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# Neutrinos at the Forward Physics Facility at the LHC

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**"Standard Model and Beyond"**  
**5th Symposium of the Division for Physics of Fundamental  
Interactions of the Polish Physical Society**  
Katowice, October 22, 2022

Forward Physics Facility: 2109.10905 (Jonathan L. Feng, Maria Vittoria Garzelli, Felix Kling et al)  
2203.05090 (Jonathan L. Feng, Felix Kling, Mary Hall Reno, Juan Rojo, Dennis Soldin et al)

**ASTROCENT**



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## Far-forward searches at the LHC in a bird's eye view

Standard Model and Beyond



FASER (Run 3)

UJ12

UJ12 Alcoves

LHC

T112

ATLAS IP1

PGC3

LHC

L~620m

SND@LHC (Run 3)

Purpose-Built Facility

Forward Physics Facility (HL-LHC)



# ALREADY ONGOING EXPERIMENTAL PROGRAM & FUTURE PLANS

## Run 3 HL-LHC

## Detector

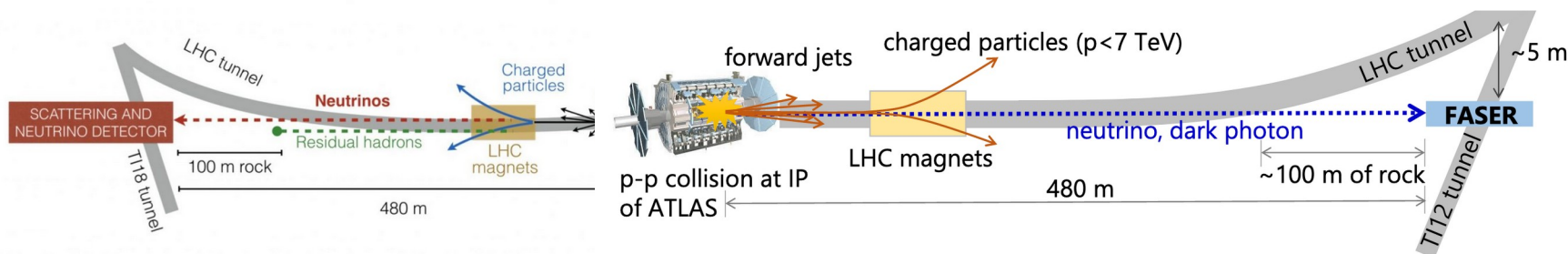
Name	Mass	Coverage	Luminosity
FASER $\nu$	1 ton	$\eta \gtrsim 8.5$	$150 \text{ fb}^{-1}$
SND@LHC	800kg	$7 < \eta < 8.5$	$150 \text{ fb}^{-1}$
FASER $\nu$ 2	20 tons	$\eta \gtrsim 8.5$	$3 \text{ ab}^{-1}$
FLArE	10 tons	$\eta \gtrsim 7.5$	$3 \text{ ab}^{-1}$
AdvSND	2 tons	$7.2 \lesssim \eta \lesssim 9.2$	$3 \text{ ab}^{-1}$

First neutrino candidate events already detected (Run 2)

FASER Collaboration, 2105.06197



- emulsion detectors (FASER $\nu$ 2, SND@LHC)
- LAr TPC (FLArE)
- electronic trackers & calorimeter (FASER[2], AdvSND@LHC)

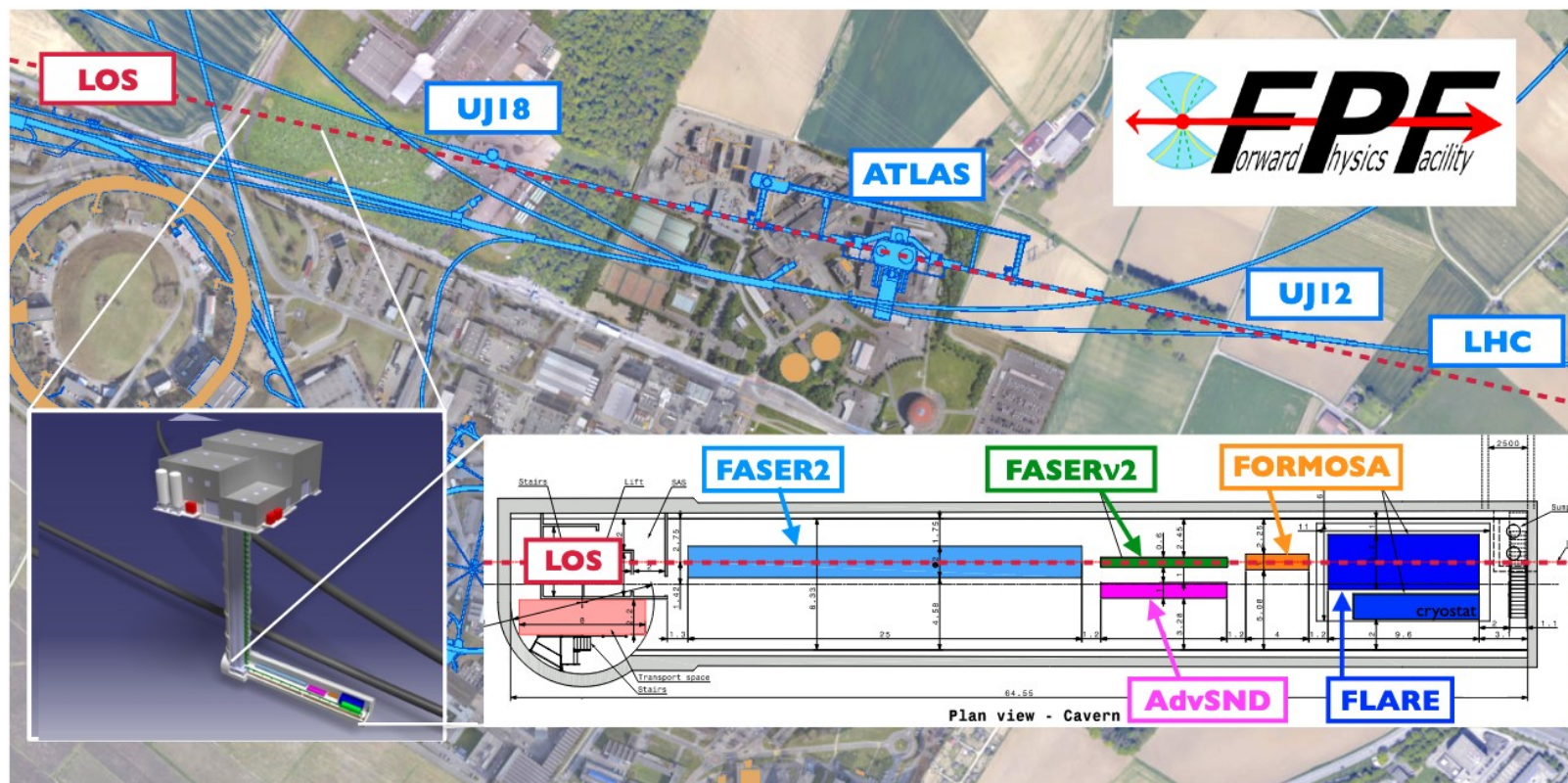




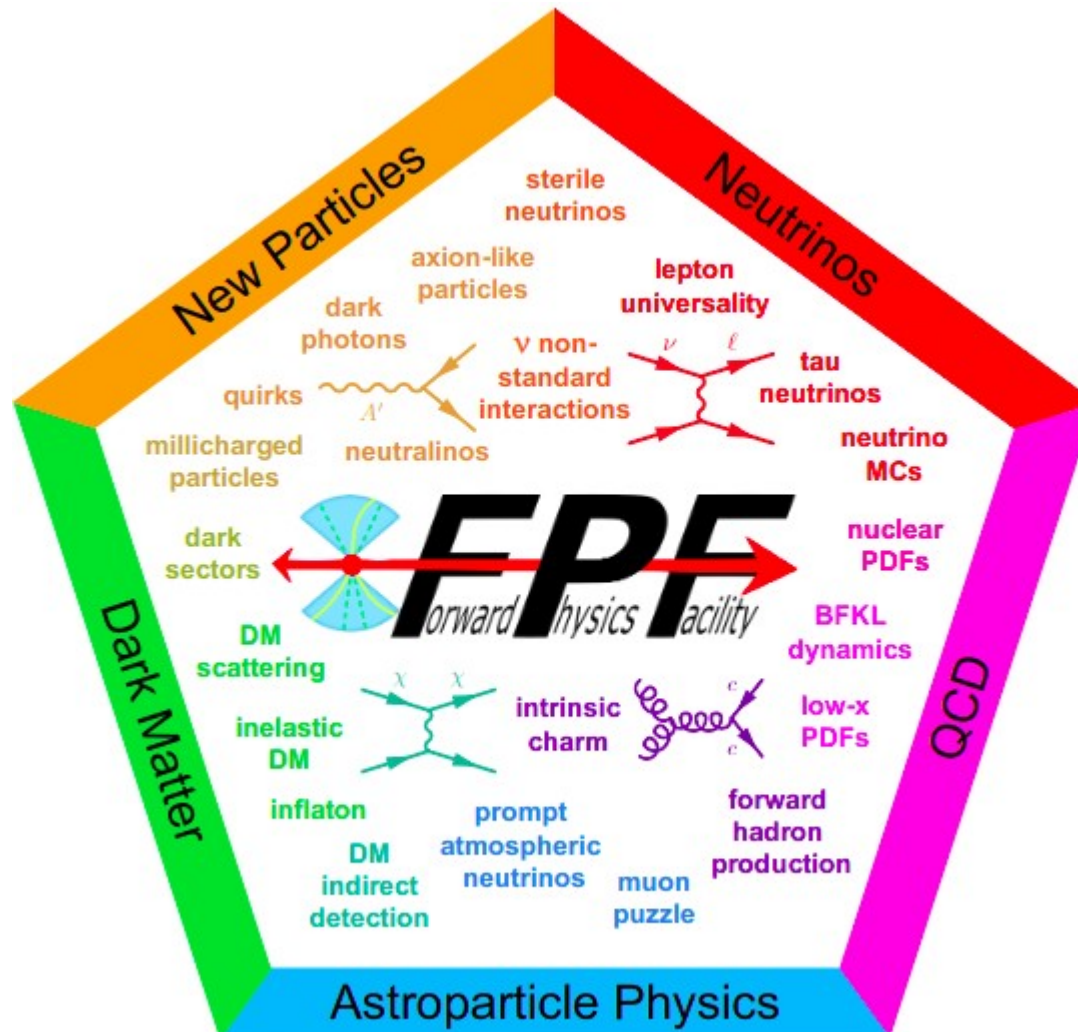
# PURPOSE-BUILT FACILITY

Underground facility:

- ~620 m far forward from the ATLAS IP,
- shielded by ~200 m concrete and rock.
- FPF experiments to detect neutrino interactions, energies up to a few TeV.



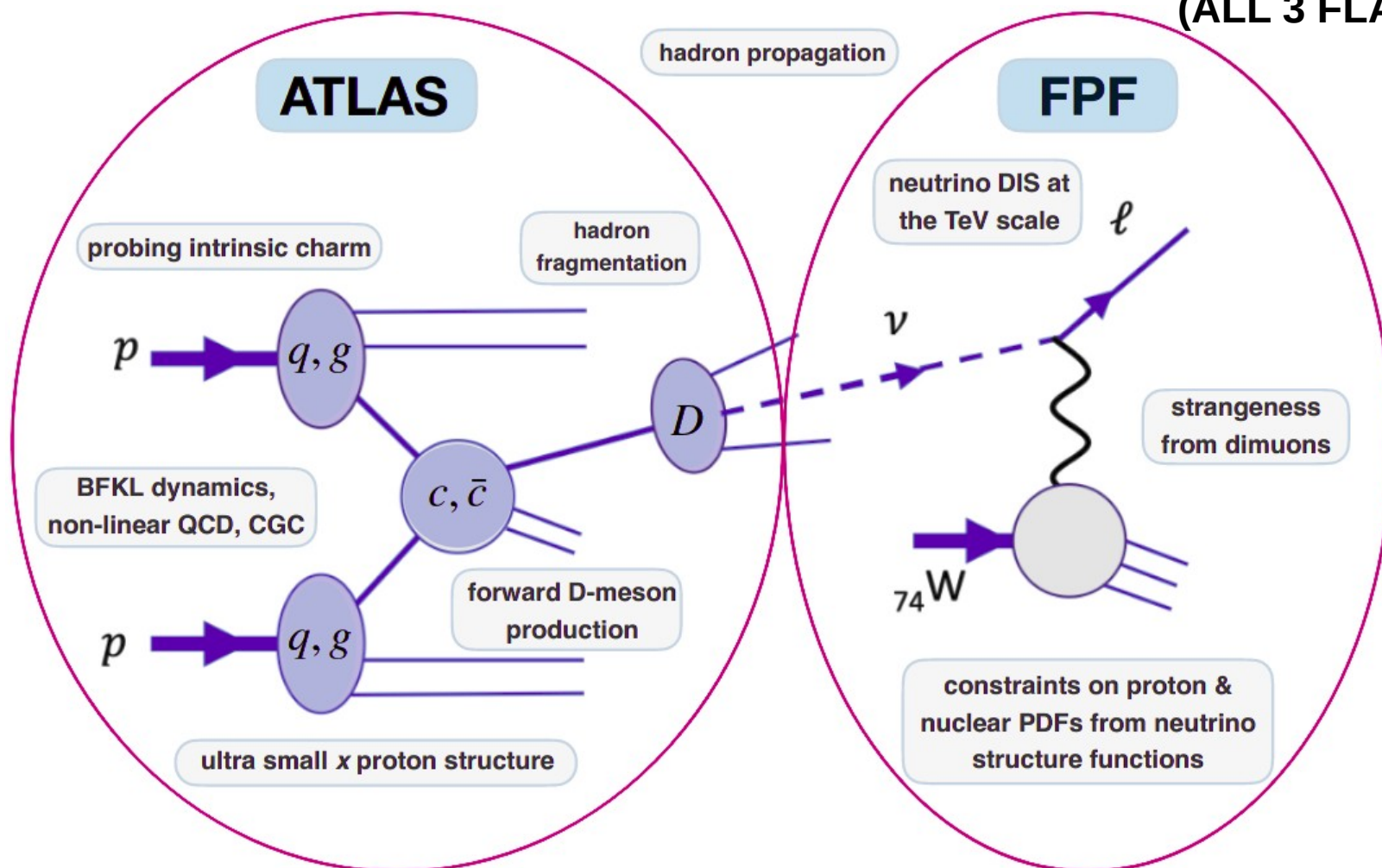
# PHYSICS AT THE FPF



# NEUTRINO PRODUCTION & DETECTION

## LIGHT HADRON & CHARM MESON DECAYS

## NEUTRINO INTERACTIONS ON NUCLEAR TARGETS (ALL 3 FLAVORS)



# FORWARD NEUTRINOS



- Pions (for  $\nu_\mu$ ) & kaons ( $\nu_e$ )  
dominate at energies up to few hundred GeV

- Charm dominates at larger energies  
(also all  $\nu_\tau$  from charm)

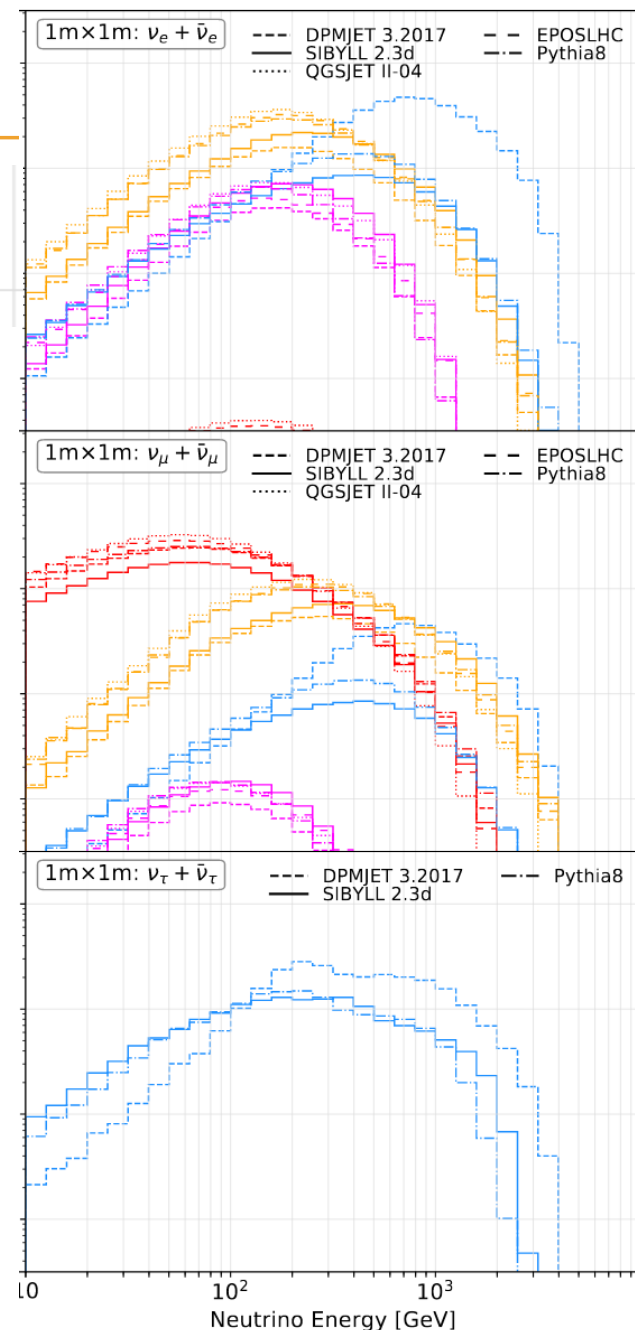
Here – larger uncertainties, further studies ongoing

## Measuring neutrino flux & spectrum

↕  
**window to study forward hadron production  
 in pp collisions at the LHC**

- Expected CC event rates (HL-LHC)

$$\sim 10^6 \nu_\mu, \text{ few } \times 10^5 \nu_e, \sim (10^3 - 10^4) \nu_\tau$$

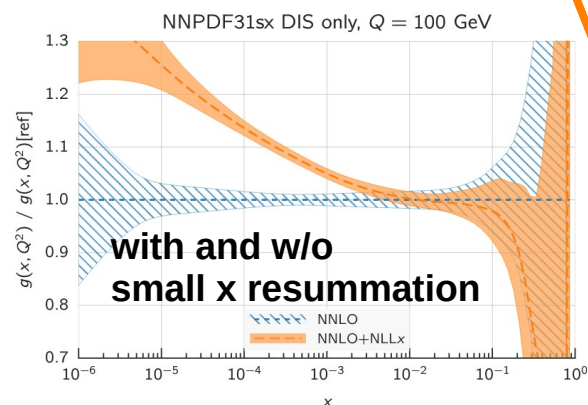




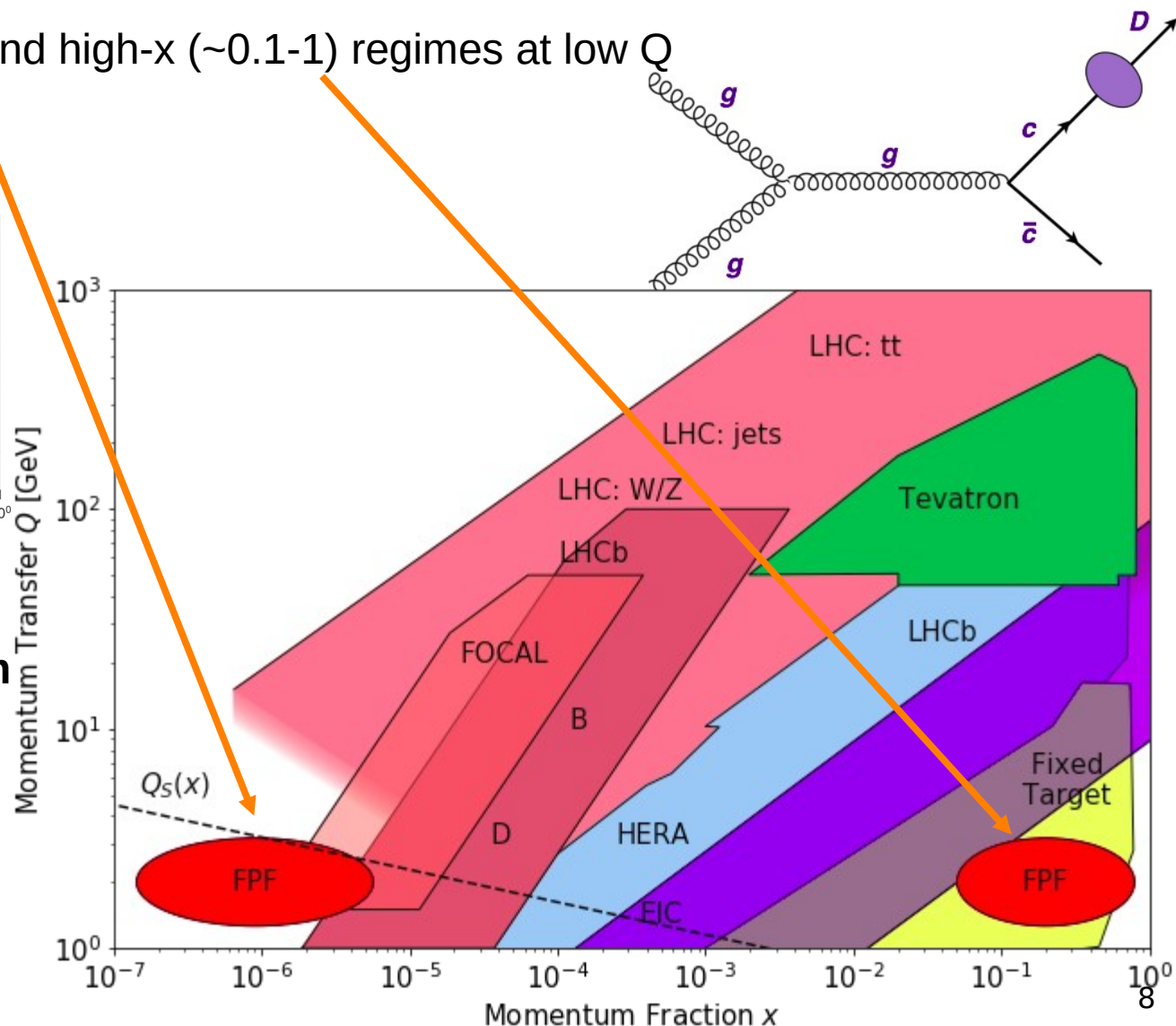
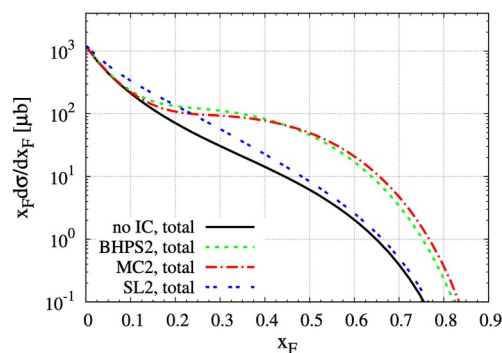
# NEUTRINOS FROM CHARM DECAYS

- probes of low- $x$  ( $\sim 10^{-7}$ ) and high- $x$  ( $\sim 0.1-1$ ) regimes at low  $Q$

- Small  $x$ : gluon PDFs**



- Large  $x$ : charm sea & potentially intrinsic charm**





# NEUTRINO DEEP INELASTIC SCATTERING

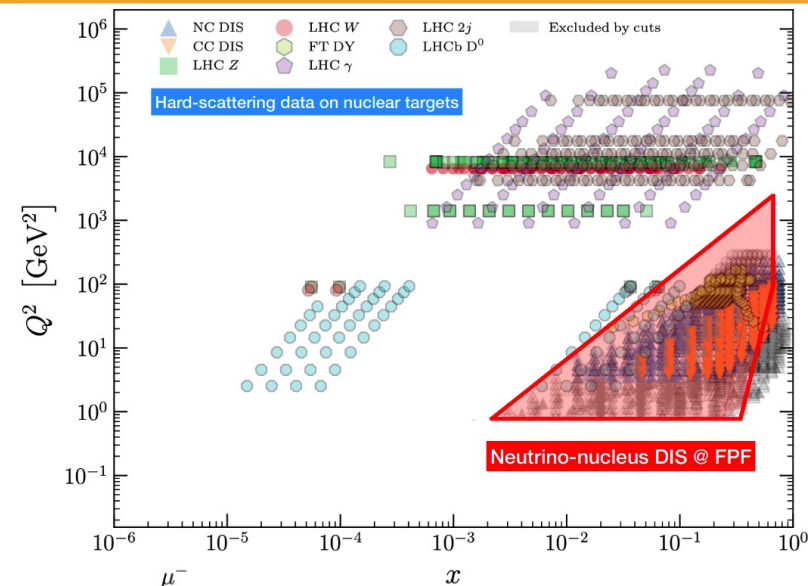
- Nuclear PDF measurements

- high-energy vs  $\rightarrow$  extended kinematic coverage
- possible measurements for various nuclear targets (Ar, W)

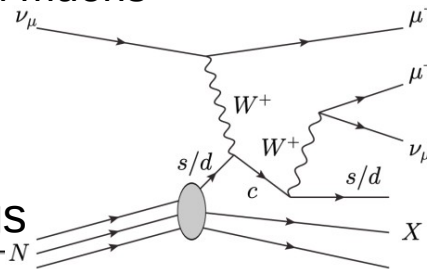
- Strange PDFs (separate s and anti-s)

Di-muon final state in CC DIS from intermediate charm,  $\nu_\mu s \rightarrow c \mu$ , and  $c \rightarrow D \rightarrow \mu X$

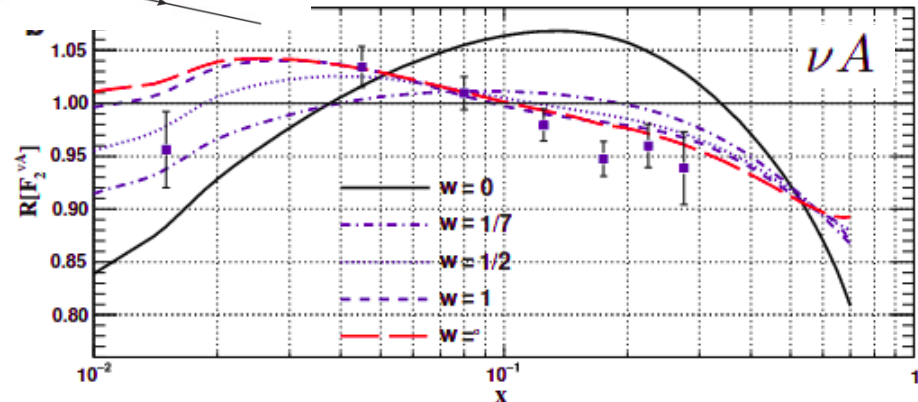
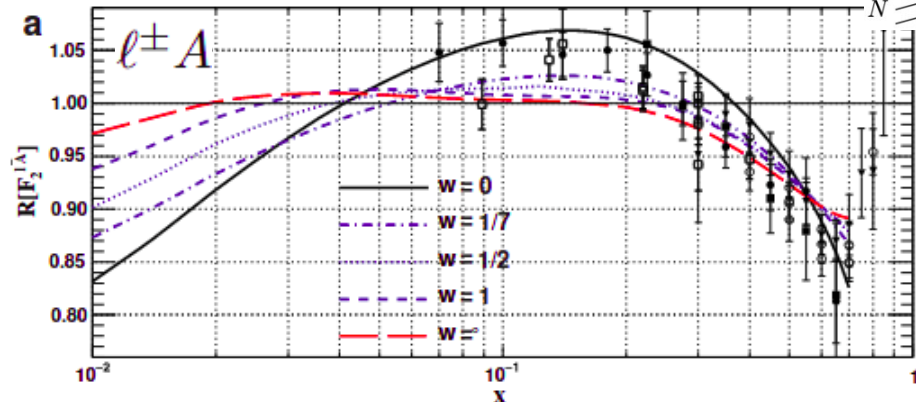
FPF: various experiments to tag charm and muons



- nuclear effects in neutrino scatterings



hep-ph/1012.0286



# STATUS – FAR-FORWARD NEUTRINOS AT THE LHC

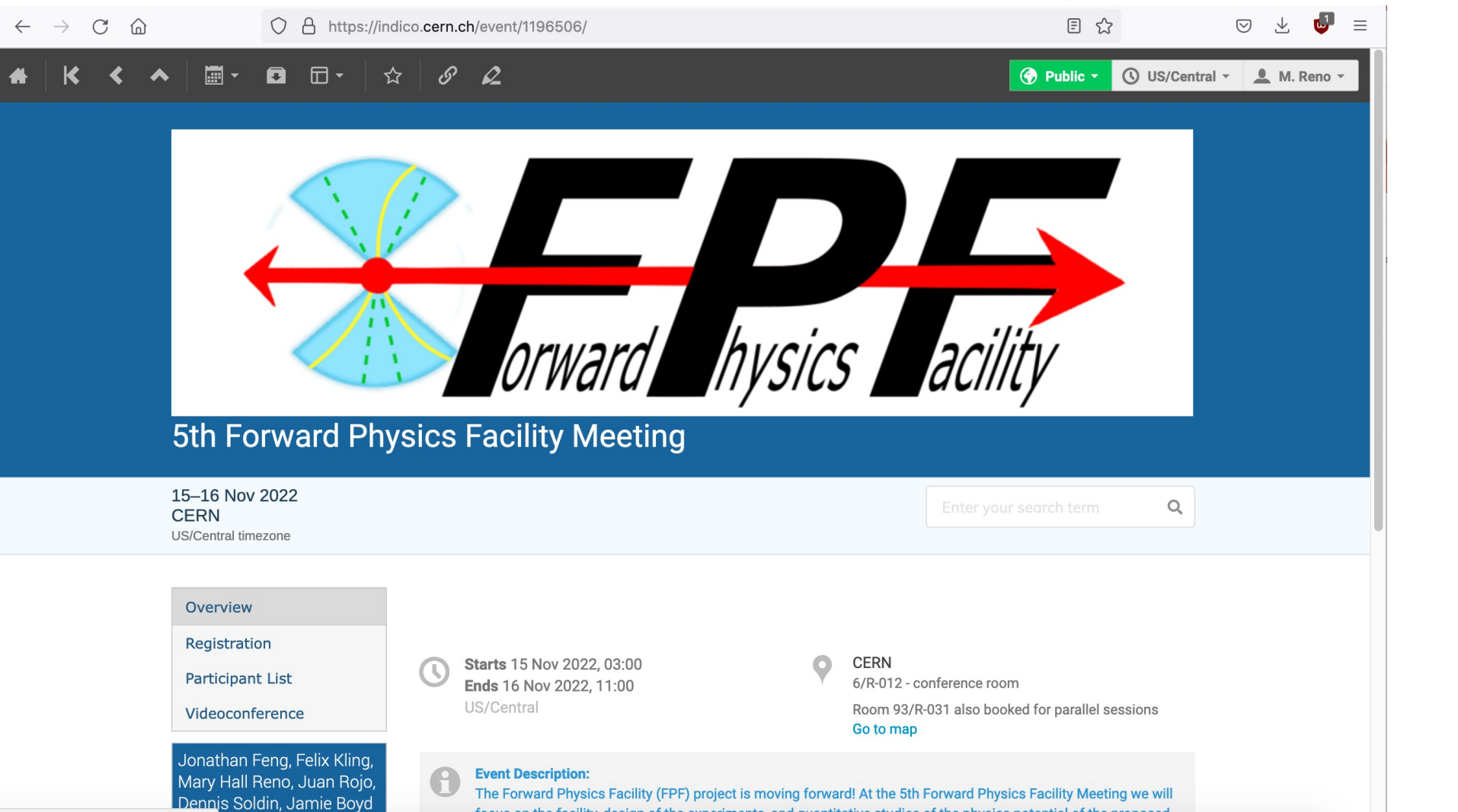
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- **FASER/FASER $\nu$  and SND@LHC experiments are currently taking data**
- Forward Physics Facility (FPF)
  - two community whitepapers (engineering, experiments, physics)
  - extensive simulations (CERN FLUKA team); BG and radiation safetyRecently:
  - strong endorsements from the US Snowmass process
  - Physics Beyond Colliders (PBC) at CERN allocated 75K CHF for site investigation
- FPF physics working groups
  - WG1 – Neutrino Interactions (Leader: Juan Rojo)
  - WG2 – Forward Charm Production (Hallsie Reno)
  - WG3 – Light Hadron Production (Luis Anchordoqui, Dennis Soldin)
  - WG4 – BSM physics (Brian Batell, Sebastian Trojanowski)
- Similar working groups for engineering efforts (Jamie Boyd)  
and for each of the proposed experiments

# 5<sup>TH</sup> FORWARD PHYSICS FACILITY WORKSHOP

Primary focus this time: facility, experiments, next steps

<https://indico.cern.ch/event/1196506/>



The screenshot shows a web browser displaying the Indico event page for the 5th Forward Physics Facility Meeting. The browser's address bar shows the URL <https://indico.cern.ch/event/1196506/>. The page features a large banner with the FPF logo, which includes a stylized particle detector cross-section and the text "Forward Physics Facility". Below the banner, the event title "5th Forward Physics Facility Meeting" is displayed. The event dates are "15–16 Nov 2022" at "CERN" in the "US/Central timezone". A search bar is present on the right. On the left, a sidebar lists navigation options: "Overview", "Registration", "Participant List", and "Videoconference". The "Overview" section is active, showing the event starts on "15 Nov 2022, 03:00" and ends on "16 Nov 2022, 11:00" at "CERN 6/R-012 - conference room". It also mentions that "Room 93/R-031 also booked for parallel sessions" and provides a "Go to map" link. The "Event Description" section begins with the text: "The Forward Physics Facility (FPF) project is moving forward! At the 5th Forward Physics Facility Meeting we will focus on the facility design of the experiments, and quantitative studies of the physics potential of the proposed".

5<sup>th</sup> Forward Physics Facility Meeting

15–16 Nov 2022  
CERN  
US/Central timezone

Enter your search term

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US/Central

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6/R-012 - conference room  
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[Go to map](#)

**Event Description:**  
The Forward Physics Facility (FPF) project is moving forward! At the 5th Forward Physics Facility Meeting we will focus on the facility design of the experiments, and quantitative studies of the physics potential of the proposed



# CONCLUSIONS

- Far-forward neutrino & BSM physics – new experimental program at the LHC
- Currently FASER/FASERv and SND@LHC experiments (LHC Run 3)

- **Future HL-LHC – Forward Physics Facility (FPF)**

Rich physics program from QCD & neutrinos to BSM

- **Neutrino physics at FPF:**

- precise neutrino measurements  
for  $\sim$ TeV energies

- high  $\nu_\tau$  statistics

- QCD studies

neutrino production through charm

& lighter mesons

neutrino interactions (PDFs, nuclear effects)

possible: neutrino tridents, ...

- BSM opportunities (oscillations into sterile neutrinos, non-standard interactions...)

