A potpourri of particle phenomenology

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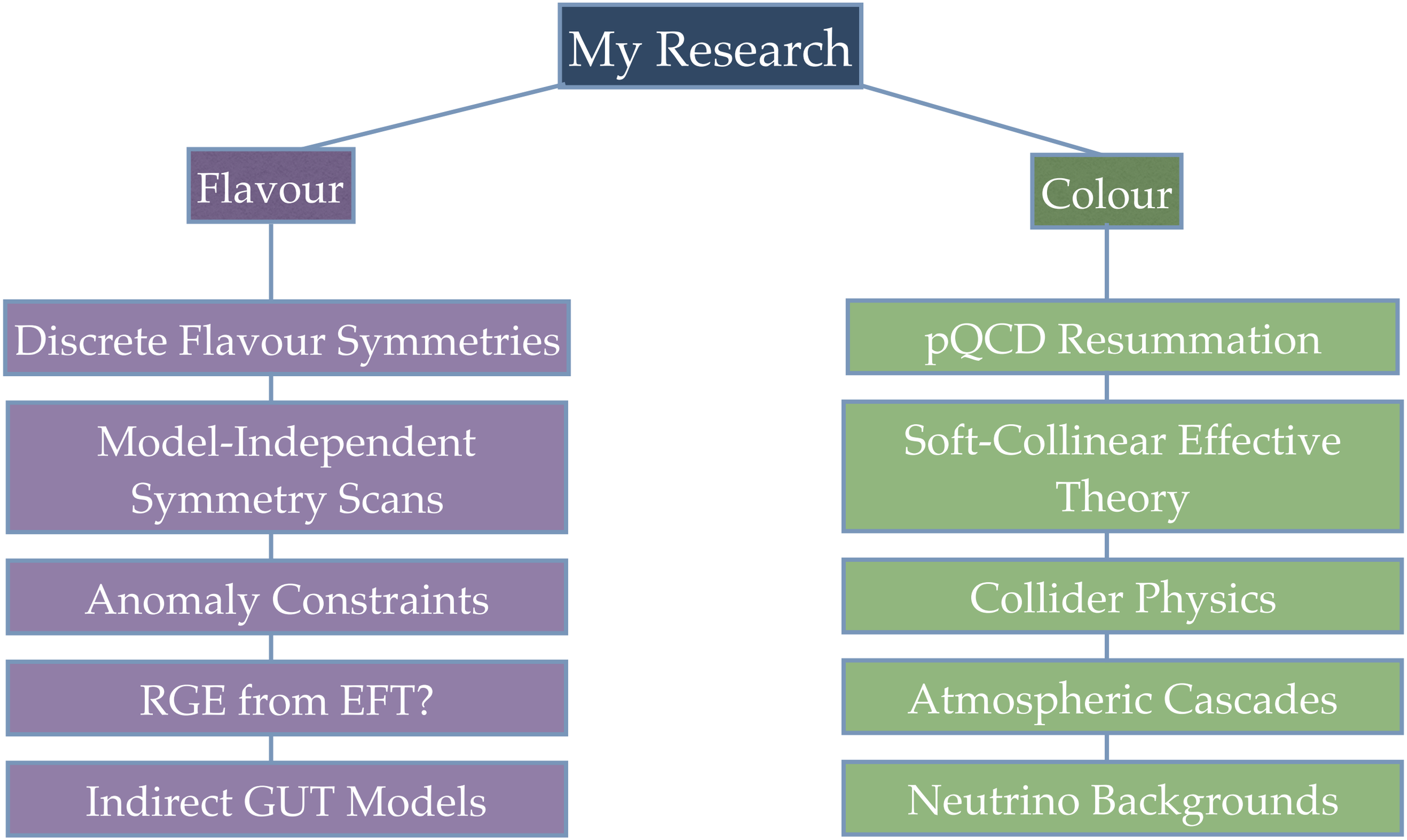
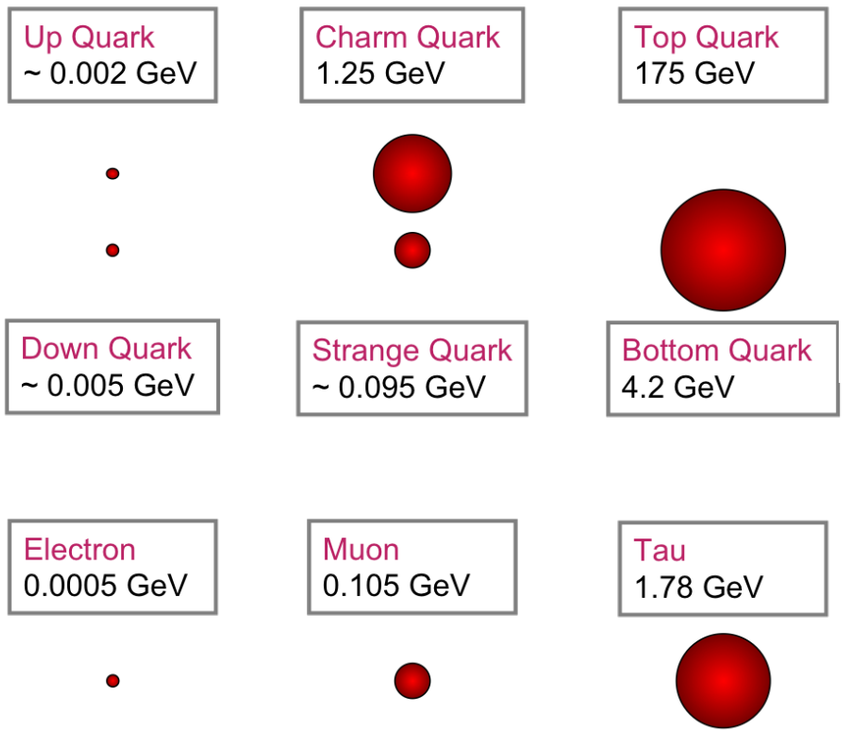
29 November 2016 | | DESY Hamburg

Running between colour and flavour

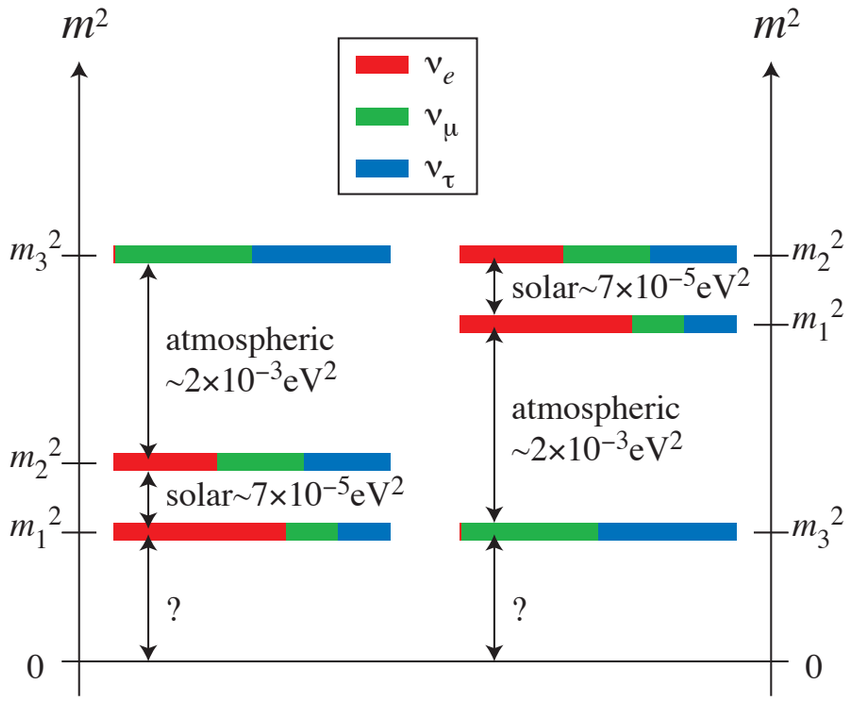


The Flavour Problem: masses and mixings



$$|U_{\rm CKM}| = \begin{pmatrix} \begin{pmatrix} 0.97441 \\ 0.97413 \end{pmatrix} & \begin{pmatrix} 0.22597 \\ 0.22475 \end{pmatrix} & \begin{pmatrix} 0.00370 \\ 0.00340 \end{pmatrix} \\ \begin{pmatrix} 0.22583 \\ 0.22461 \end{pmatrix} & \begin{pmatrix} 0.97358 \\ 0.97328 \end{pmatrix} & \begin{pmatrix} 0.0426 \\ 0.0402 \end{pmatrix} \\ \begin{pmatrix} 0.00919 \\ 0.00854 \end{pmatrix} & \begin{pmatrix} 0.0416 \\ 0.0393 \end{pmatrix} & \begin{pmatrix} 0.99919 \\ 0.99909 \end{pmatrix} \end{pmatrix}$$

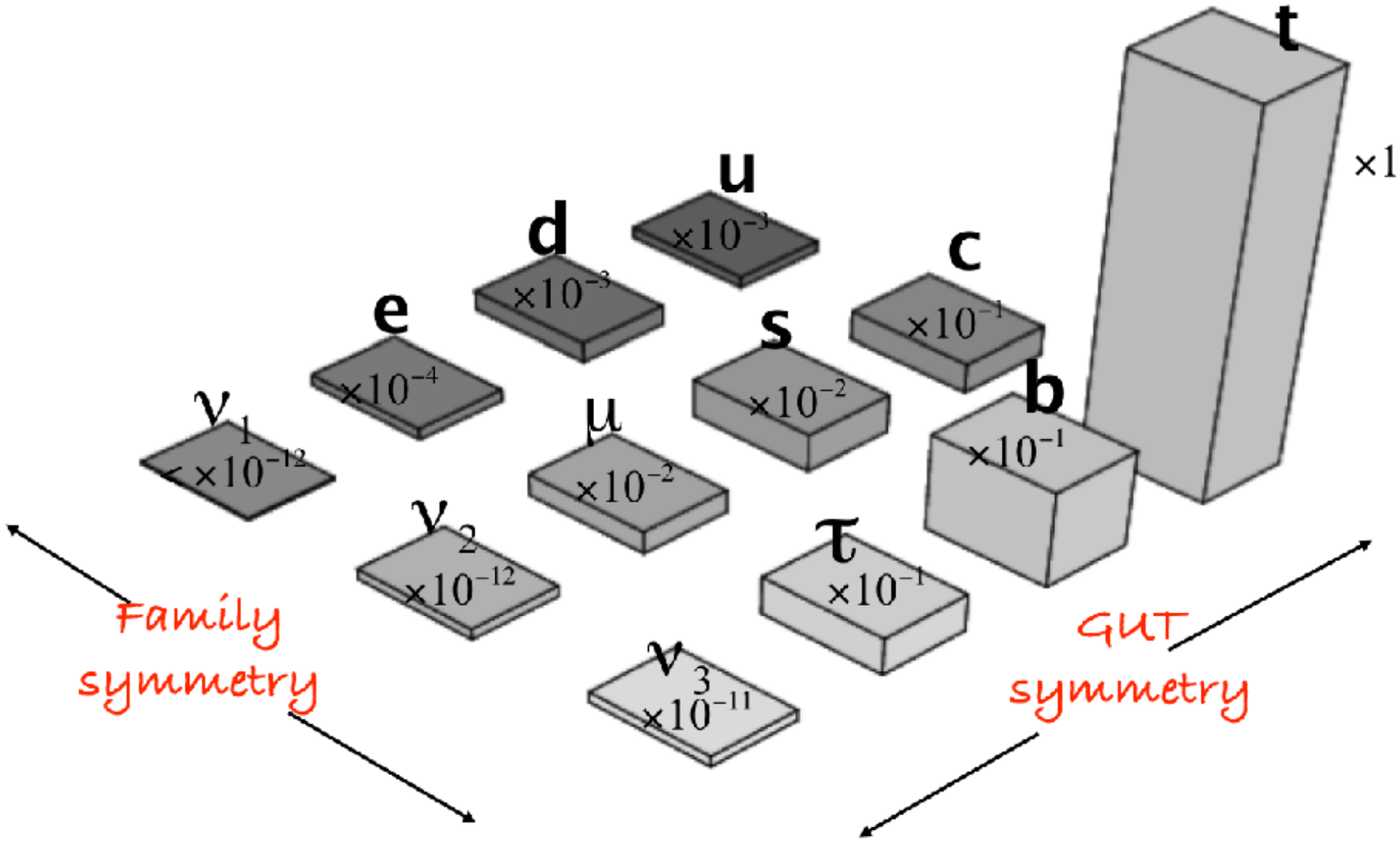
$$|U_{\rm PMNS}| \begin{pmatrix} \begin{pmatrix} 0.845 \\ 0.791 \end{pmatrix} & \begin{pmatrix} 0.592 \\ 0.512 \end{pmatrix} & \begin{pmatrix} 0.172 \\ 0.133 \end{pmatrix} \\ \begin{pmatrix} 0.521 \\ 0.254 \end{pmatrix} & \begin{pmatrix} 0.698 \\ 0.455 \end{pmatrix} & \begin{pmatrix} 0.782 \\ 0.604 \end{pmatrix} \\ \begin{pmatrix} 0.521 \\ 0.254 \end{pmatrix} & \begin{pmatrix} 0.698 \\ 0.455 \end{pmatrix} & \begin{pmatrix} 0.782 \\ 0.604 \end{pmatrix} \end{pmatrix}$$



Define the *Flavour Problem* as an absence of explanations for:

- (only) 3 generations of fermions
- mass hierarchies
- fermionic mixing, CP violation, and quark vs. lepton discrepancies

Symmetries as solutions



Discrete flavour symmetries

hep-ph/1002.0211
hep-ph/1110.6376
hep-ph/1301.1340

- The data (arguably) indicate some ordering to flavoured parameters—new flavour symmetries can provide for such organization.

- Discrete symmetries (imposed via finite groups) have been favored candidates, especially in the leptonic sector.

- Such discrete symmetries can quantize **precise mixing patterns** and provide interesting relations amongst masses.

- Furthermore, breaking discrete symmetries does not necessitate goldstone modes that could spoil phenomenology, and **vacuum alignment** can also be achieved.

- Discrete symmetries can also be embedded into **Grand Unified Theories**, and could have origins in **extra dimensions**, e.g. heterotic orbifold compactifications, thus naturally connecting them to UV complete theories

Status of discrete flavour symmetries?

- Multiple symmetries predict the same mixing patterns, and the same symmetry can predict multiple patterns
- In the absence of an exact symmetry, sub-leading corrections become important for phenomenology.
- It is not presently clear that any discrete symmetry can, without special modeling, successfully describe all fermionic structure.
- Vacuum alignment mechanisms are often involved, and additional symmetries often needed.
- It is also not yet clear how such models should be completed/realized in the UV.

Input is needed from UV physics. Guideposts could come from:

- Renormalization Group Evolution
- Anomaly cancellation constraints
- Higher dimensional theories

Projects, ideas, and interests

Generalized anomaly constraints -
w/ Sven Krippendorf (Oxford)

Indirect model for quarks and leptons -
w/ GG Ross (Oxford)

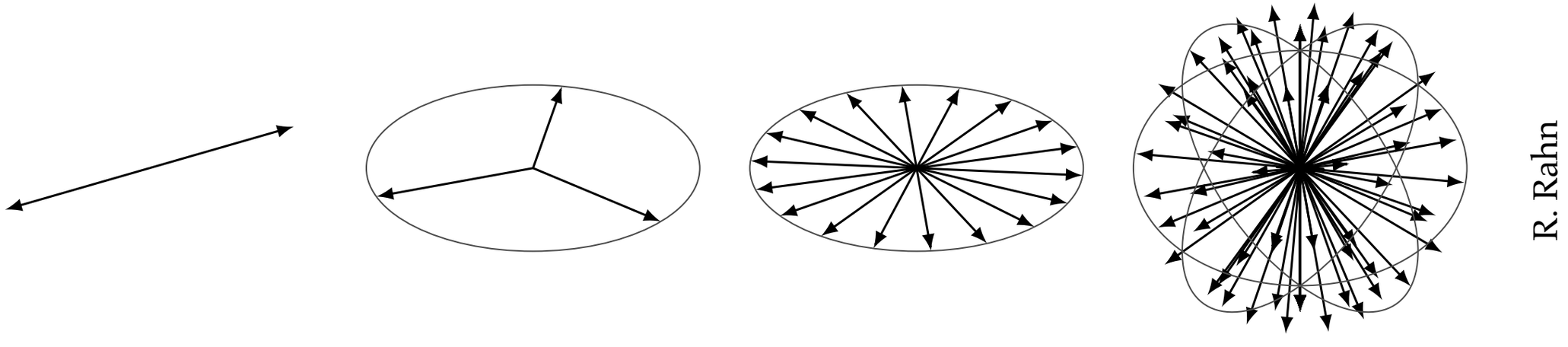
Can the RGE for mass and mixing parameters be generalized with an EFT approach?

Are there alternative mechanisms/constraints for flavoured vacuum alignment?

What are the connections between flavour and cosmology?

Event shape distributions: thrust

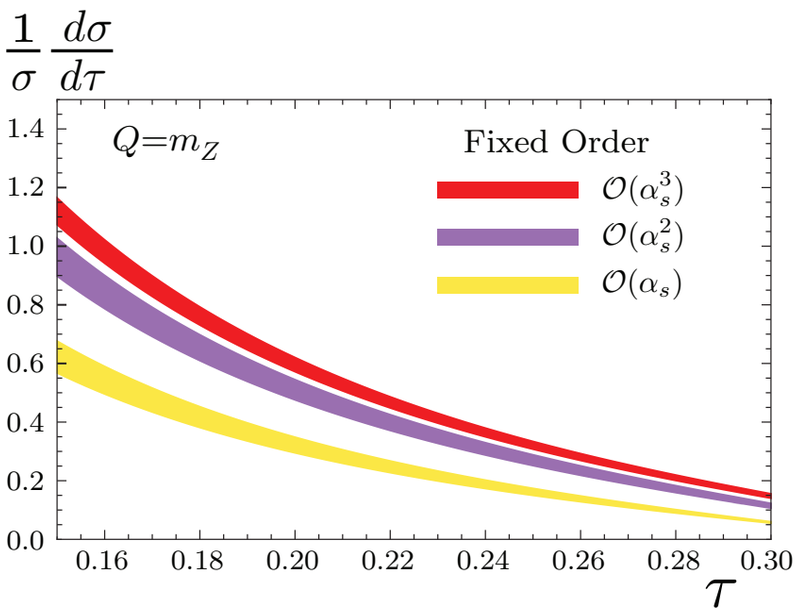
- The classic example is ***Thrust:*** $\tau \equiv 1 - T = 1 - \frac{1}{Q}\max_{\hat{\mathbf{t}}} \sum_{i \in X} |\hat{\mathbf{t}} \cdot \mathbf{p_i}|$

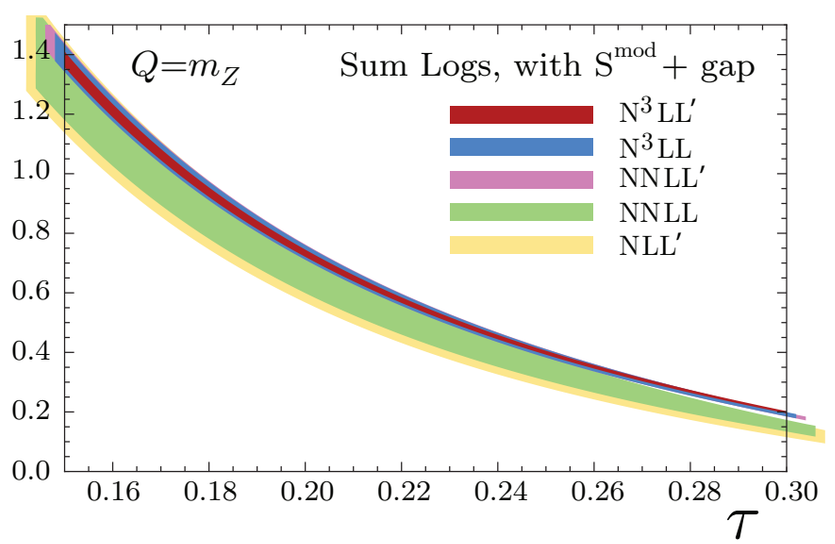


R. Rahn

$T = 1$ $\quad T = \frac{2}{3}$ $\quad T \geq \frac{2}{\pi}$ $\quad T \geq \frac{1}{2}$

- The fixed order distribution can readily be computed in QCD, though the current state of the art is a N^{3}LL′ + $\mathcal{O}(\alpha_s^3)$ resummation performed with EFT techniques:

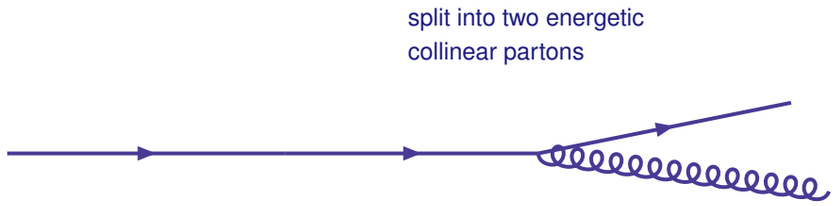


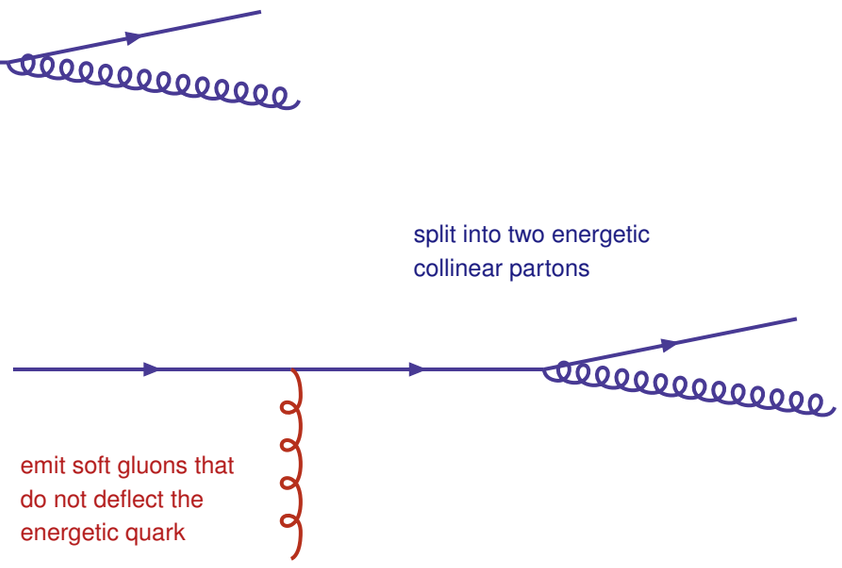


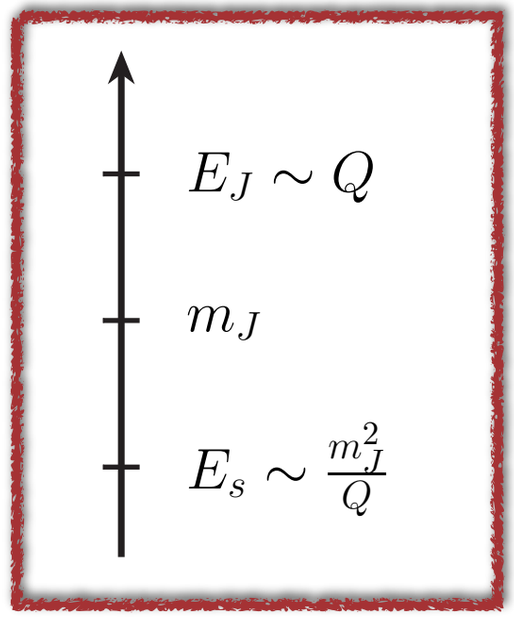
hep-ph/1006.3080

Jet evolution with soft and collinear radiation

- Event shapes can be predicted with SCET, an effective theory describing collinear and soft degrees of freedom (light, energetic particles) occurring alongside main channel collider scale Q

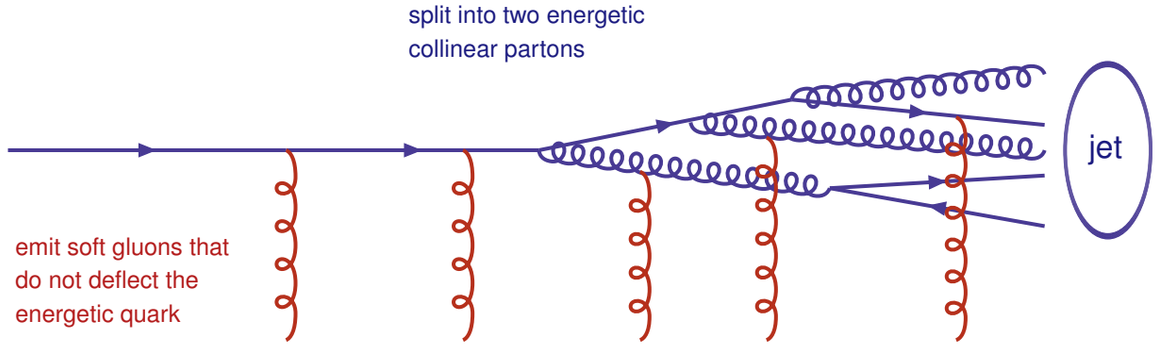






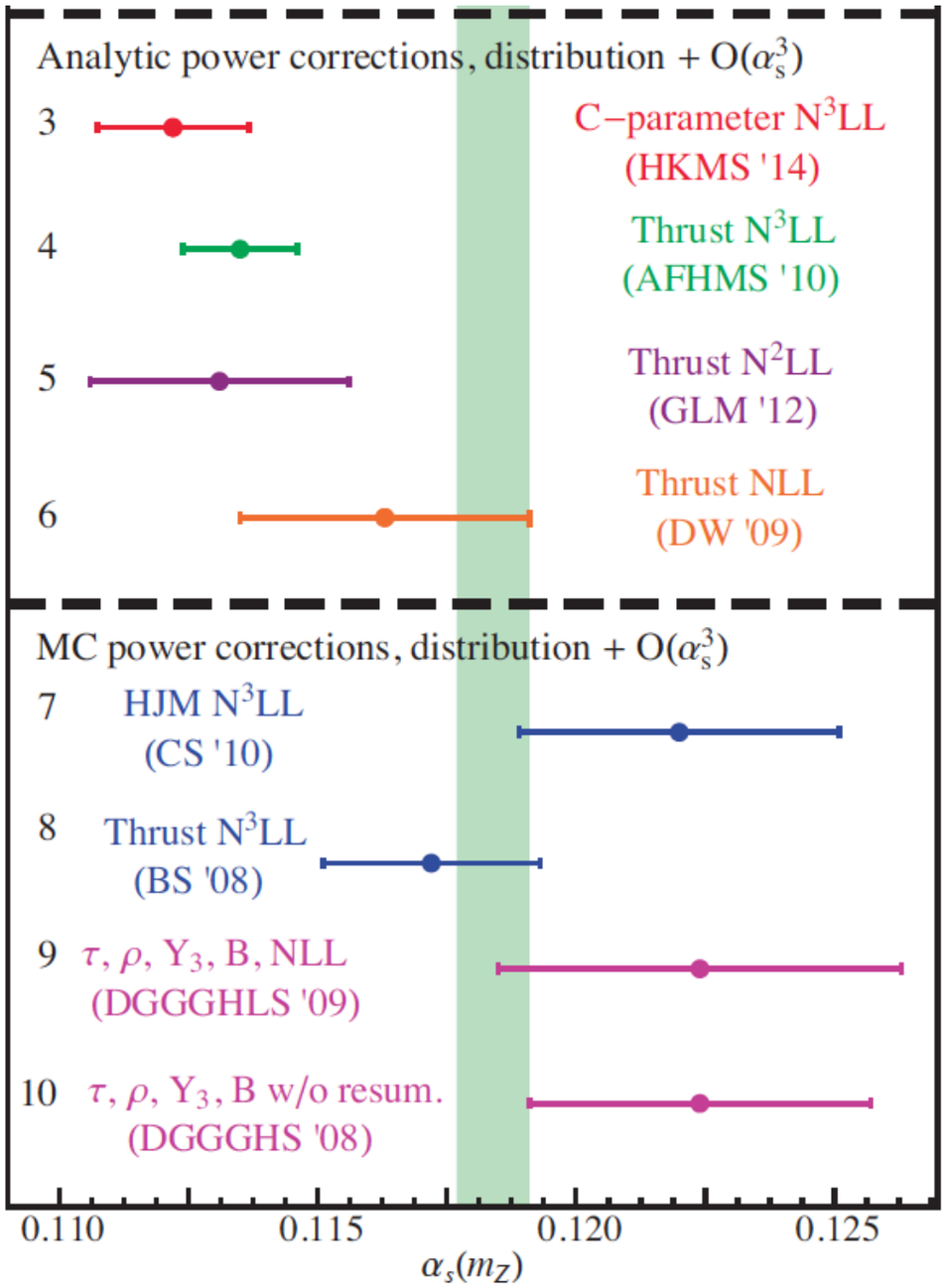
$\Rightarrow$ jet of collinear particles $m_J^2 \ll E_J^2$

soft large-angle radiation $E_s \ll E_J$



- SCET permits the precision resummation of large logs of these scales via renormalization group evolution!

Strong coupling extractions



2016 world average:
.1181 +- .0013

A. Hoang, *2015 workshop on precision α_s extractions*

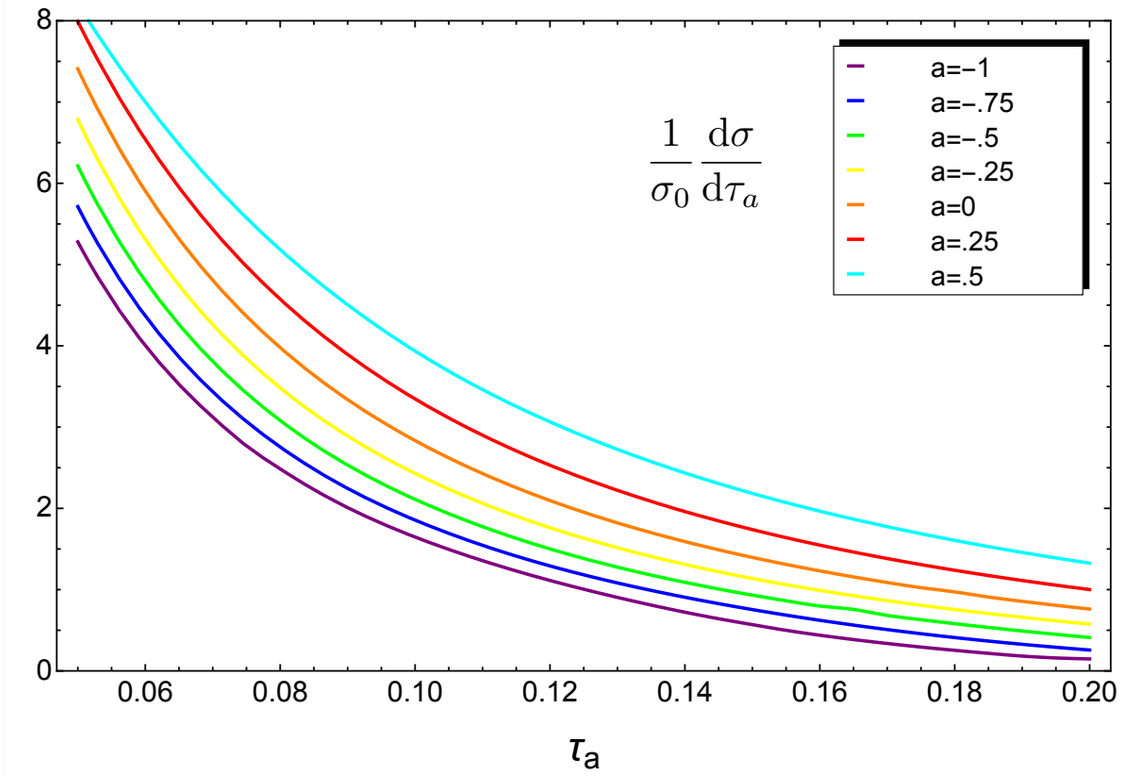
- Many groups have utilized high-precision event-shape results to extract a value for α_s. Recently, N^{3}LL resummations for multiple observables have been achieved.

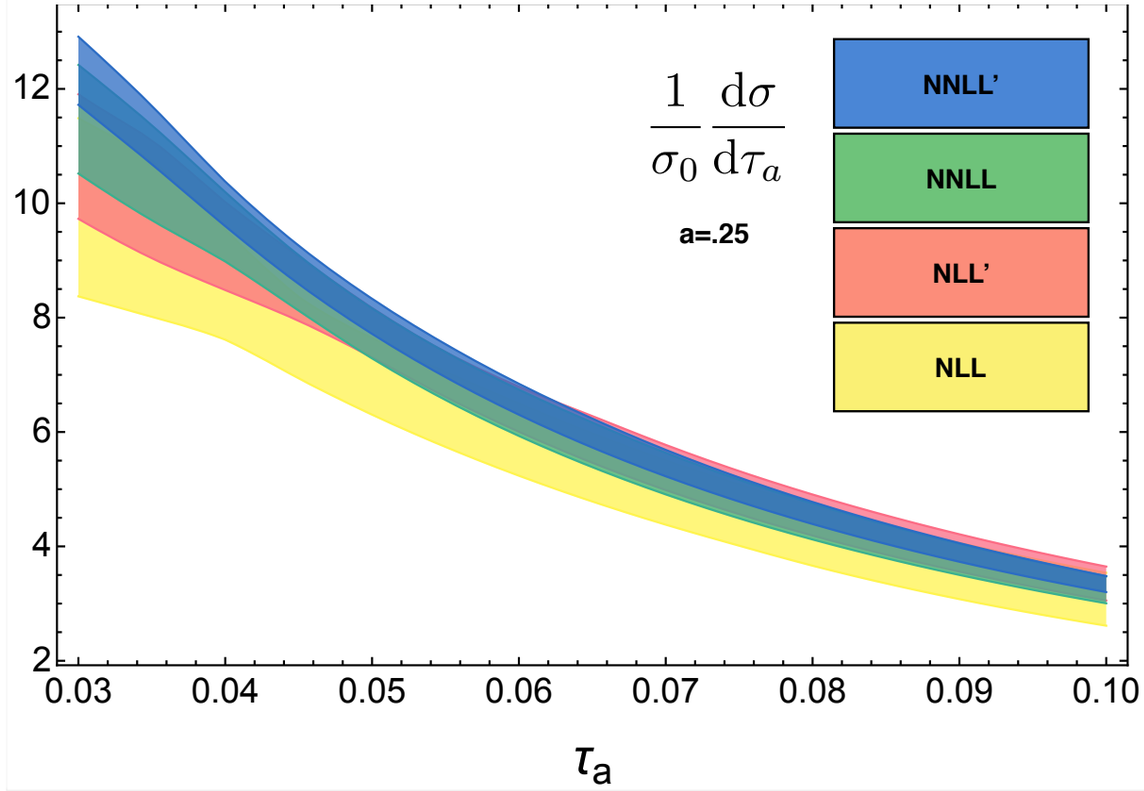
- However, the value of α_s is highly correlated to non-perturbative physics.

What can break the α_s conundrum?

Angularities: spectrum and convergence

Preliminary!





Spectrum

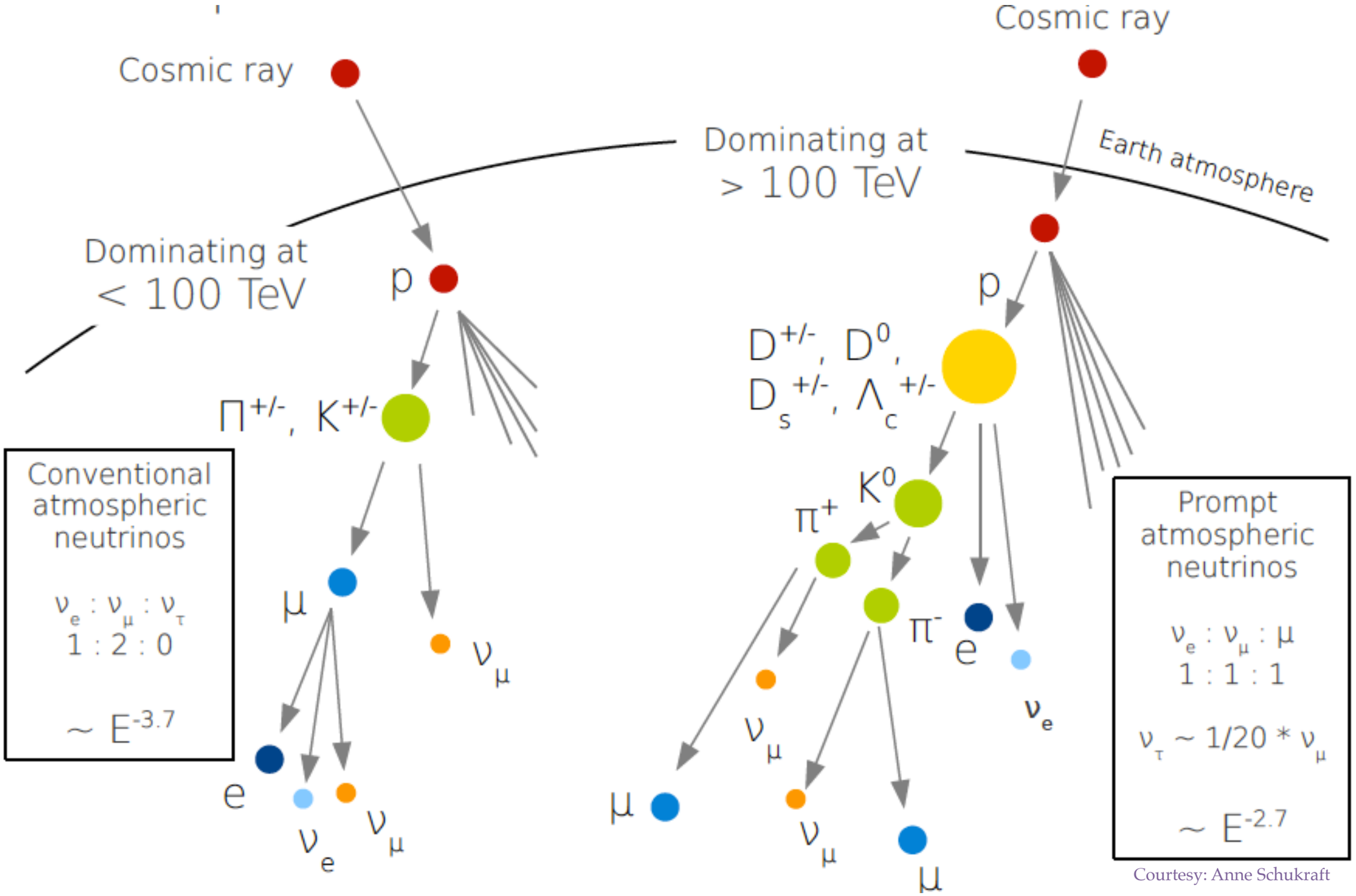
- Q = 91.2 [GeV]
- The results are matched to $\mathcal{O}(\alpha_s^2)$.
- No NP shift applied.

Convergence

- a = .25
- Nice convergence between NLL -> NNLL'.
- Former state-of-the-art was at NLL'.

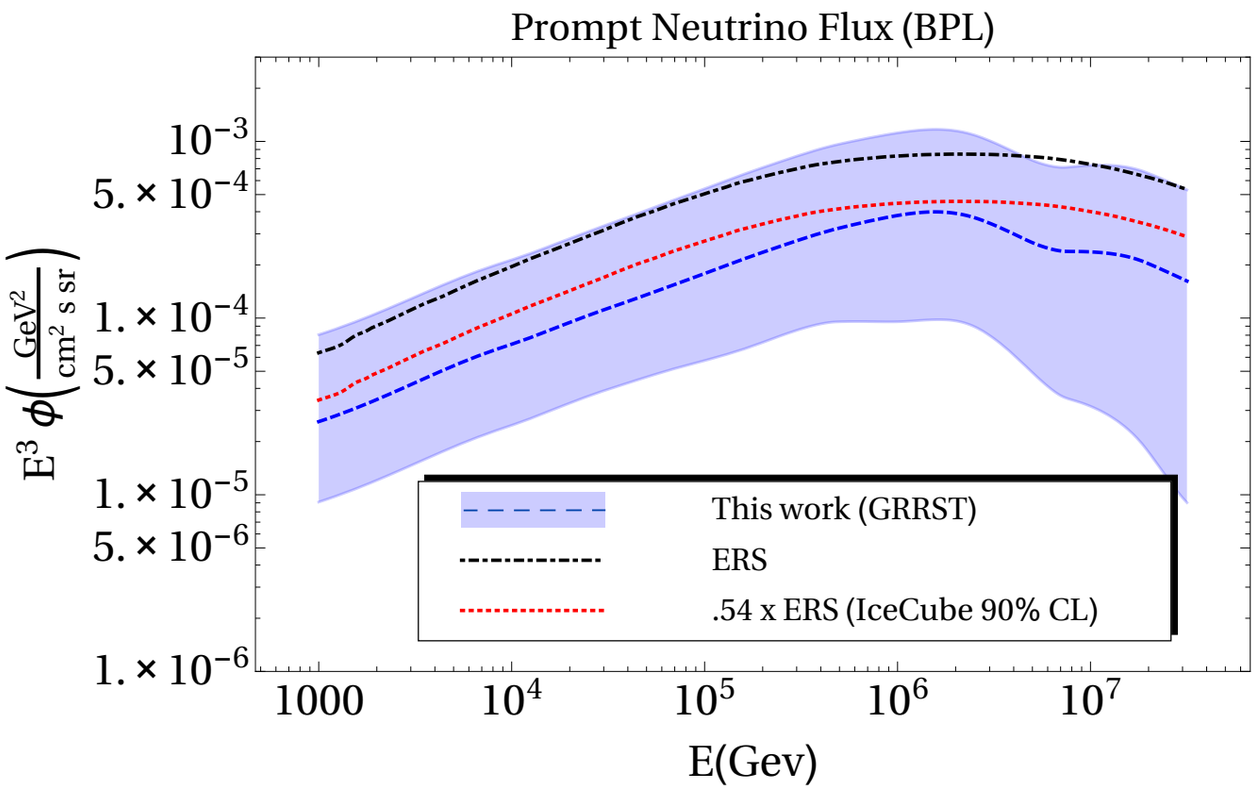
arXiv:1506.08025 + 1511.06346

Atmospheric charm production



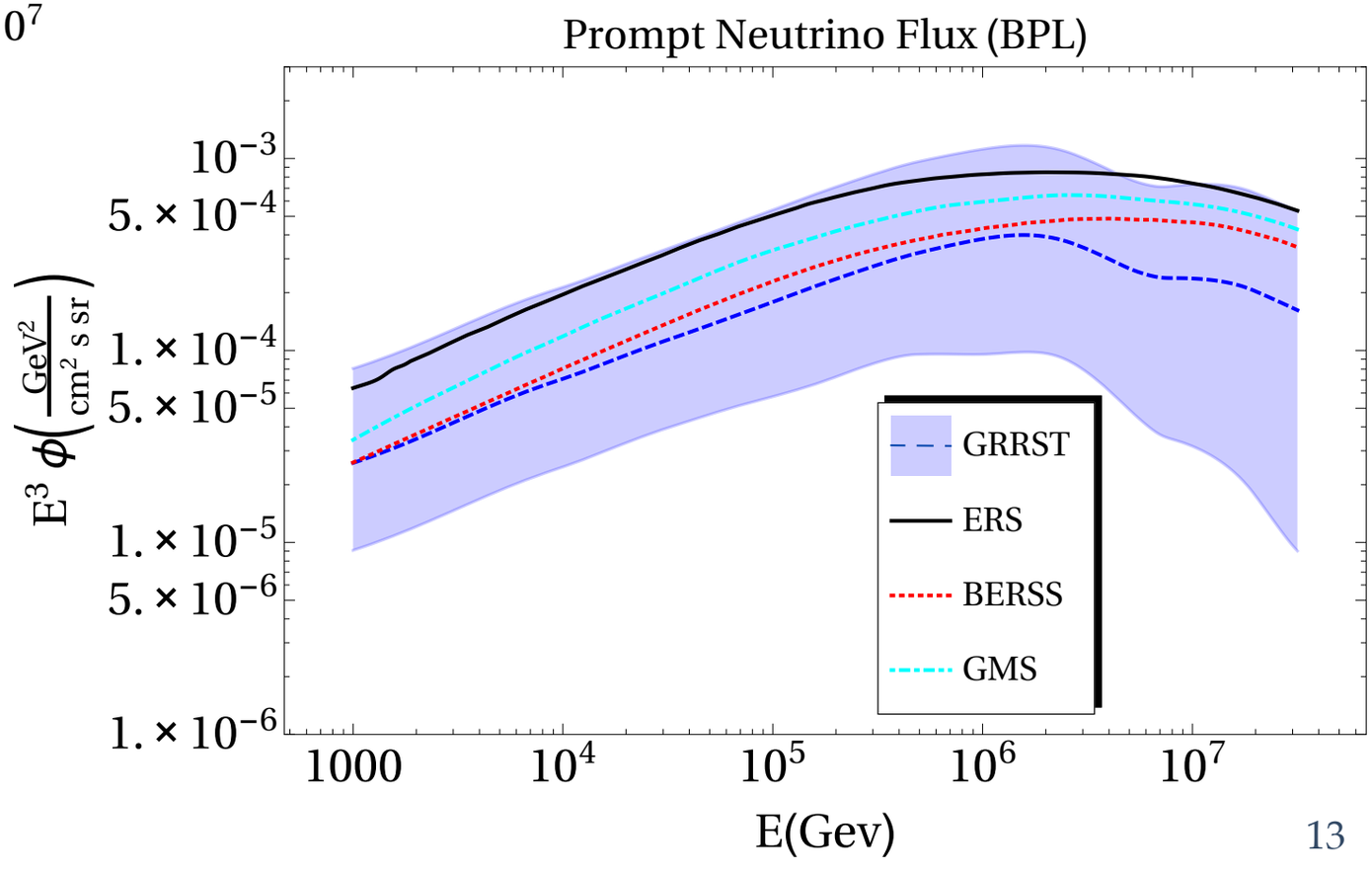
Courtesy: Anne Schukraft

Prompt neutrinos @ terrestrial detectors



- Our central result is just below the most recent IceCube bound, indicating that **a prompt component of the incoming flux should be observed soon**….

- Our central result is consistent with the recent **BERSS** collaboration, though with **better estimates of the uncertainties**, which also encompass the 2008 **ERS** result and the most recent **GMS** calculation.



Projects, ideas, and interests

Finalizing automated calculation of NNLO soft functions

w/ Guido Bell (Siegen) and Rudi Rahn (Bern)

NNLL resummation of angularities

w/ Chris Lee (LANL), Andrew Hornig, and Guido Bell

What's the value of the strong coupling constant at M_{Z}?

Are there any other systematic uncertainties in the prompt atmospheric neutrino flux?

What can SCET say about the (forward) production of heavy mesons?