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on New Frontiers in Physics
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From ENUBET to nuSCOPE

a monitored and tagged neutrino beam for high precision cross section measurements

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on behalf of the nuSCOPE Collaboration

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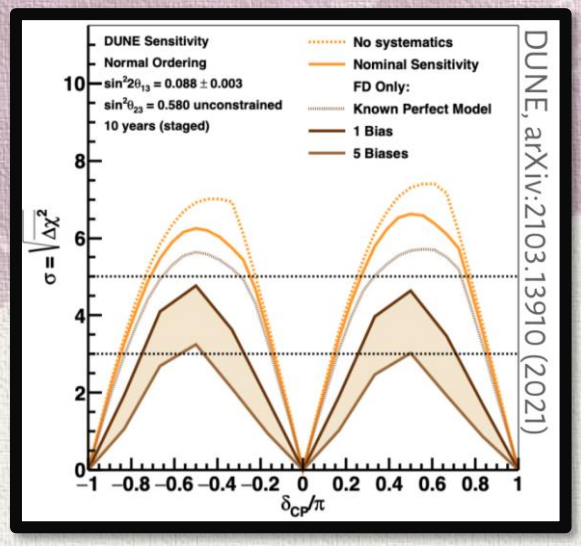
Motivation

Accelerator based neutrino experiments have moved from statistics- to the systematics-dominated era

$$\frac{d^2N}{dEdt}(E_\nu) = P(\nu_\mu \rightarrow \nu_e)\phi(E_\nu)\sigma(E_\nu)\epsilon(E_\nu)$$

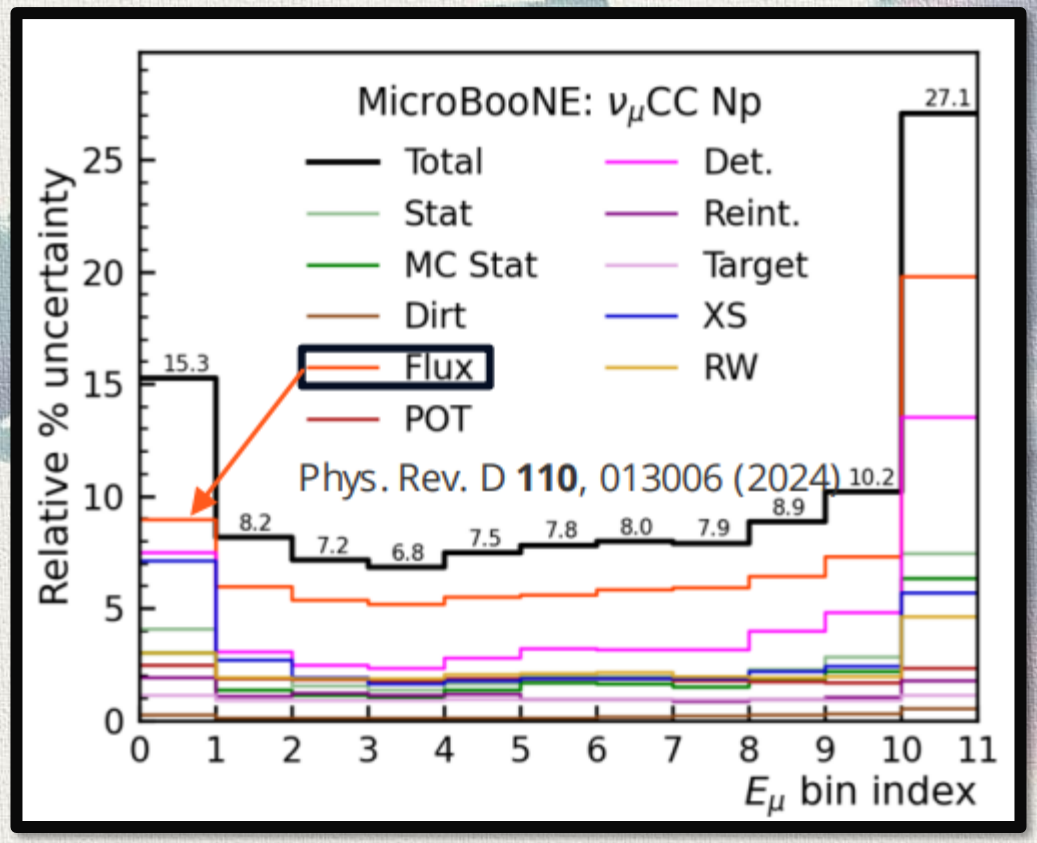
Knowledge of neutrino interaction cross section and neutrino flux dominate the final systematic uncertainty of the experiment

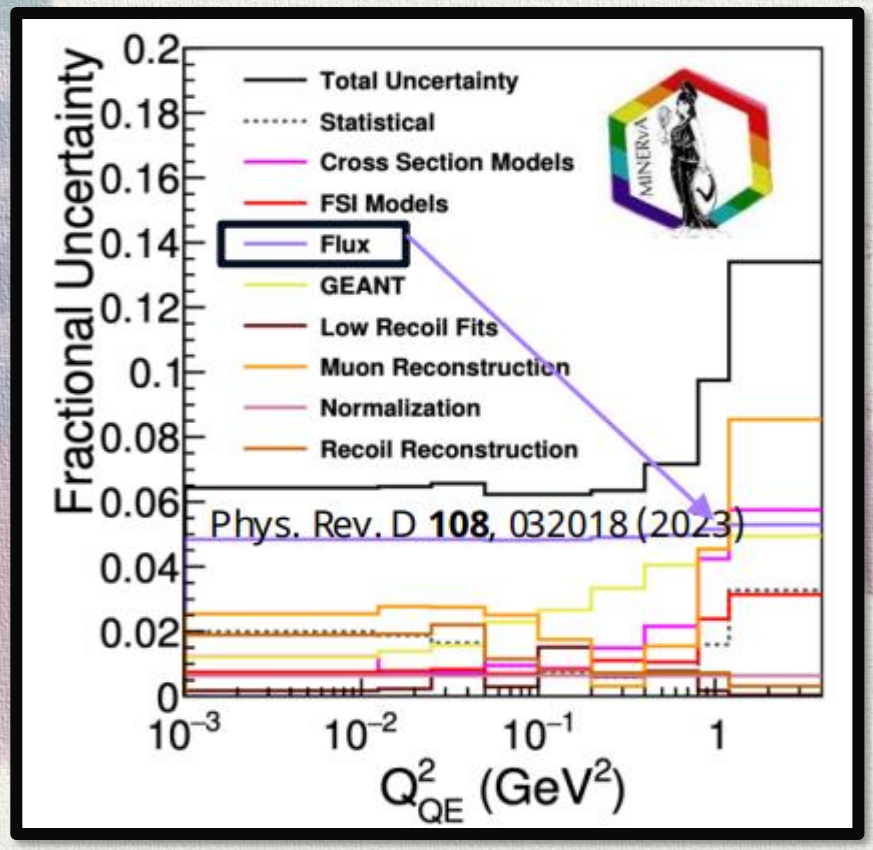
Neutrino cross section uncertainty is stuck at 10-30% level, while the community needs are close to 1% cross section uncertainty



Motivation

Knowledge of the neutrino flux dominates the final systematic uncertainty of the neutrino cross section measurements experiments





nuSCOPE = ENUBET + NuTag

Neutrino SPS Complex for Precision Experiments

Merger of 2 novel approaches to solve the neutrino flux uncertainty

Monitored beam

*Prototype designed and tested by **ENUBET***

Observing the charged leptons created in the meson decays in the decay tunnel

Charge lepton information gives us direct information on neutrino flux

Tagged beam

*Prototype designed and tested by **NuTag***

Tracking secondary mesons and daughter muons

Event-by-event time coincidence between neutrino, muon and parent meson

ENUBET – monitored neutrino beam

*Fully **static beamline** with a long extraction time*

***Instrumented decay tunnel** to observe charged leptons passing through the decay tunnel walls*

***Segmented calorimeter** with plastic scintillator as the active medium*

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*Goal is to **count and identify charged particles** passing through the calorimeter*

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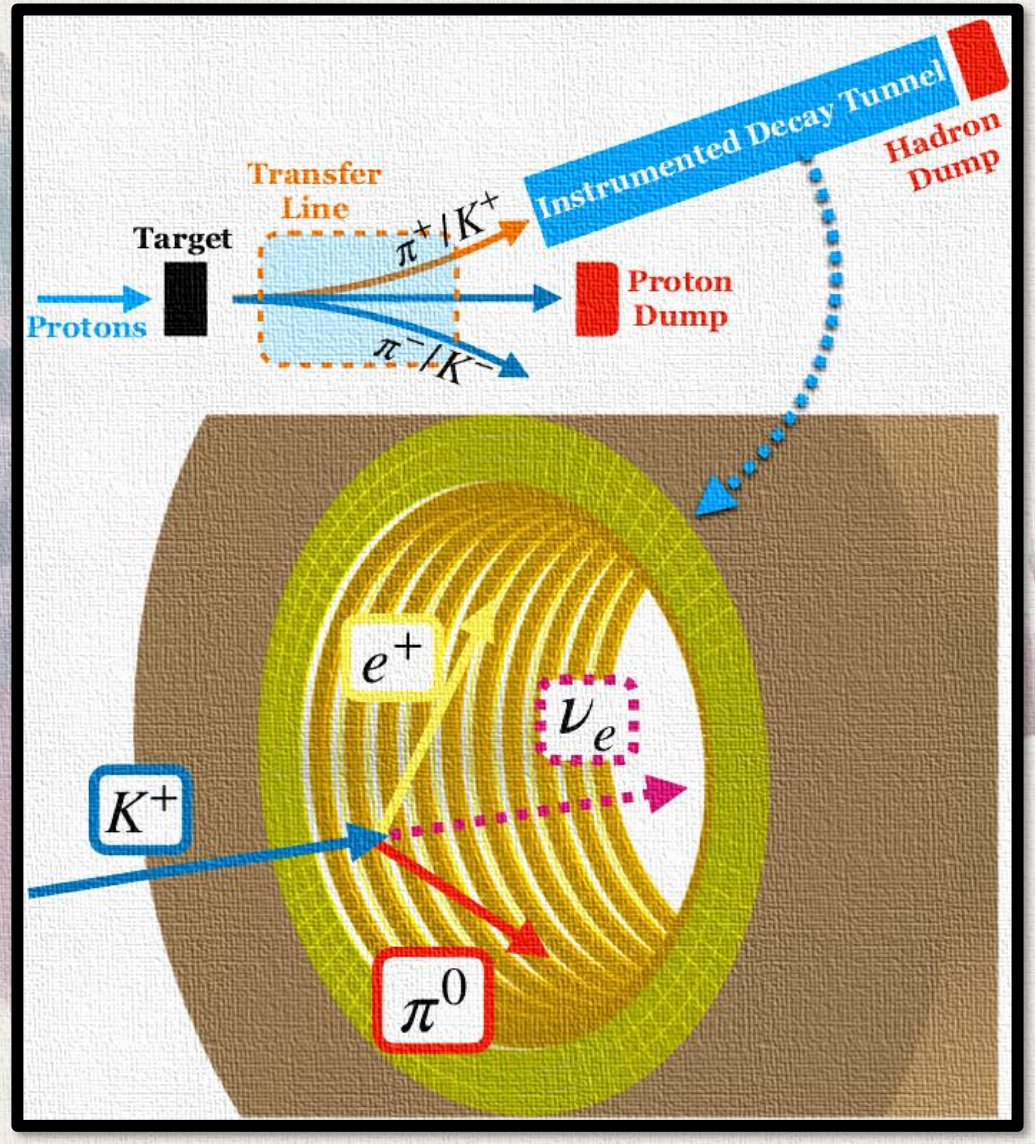
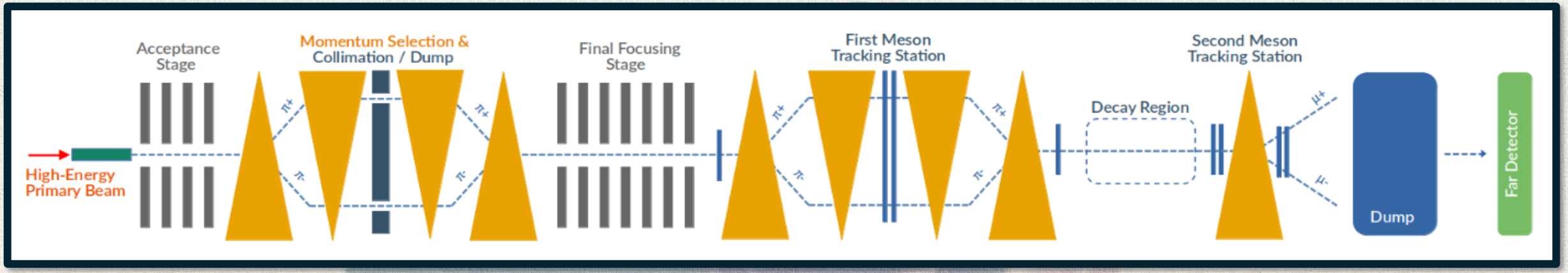
*Gives information on **flux intensity** and **flavour composition***



NuTag – tagged neutrino beam



*Fully **static beamline** with a long extraction time*

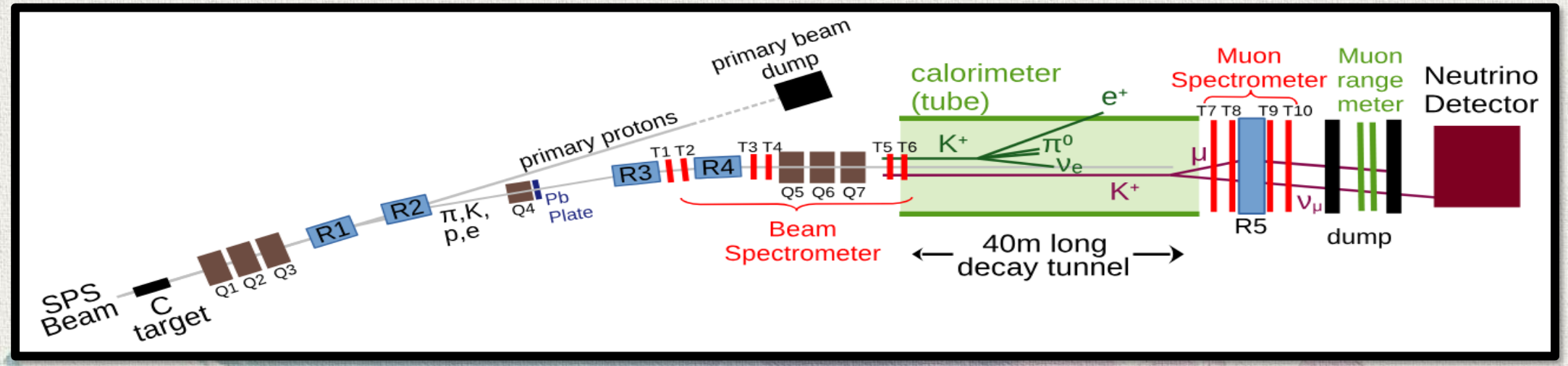
*Instrumenting the beamline to track the **position, momentum and timing** of π, K and μ*

Using NA62 state-of-the-art GigaTrackers to tag all the secondary mesons

*Each ν_μ **interaction** observed is **uniquely associated** to its **muon and parent meson***

*This association allows for a reconstruction of **neutrino energy to <1% resolution***

nuSCOPE – tagged & monitored neutrino beam



*Combines the ideas of **ENUBET** and **NuTag***

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*Instrumenting the beamline and the decay tunnel for **almost complete monitoring of ν flux***

Monitoring of both ν_e and ν_μ flux and tagging of the ν_μ flux

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*Unprecedented precision of **<1% uncertainty on the flux and <1% energy resolution***

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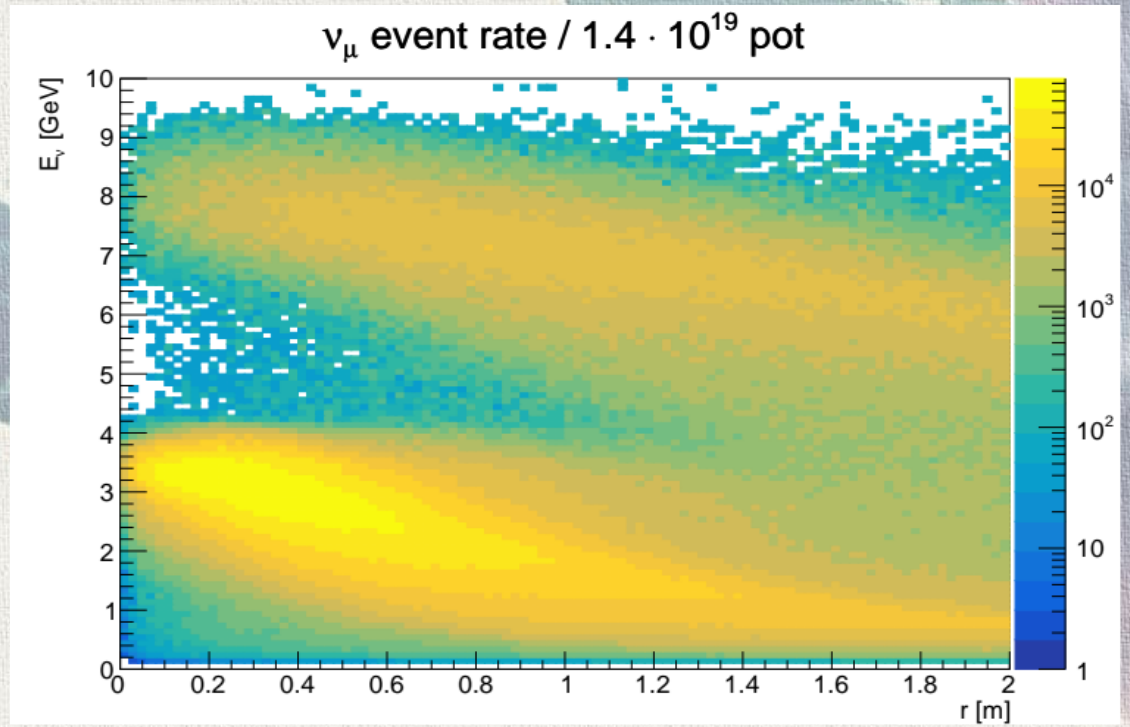
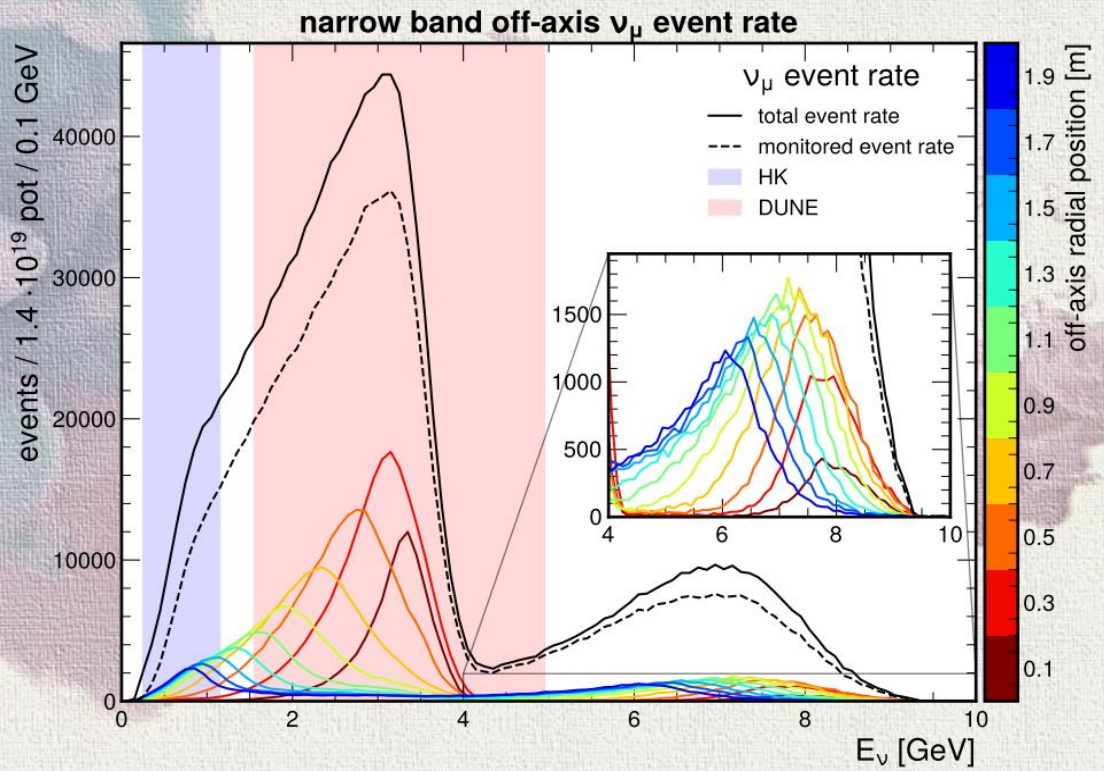
*Proposal is to **implement such a facility at CERN** taking advantage of the SPS accelerator*

nuSCOPE – additional techniques to be exploited

Narrow-band off-axis

Measuring neutrino energy solely on the interaction vertex position





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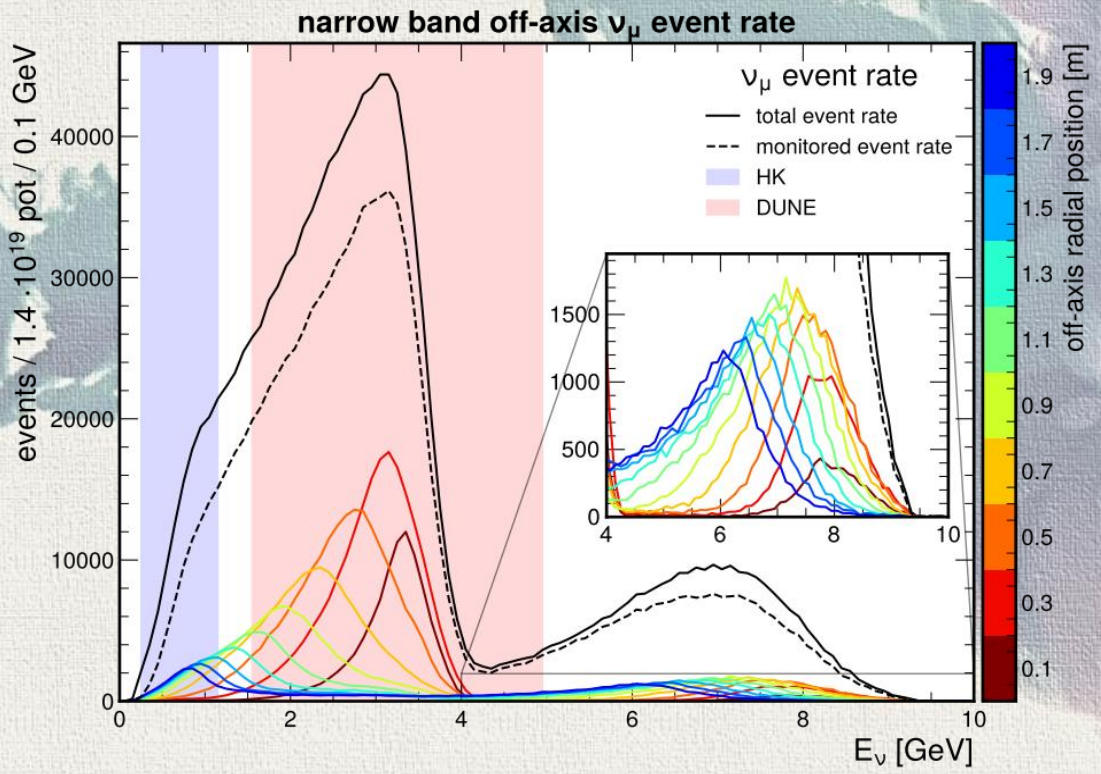
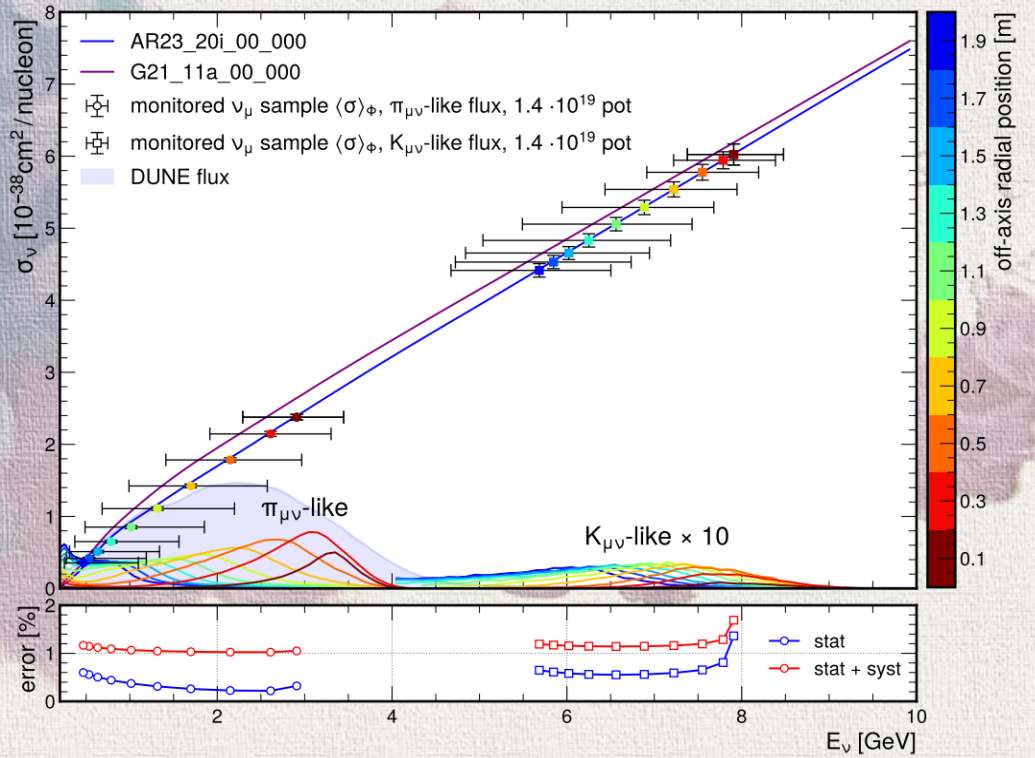




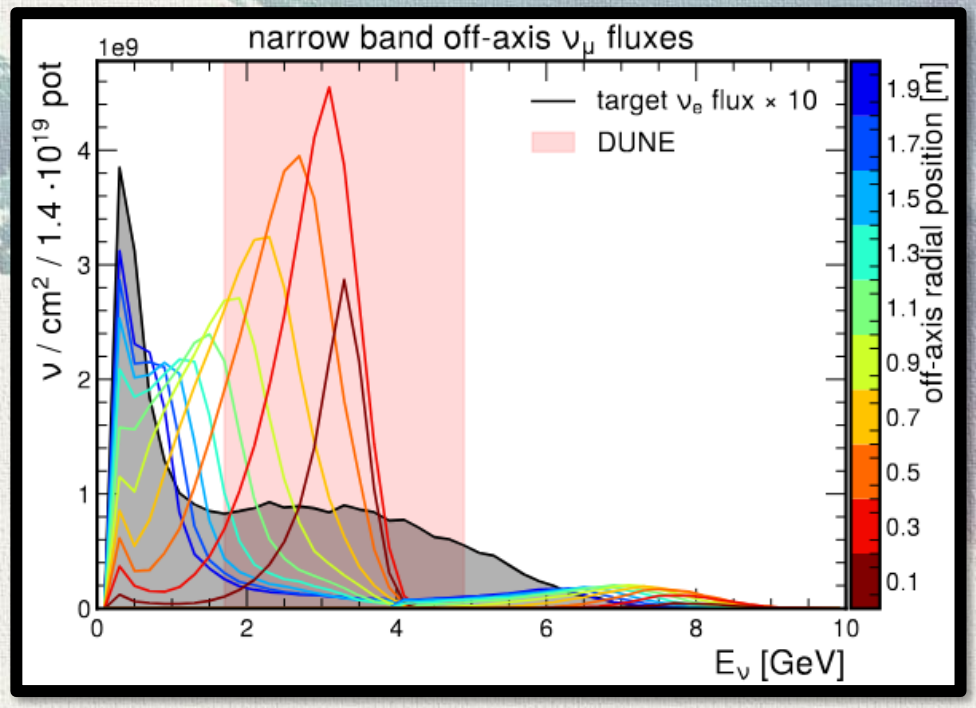
nuSCOPE – additional techniques to be exploited

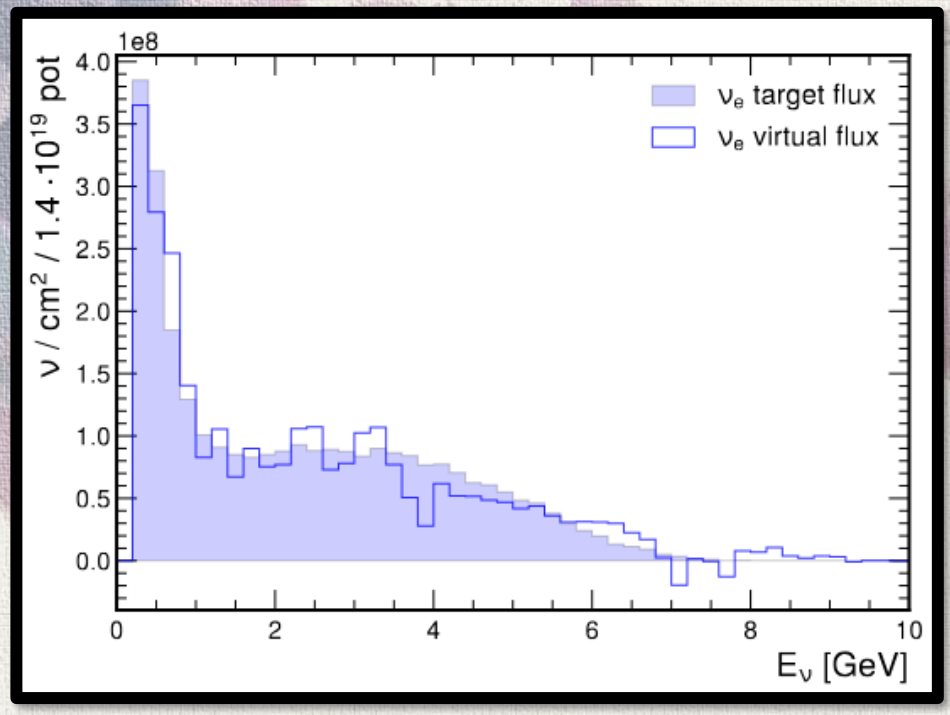
PRISM

Calculating the ν_e / ν_μ cross section ratio by exploiting the NBOA with the ν_μ flux

$$\phi(E_\nu) = \sum_j c_j \phi_j(E_\nu)$$

Using linear combinations of the off-axis ν_μ fluxes to mimic the shape of the on-axis ν_e flux





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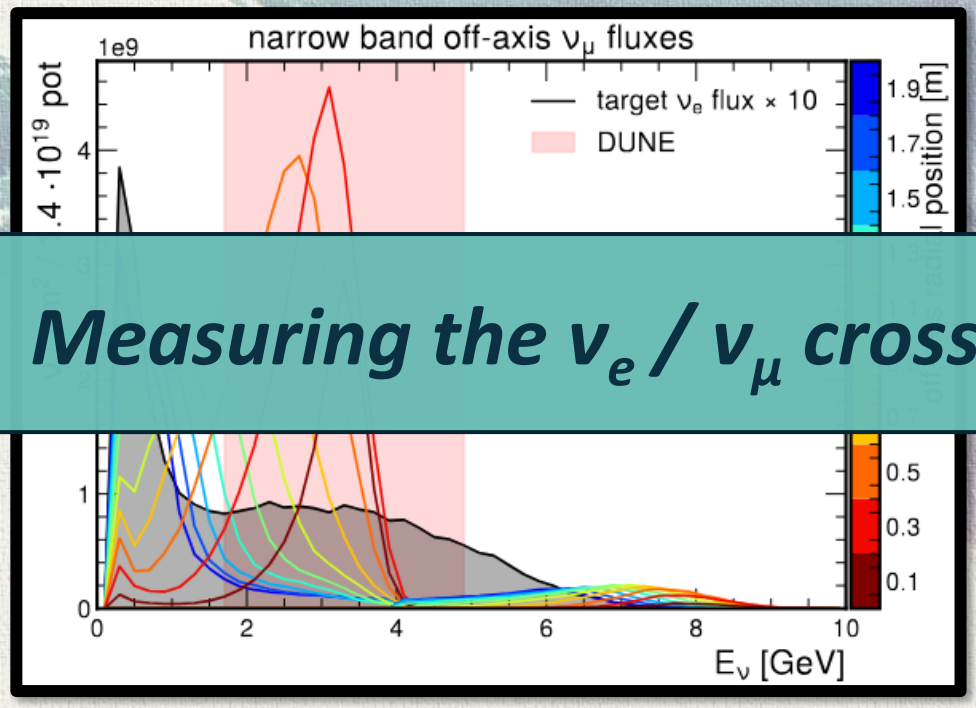
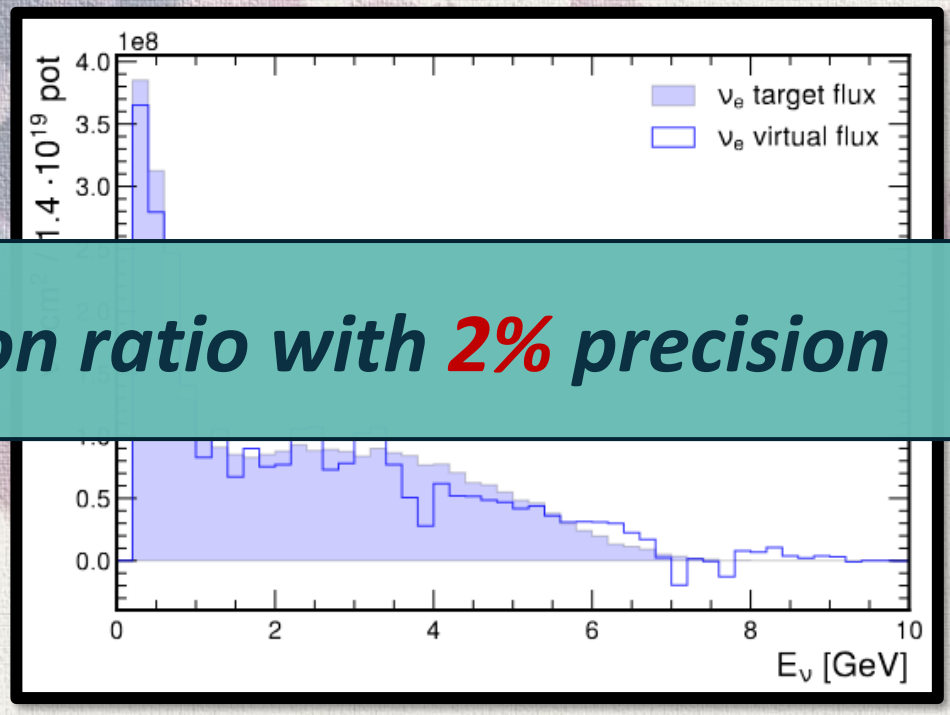


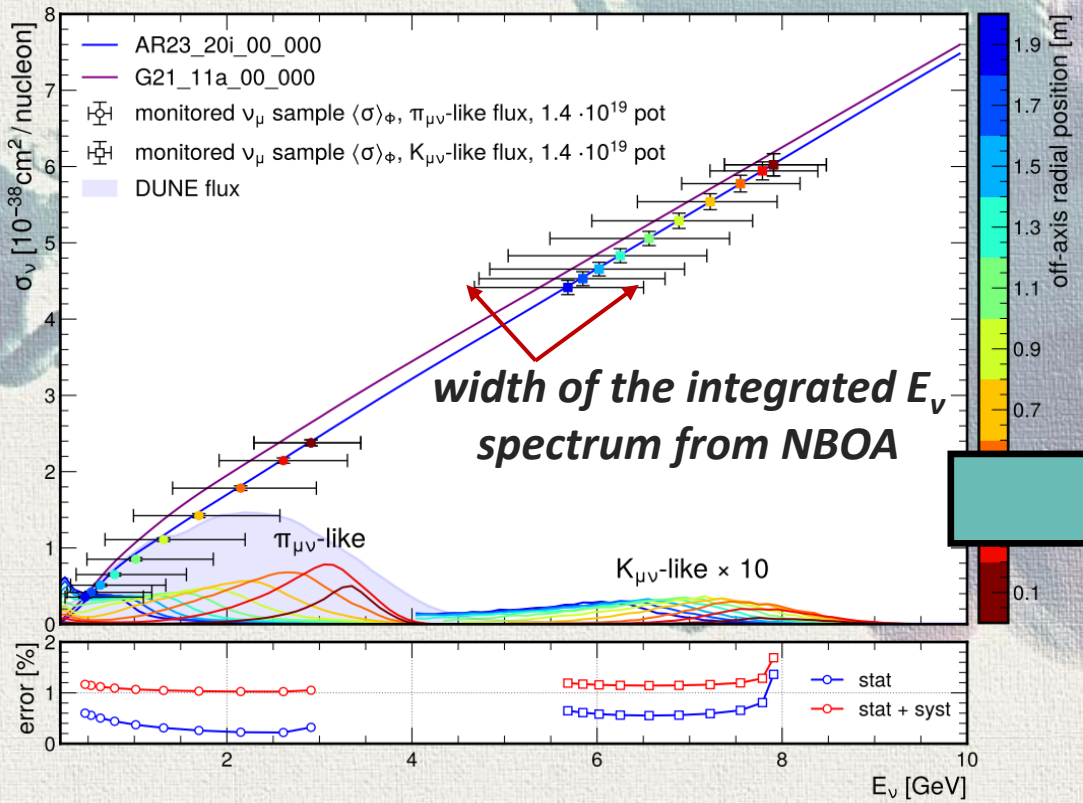


Measuring the ν_e / ν_μ cross section ratio with 2% precision

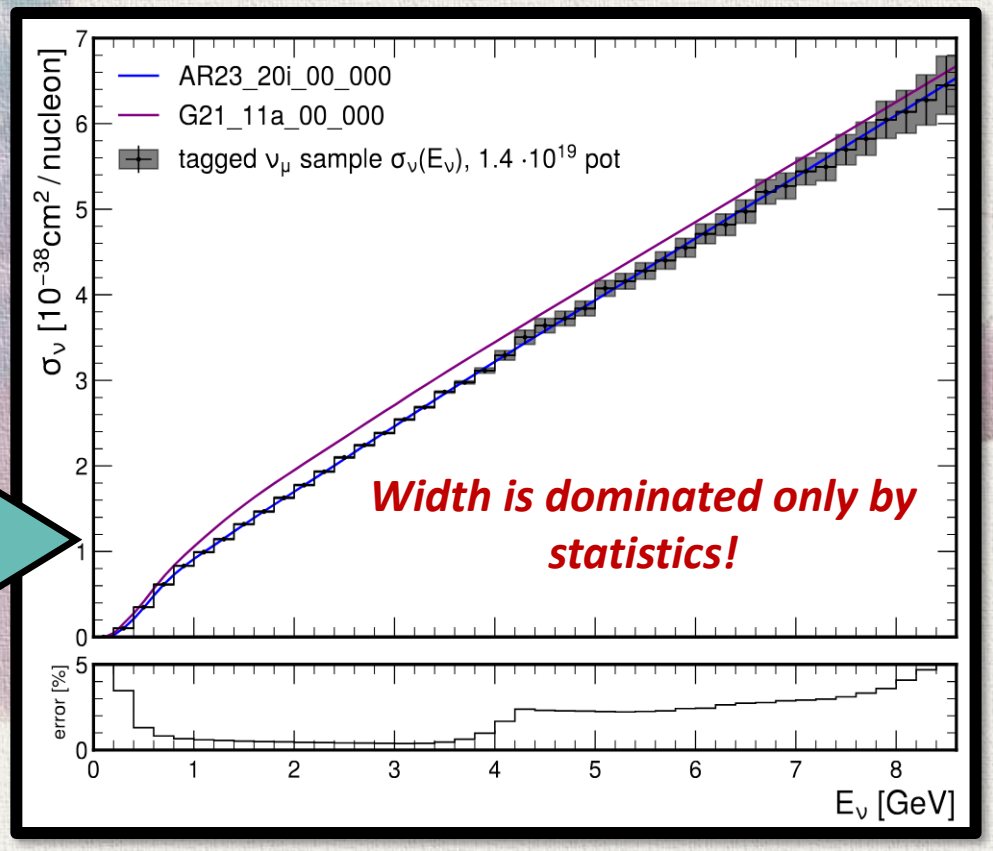
nuSCOPE – expected performance

ν_μ cross section as a function of true E_ν

Using the <1% energy resolution to disentangle different neutrino cross section models



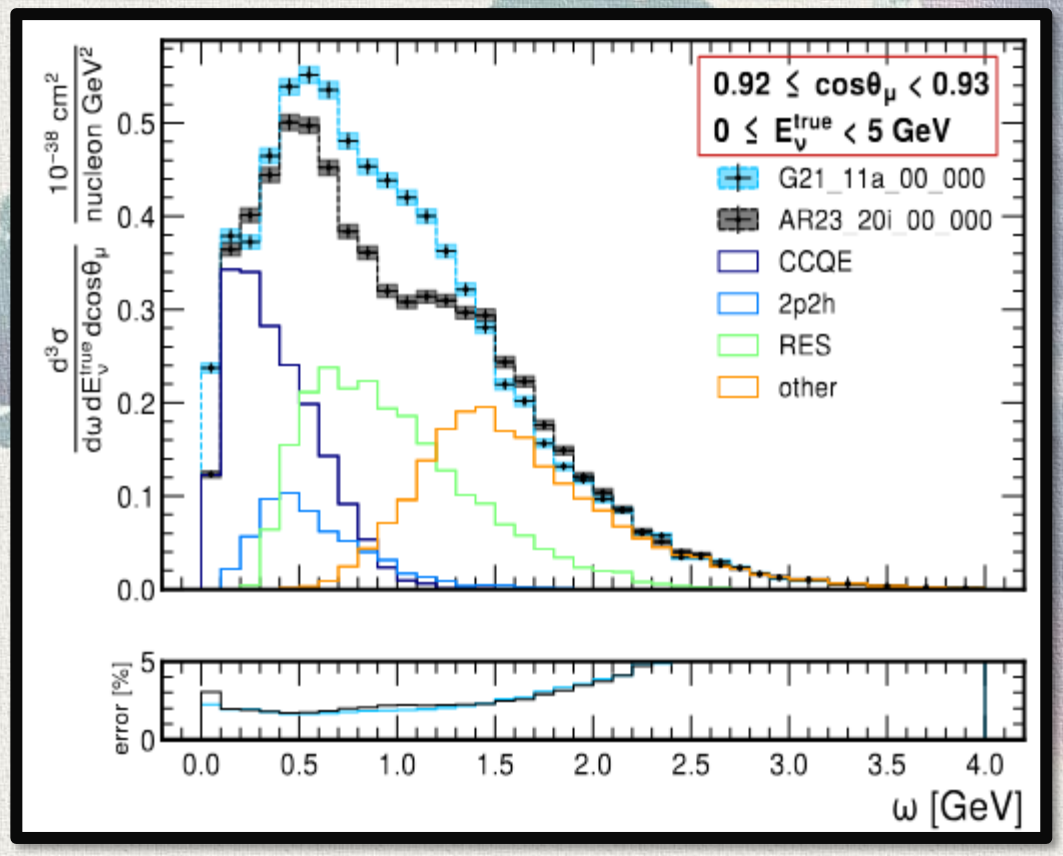
Tagging

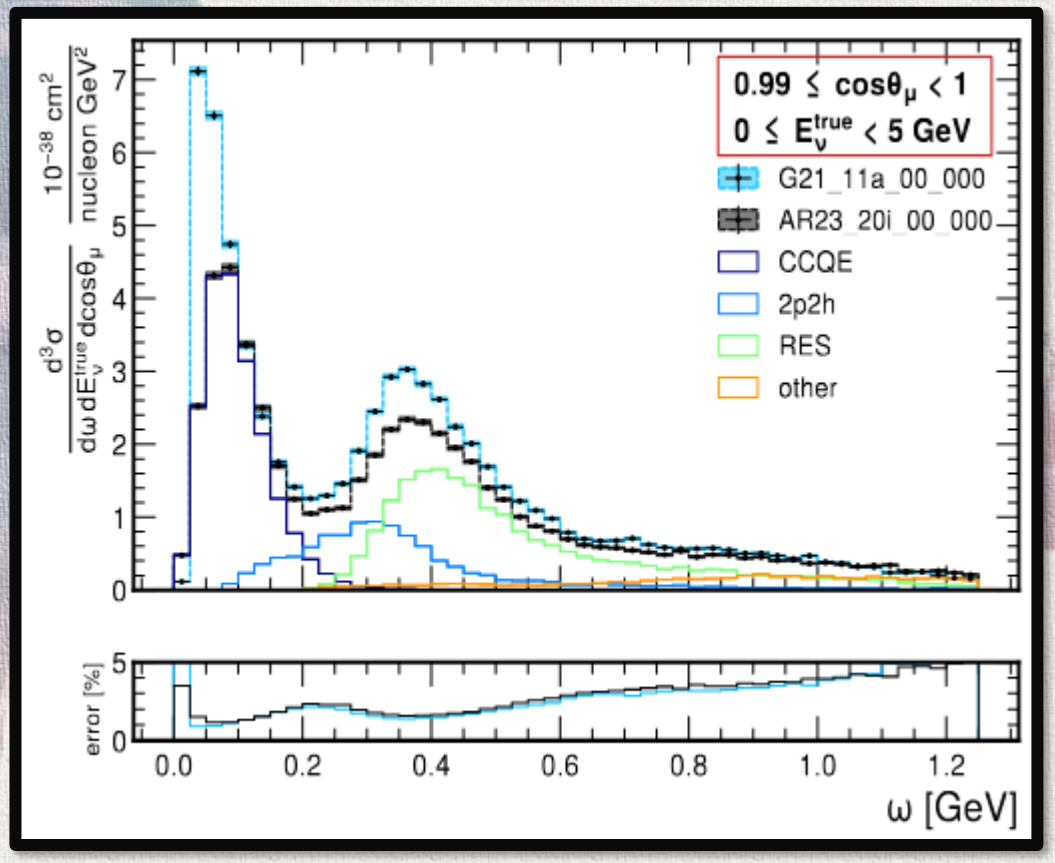


nuSCOPE – expected performance

Electron scattering-like measurements with neutrinos

Gives access to fundamental processes in nuclear physics

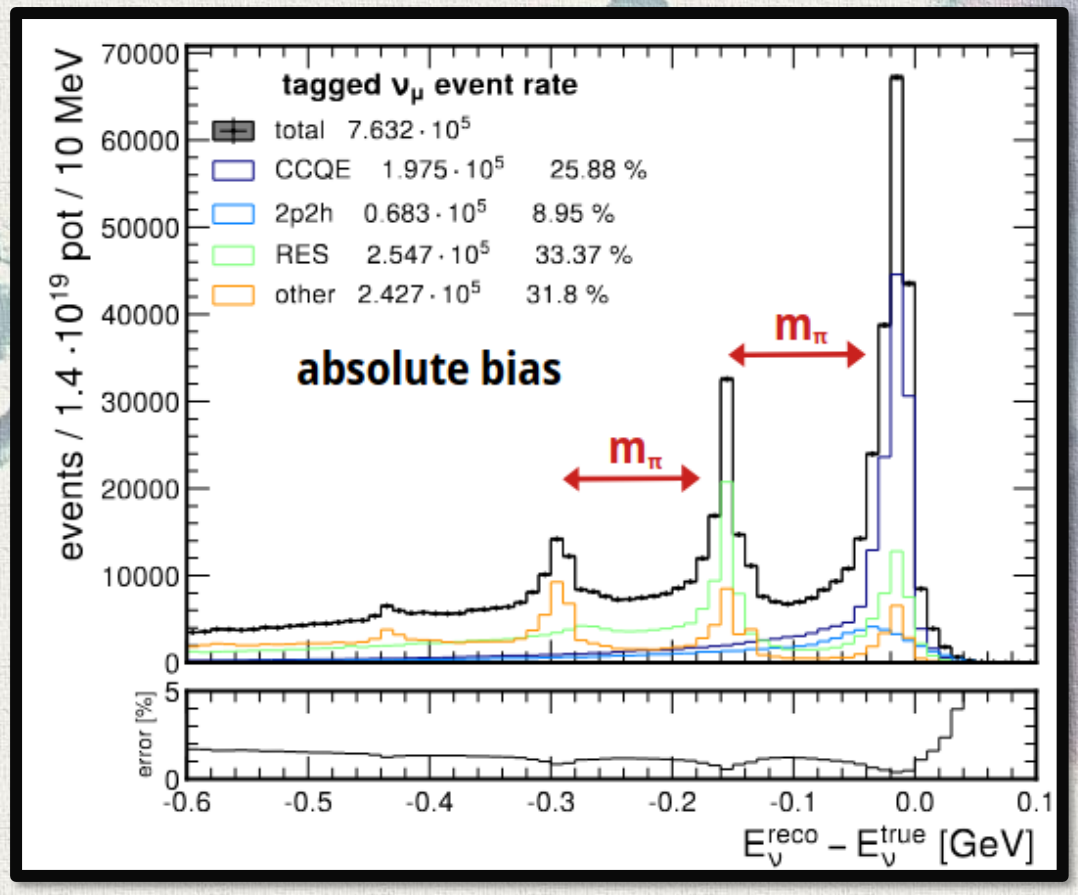


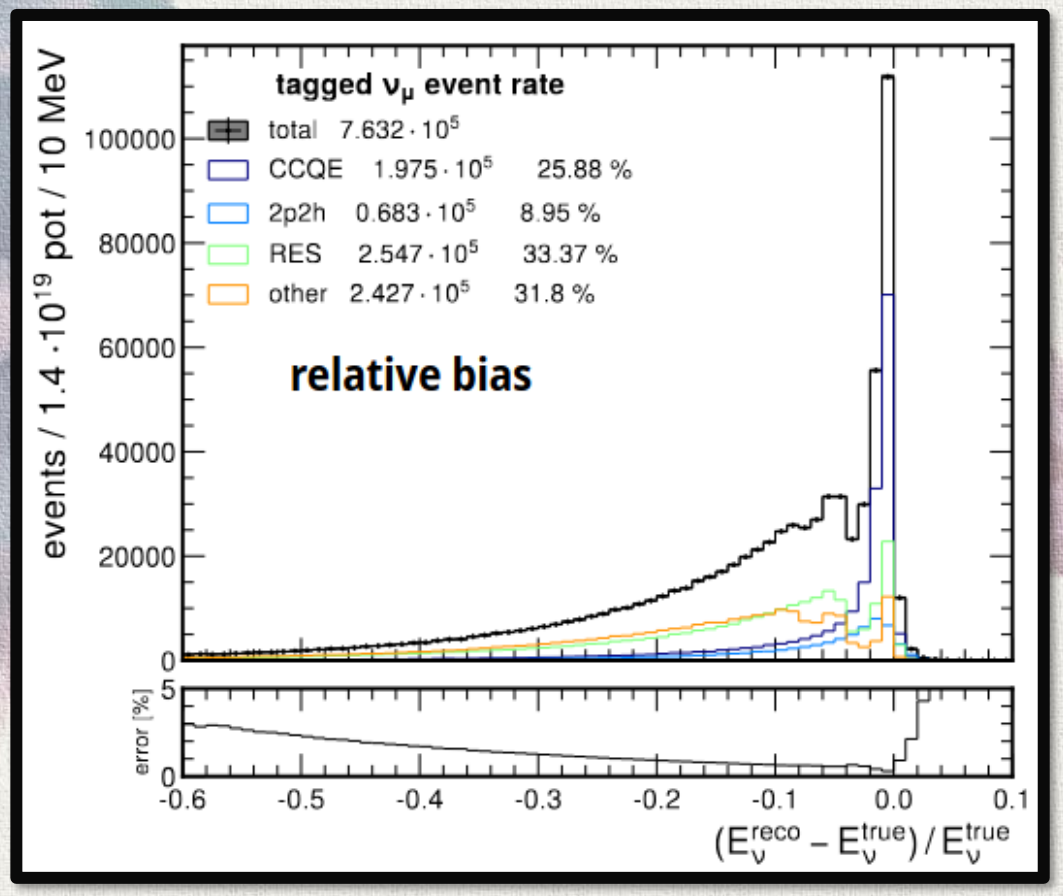


nuSCOPE – expected performance

Calibration of detector energy response

Can measure the difference between true and reconstructed neutrino energy





Takeaway points

Neutrino oscillation experiments entering systematics dominated era

Main contributor to the systematics is the neutrino cross sections

Neutrino cross section measurement experiments struggle with initial flux knowledge

Having to rely mostly on simulations, flux uncertainty is stuck at 5-10%

nuSCOPE uses monitored and tagged neutrino beam

Possibility of <1% flux intensity and composition uncertainty and <1% energy resolution

Such a facility enables an extensive measurement program

Enables us to disentangle different cross section models and probe into nuclear processes