Calibration of atmospheric neutrino flux calculations using cosmic muon flux and charge ratio measurements

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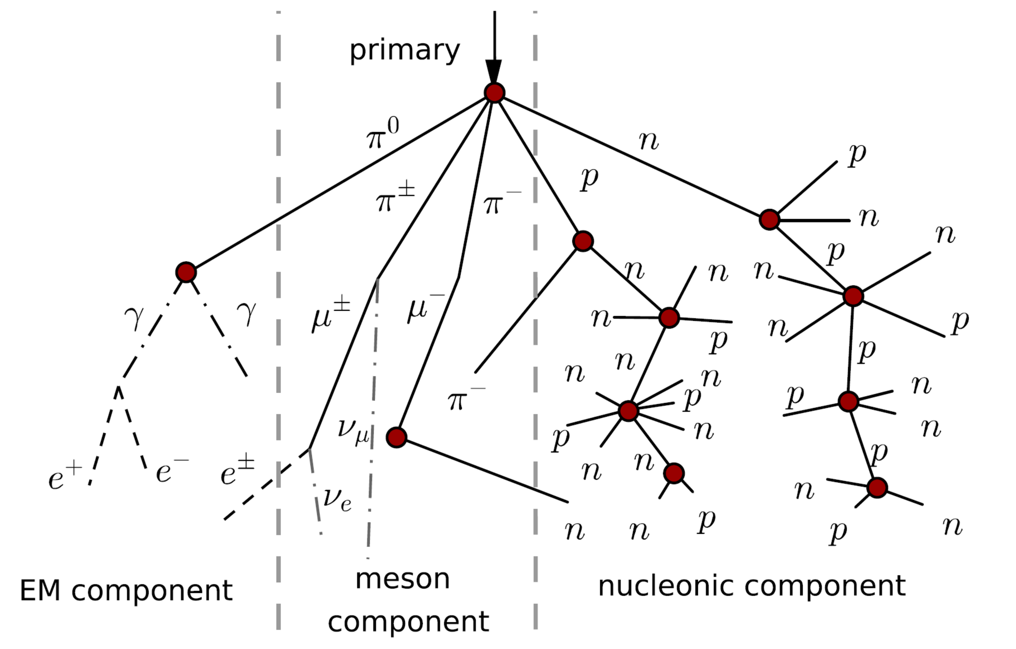
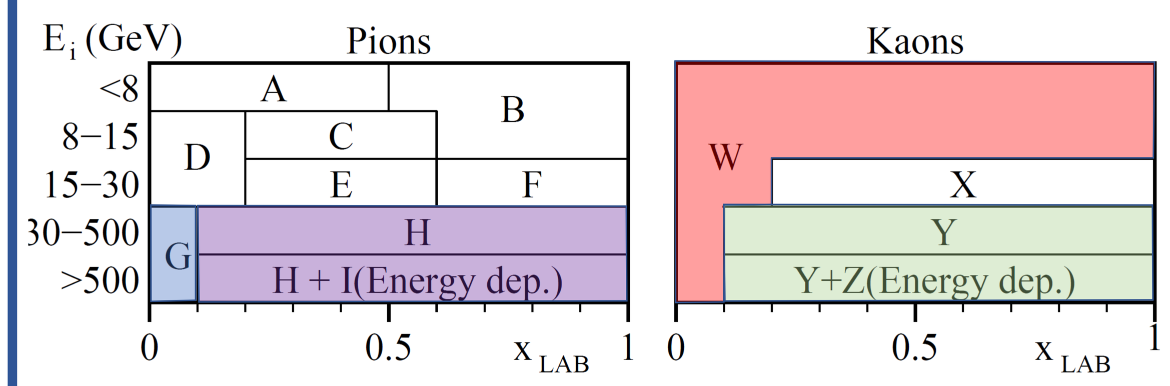
MOTIVATION

- Atmospheric neutrinos are an invaluable tool
- General flux features are well characterized – not its details or uncertainties
- Modeling of inclusive spectra of secondary hadrons the dominant theoretical uncertainty
- Atmospheric muons and neutrinos share same origin
- Inclusive muon measurements can be used to calibrate neutrino flux predictions



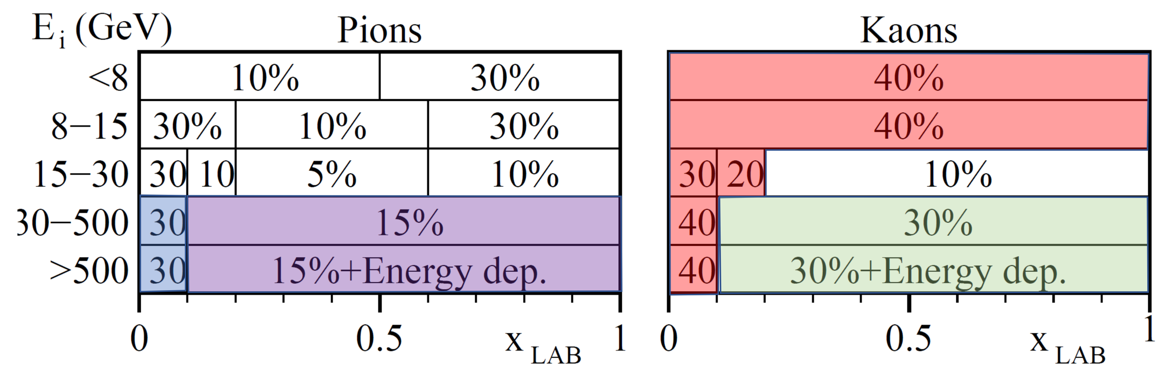
CALIBRATION METHOD

- Spectra of secondary hadrons are uncertain
- The scheme from [1] splits particle production parameter space in
  - Nucleon projectile energy
  - $x_{lab} = E_{secondary} / E_{incident}$

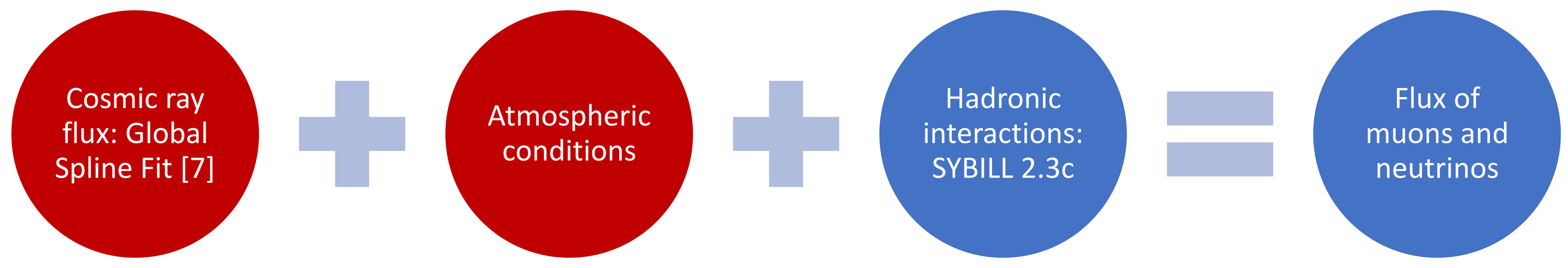


Division of the phase space for pion and kaon production in physically and experimentally motivated regions

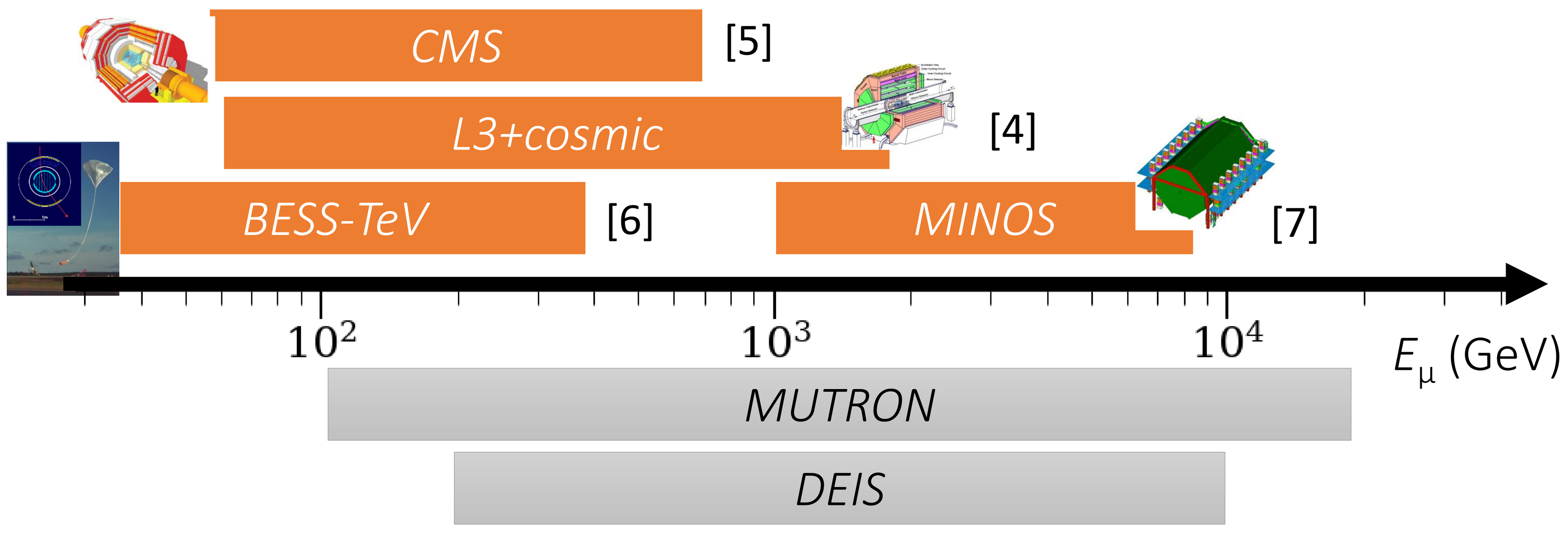
Estimated errors from uncertainties of data



- Together with the scheme (left), MCEq [2] is used to compute fluxes

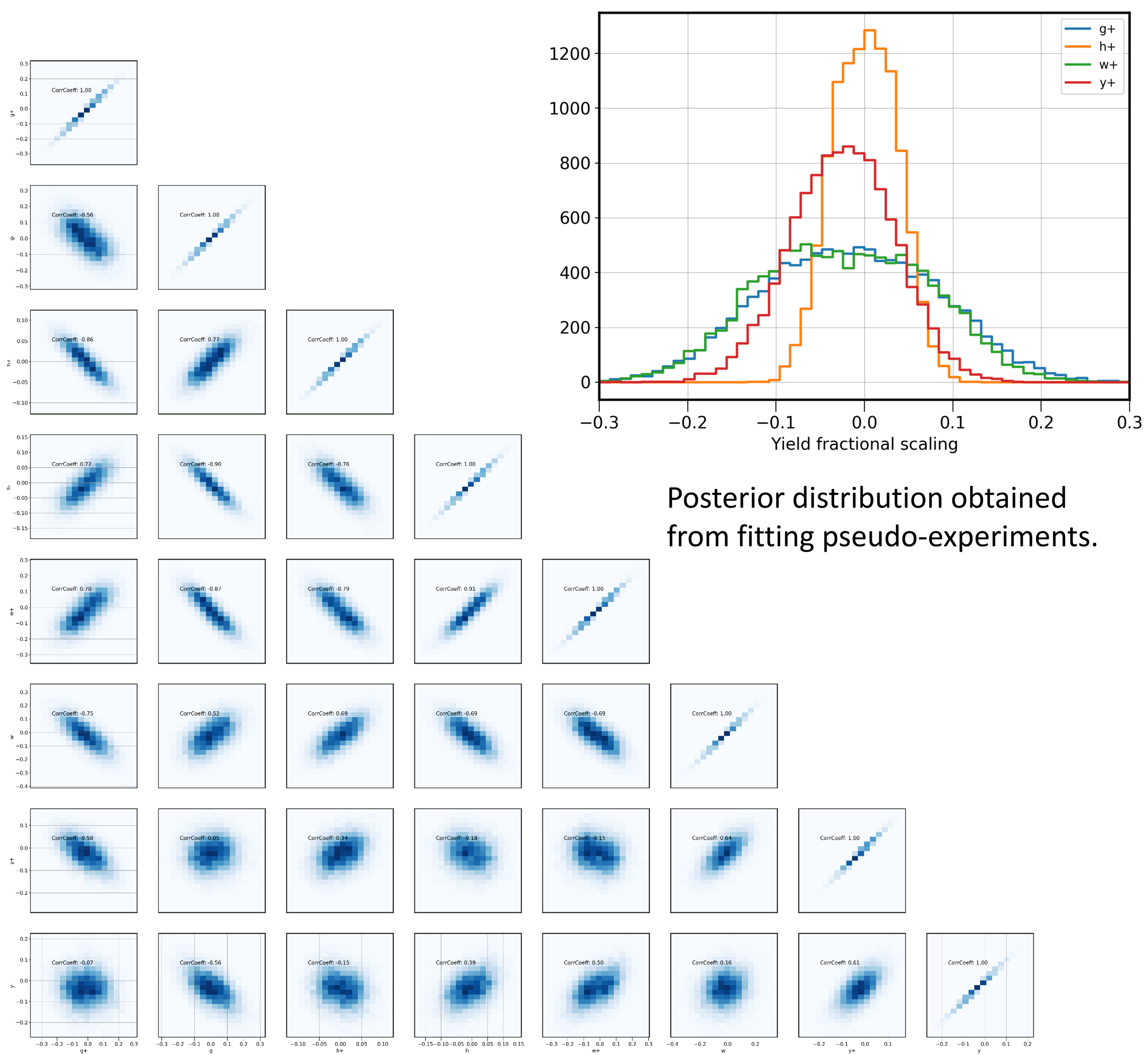


- Fit G, H, Y, W parameters to the atmospheric muon flux and charge ratio at high energies



DATA ANALYSIS

- Minimizing a χ2 function with prior penalty terms
- Experimental systematic uncertainties as nuisance parameters
- Restricted to experiments with full uncertainty description
  - MINOS, CMS, L3+cosmic, BESS-TeV
- Atmospheric conditions fixed
- Sensitivity tested leaving pion/kaon yield scaling unconstrained
- Data considered can only constrain pion yields for E > 30 GeV
- Strong correlations between + & - scaling factors

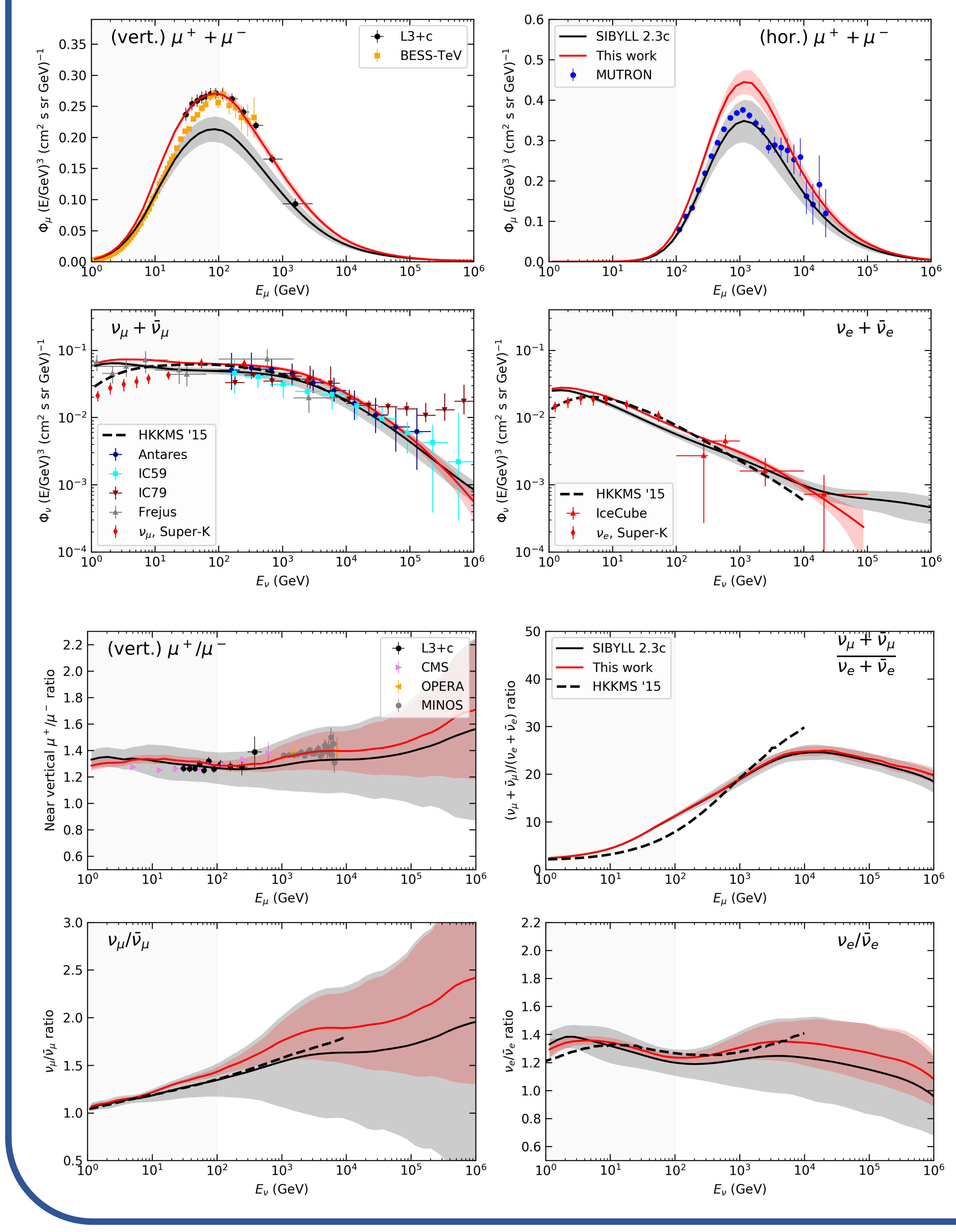


Posterior distribution obtained from fitting pseudo-experiments.

Correlations between the flux parameters that can be constrained using the muon data. Density maps populated using pseudo-experiments at the experimentally observed data.

PRELIMINARY RESULTS AND NEXT STEPS

- Fit performed above 100 GeV to Bess-TeV, L3+c, CMS and MINOS in all angular bins
- The "Barr-scheme" in MCEq [8] is used to propagate the covariance matrix
- No fit to MUTRON or other horizontal muon observations, yet
- No fit neutrino data



Name	value, error
π+: G	0.13±0.10
π+: H	0.30±0.03
K+: W	0.14±0.08
K+: Y	0.47±0.07
π-: G	0.44±0.08
π-: H	0.16±0.04
K-: W	0.20±0.10
K-: Y	0.11±0.07

Improvements planned

- Include horizontal muons
- Include constraints from fixed-target experiments
- Test sensitivity to pion-air interactions or secondary baryons
- Use priors for insensitive parameters
- Account for CR flux parameter covariances

[1] G. D. Barr et al., PRD 74, 094009 (2006)
[2] A. Fedynitch et al., PoS ICRC (2015) 1129
[3] F. Riehn et al., PoS ICRC2017 (2017) 301
[4] P. Achard et al. (L3), Phys. Lett. B598 (2004) 15–32
[5] P.Khachatryan et al. (CMS), Phys. Lett. B692 (2010) 83-104
[6] Haino et al. (BESS-TeV), Phys. Lett. B594 (2004) 35-46
[7] H. Dembinski et al., PoS ICRC2017 (2017) 533
[8] A. Fedynitch et al., PoS ICRC2017 (2017) 1019

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