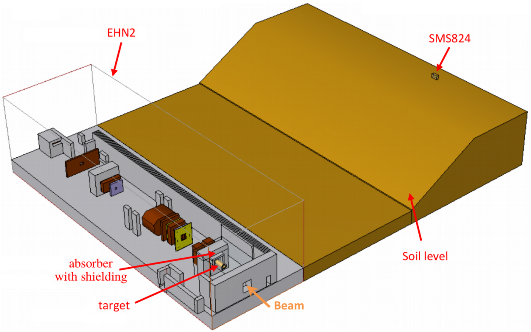
Conclusion

- Nice measurements to come
- Vertex detection system is essential
- Detector and Front-End should be radiation hard
- DAQ should be able to digest about 150 kHz

BACKUP

Radio-protection consideration





Supervised Area:

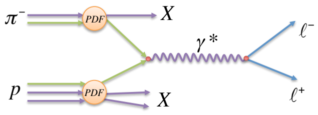
- 6 mSv/y
- Low occup. (<400h/y): 15 μSv/h
- Working place (2 kh/y): 3 μSv/h

Non-designated area:

- 1 mSv/y
- Low occup. (<400h/y): 2.5 μSv/h
- Working place (2 kh/y): 0.5 μSv/h

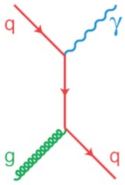
How to access meson structure

Drell-Yan:



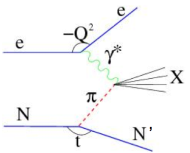
- 90's: NA3, NA10, E615
- 10's: COMPASS-II
- 20's: New Experiment

Prompt photon production:



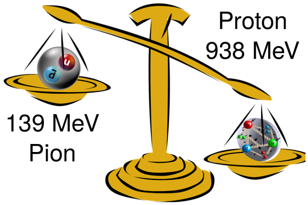
- 90's NA24, W70
- 20's New experiment

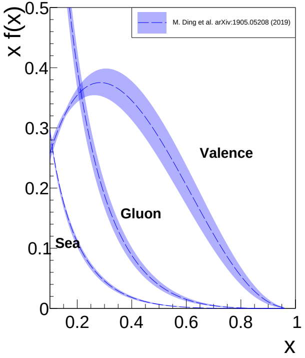
DIS with leading N:

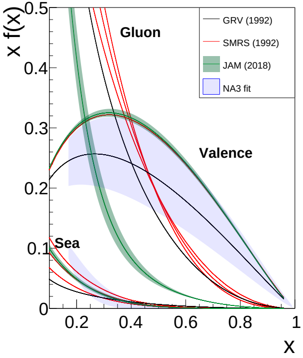


- 90's: H1, ZEUS
- 10's: JLAB TDIS
- 30's: EIC

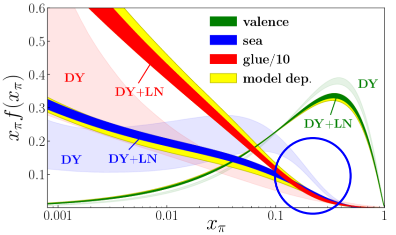
- Recent renewed of interest
  - Reanalysis of old data with NLL (agreement with DSE)
  - Emergence of the mass
- Limited knowledge from old data (DY, prompt photon, TDIS)







P. C. Barry *et al.* arXiv:1804.01965v1



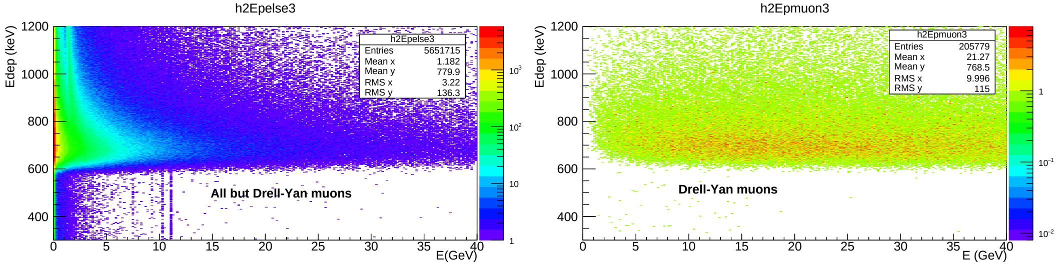
3.1 Physics motivation rewritten

Thanks to Craig Roberts for his valuable contribution

Conservative estimates:

- with current beam intensities and RP limits: $7 \times 10^7/\mathrm{s}$ total beam flux
- and a super-cyle: 1 spill every 26s
- exploitable spills (stability beam and apparatus, analysis cut): 65%
- CEDARs: 90% efficiency

Can we discriminate some hits to facilitate the reconstruction?

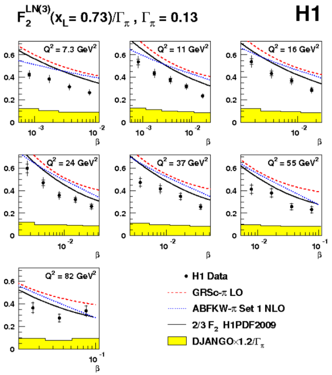


Cannot reduce the hit multiplicity with a cut on the amplitude with a FI detector

Since we have to deal with that, I will try now to reconstruct tracklets in order to have more than 3 tracks attached to the vertex (beam+2muons)

DIS with di-jet and leading neutron

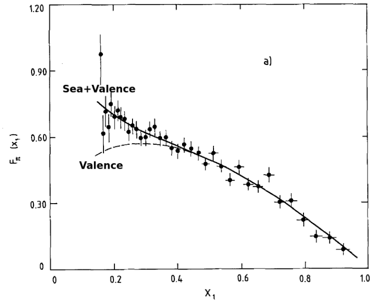
Aaron et al. Eur. Phys. J. C68, 2010



- Wide x coverage
- Estimation of pion flux introduce a strong model dependence

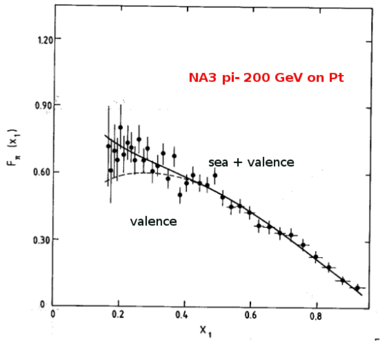
Drell-Yan NA3

Badier *et al.*, Z. Phys. C18, 1983



- Limited statistics: 4.7k π^--event (shown) and 1.7k π^+-event
- Heavy nuclear target (Pt)

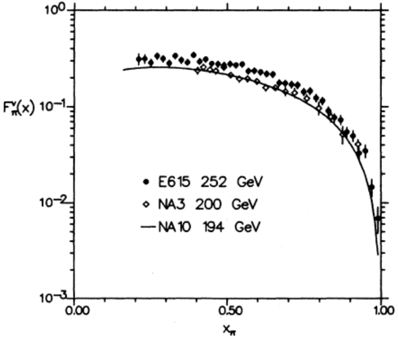
Pion Structure Function: $F_{\pi}(x_1)$



Simultaneous fit of NA3 π^+, π^- and p at 200 GeV Drell-Yan data, using CDHS nucleon PDF set.

NA3 Coll.; Z.Phys.C **18** (1983) 281-287

$v^{\pi}(x_1)$



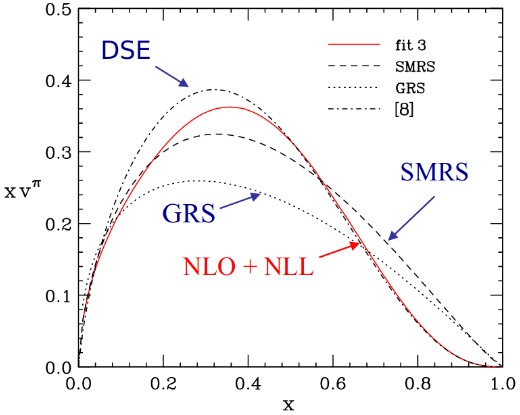
Discrepancy by 20% between E615 and NA3/NA10

E615 Coll.; Phys.Rev. D **39** (1989) 92-122

Left: Curve scaled with $K_{factor} = 2.3$; Right: Data point corrected by K_{factor}

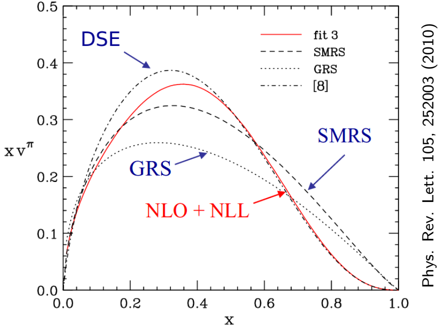
Status of the pion structure at mid-large x

- Recent reanalysis at NLL
- Agreement resstored between DSE and dat
- Only valence quark distributions are fitted
- Sea and gluon from GRS



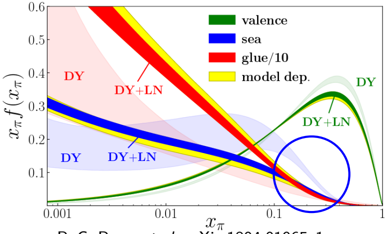
Renewed interest in pion structure

- Recent reanalysis at NLL
- Agreement restored between DSE and data
- Sea and gluon from GRS



- First MC global QCD analysis ("model dependence")
- Hera data included
- Clear impact on sea and gluon distribution

Direct data would constrain the circled area and check the method.



P. C. Barry *et al.* arXiv:1804.01965v1

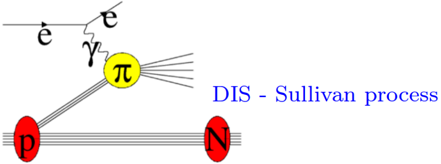
Expected statistics with beam time sharing $\pi^+ : \pi^- = 3:1$ for 280 days

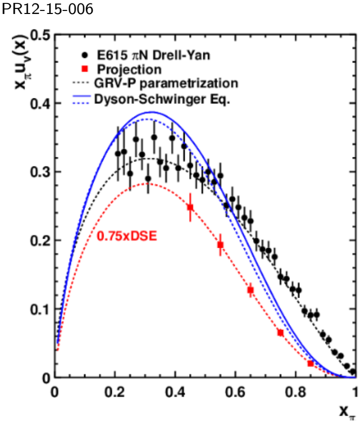
Experiment	Target type	Beam energy (GeV)	Beam type	Beam intensity (part/sec)	DY mass (GeV/c^2)	DY events
E615	20cm W	252	π^+ π^-	17.6×10^7 18.6×10^7	4.05 – 8.55	5,000 30,000
NA3	30cm H_2	200	π^+ π^-	2.0×10^7 3.0×10^7	4.1 – 8.5	40 121
	6cm Pt	200	π^+ π^-	2.0×10^7 3.0×10^7	4.2 – 8.5	1,767 4,961
NA10	120cm D_2	286 140	π^-	65×10^7	4.2 – 8.5 4.35 – 8.5	7,800 3,200
	12cm W	286 140	π^-	65×10^7	4.2 – 8.5 4.35 – 8.5	49,600 29,300
COMPASS 2015 COMPASS 2018	110cm NH_3	190	π^-	7.0×10^7	4.3 – 8.5	35,000 52,000
This exp	75cm C	190	π^+	1.7×10^7	4.3 – 8.5 4.0 – 8.5	**21,700** **31,000**
		190	π^-	6.8×10^7	4.3 – 8.5 4.0 – 8.5	**67,000** **91,100**
	12cm W	190	π^+	0.2×10^7	4.3 – 8.5 4.0 – 8.5	**8,300** **11,700**
		190	π^-	1.0×10^7	4.3 – 8.5 4.0 – 8.5	**24,100** **32,100**

Forseen meson structure measurements

Tagged DIS at JLab

- Same approach as H1 and Zeus:





- Test of pion cloud
- Caveat: Model depedence from the unknown pion flux

Provide complementary data at large x
Same process is also forseen for the future EIC to reach very low x

Target choice and sea-valence separation

With π^+ and π^- beam and isoscalar target:

$$\sigma(\pi^+ d) \propto \frac{4}{9}[u^\pi \cdot (\bar{u}_s^p + \bar{d}_s^p)] + \frac{4}{9}[\bar{u}_s^\pi \cdot (u^p + d^p)] + \frac{1}{9}[\bar{d}^\pi \cdot (d^p + u^p)] + \frac{1}{9}[d_s^\pi \cdot (\bar{d}_s^p + \bar{u}_s^p)]$$

$$\sigma(\pi^- d) \propto \frac{4}{9}[u_s^\pi \cdot (\bar{u}_s^p + \bar{d}_s^p)] + \frac{4}{9}[\bar{u}^\pi \cdot (u^p + d^p)] + \frac{1}{9}[\bar{d}_s^\pi \cdot (d^p + u^p)] + \frac{1}{9}[d^\pi \cdot (\bar{d}_s^p + \bar{u}_s^p)]$$

- Assumption:
  - Charge conjugation and $SU(2)_f$ for valence: $u_v^{\pi^+} = \bar{u}_v^{\pi^-} = \bar{d}_v^{\pi^+} = d_v^{\pi^+}$
  - Charge conjugation and $SU(3)_f$ for sea:
    $u_s^{\pi^+} = \bar{u}_s^{\pi^-} = u_s^{\pi^-} = \bar{u}_s^{\pi^+} = \bar{d}_s^{\pi^+} = d_s^{\pi^+} = \bar{d}_s^{\pi^-} = d_s^{\pi^+} = s_s^{\pi^+} = s_s^{\pi^-} = \bar{s}_s^{\pi^+} = \bar{s}_s^{\pi^-}$
- Two linear combination
  - Only valence sensitive: $\Sigma_v^{\pi D} = -\sigma^{\pi^+ D} + \sigma^{\pi^- D} \propto \frac{1}{3} u_v^\pi (u_v^p + d_v^p)$
  - Sea sensitive : $\Sigma_s^{\pi D} = 4\sigma^{\pi^+ D} - \sigma^{\pi^- D}$

Systematics (Sec.3.6)

Effects	Comments
Beam momentum	momentum spread $\sim 2\% \to$ negligeable
Kaon PID	K/π <6% and highly suppressed K^+
Proton PID	Easy to discriminate
Re-interaction	Not negligeable, evaluation ongoing
Trigger efficiency	monitored with Calorimeter trigger
Acceptance	a few percents (ongoing)
Luminosity	<5%
Nuclear effects	$\sim$ 4% on $\Sigma_{sea}/\Sigma_{val}$

Expected to be smaller than the statistical error bars