Tomáš Kadavý (Charles University, Prague, Czech Rep.)

- Study of odd-intrinsic parity sector of QCD with χPT and RχT.
- We assume the saturation of dynamics with the lightest resonances.
- At the NLO, relevant resonance Lagrangian in the odd-intrinsic parity sector was formulated by [K. Kampf and J. Novotný '11]:

$$\mathcal{L}^{(6)}_{\mathrm{R}\chi\mathrm{T}} = \sum_X \sum_i \kappa_i^X \widehat{\mathcal{O}}^X_{i\,\mu\nu\alpha\beta} \varepsilon^{\mu\nu\alpha\beta} .$$

- $\mathcal{L}^{(6)}_{\mathrm{R}\chi\mathrm{T}}$: 67 operators and 67 corresponding unknown couplings κ_i^X in total.
- How to obtain the couplings?

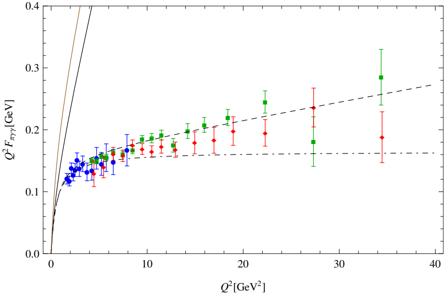
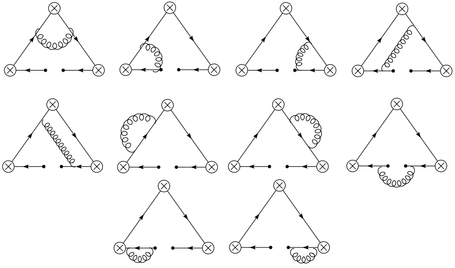
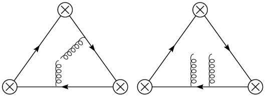
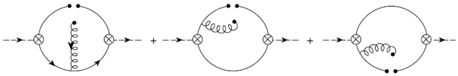


Figure: A plot of BABAR (green), BELLE (red) and CLEO (blue) data fitted with the formfactor $\mathcal{F}^{\mathrm{R}\chi\mathrm{T}}_{\pi^0\gamma\gamma}(0, -Q^2; 0)$ using the modified Brodsky-Lepage condition. The full black line: $\delta_{\mathrm{BL}} = -1.342$. The full brown line: LMD. The dashed line: fit with $\delta_{\mathrm{BL}} = -0.055$. The dot-dashed line: fit with $\delta_{\mathrm{BL}} = 0$.

- We try to use pure OPE instead of AdS/QCD to constraint unknown parameters.
- For $x_1, x_2 \to 0$ (i.e. for large external momenta) Green function $\langle \mathcal{O}_1(x_1)\mathcal{O}_2(x_2)\mathcal{O}_3(0)\rangle$ can be expanded into a series of nonperturbative parameters with c-number coefficients.
- Contributions from QCD condensates:
  - $\langle 0|\bar{q}q|0\rangle$
  - $\langle 0|G_{\mu\nu}G^{\mu\nu}|0\rangle$
  - $\langle 0|\bar{q}\sigma_{\mu\nu}G^{\mu\nu}q|0\rangle$
  - $\langle 0|\bar{q}\,\Gamma_1\,q\bar{q}\,\Gamma_2\,q|0\rangle$
  - $\langle 0|G^a_{\mu\nu}G^b_{\nu\sigma}G^c_{\sigma\mu}|0\rangle f^{abc}$

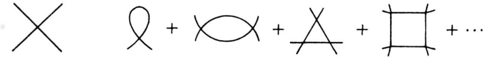






Pawel Kozow, Faculty of Physics University of Warsaw

- Higgs mechanism - key feature in the SM
- However, μ^2 only a parametrization, $v \sim \sqrt{-\mu^2}$
- A possible solution (CW): quantum fluctuations in vacuum (works in simple models, e.g. SQED)
- In ϕ^4 theory:



- Is it possible to apply in SM?
- Need of extra bosonic degrees of freedom
- GW framework: flat direction in ϕ_i space (SSB of SI at tree-level $\rightsquigarrow$ GB)
- Loops break SI explicitly (the GB mode is now a PGB)
- If loop corrections small then simplified analysis of V along the flat direction
- What about the, formally, sub-leading effects?

- We take SM with $\mu^2 = 0$ and focus on minimal scalar sector extensions
- As a result we need at least 2 extra scalars
- and after imposing Z_2: $s_i \to -s_i$

$$
\begin{aligned}
V &= \lambda_H (H^\dagger H)^2 + \lambda_{H1} H^\dagger H \, s_1^2 + \lambda_{H2} H^\dagger H \, s_2^2 + \\
&\quad + \lambda_1 s_1^4 + \lambda_2 s_2^4 + \lambda_{12} s_1^2 \, s_2^2
\end{aligned}
$$

- If one of Z_2 left unbroken $\rightsquigarrow$ DM candidate
- LHC Higgs physics bounds and DM direct detection and relic density constraints can be fulfilled for some region in λ's

Lattice to $\overline{MS}$ Conversion

Sandra Kvedaraite, University of Sussex, UK

- Following a paper by Y. Aoki *et al.* [arXiv:1012.4178] – one-loop calculation
- Kaon bag parameter: $$B_K = \frac{\langle K^0 | \mathcal{O}_{VV+AA} | \bar{K}^0 \rangle}{\frac{8}{3} f_K^2 M_K^2},$$

  where f_K is the leptonic decay constant, M_K is the mass of the kaon and in the numerator we have a QCD hadronic matrix element of the effective weak $\Delta S = 2$ four quark operator $\mathcal{O}_{VV+AA} = (\bar{s}\gamma_\mu d)(\bar{s}\gamma_\mu d) + (\bar{s}\gamma_5\gamma_\mu d)(\bar{s}\gamma_5\gamma_\mu d)$.
- Conversion factors: $$C_{q,m}^{RI/SMOM} = \frac{Z_{q,m}^{\overline{MS}}}{Z_{q,m}^{RI/SMOM}}$$

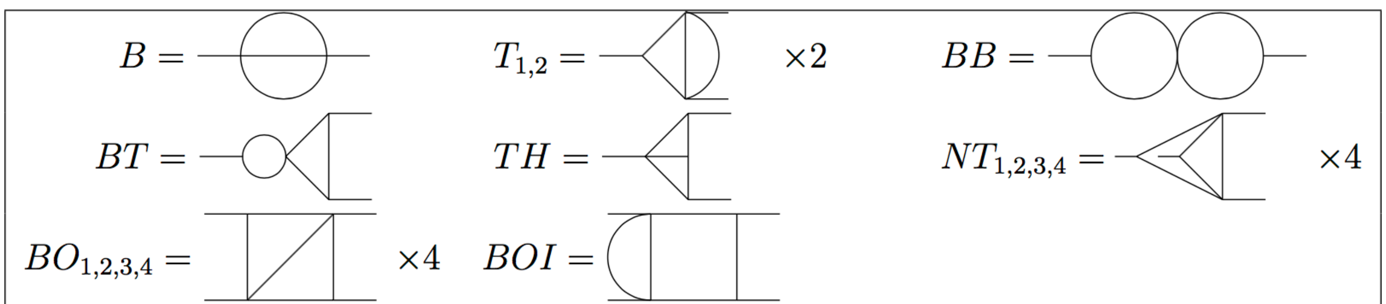
Lattice to $\overline{MS}$ Conversion

- Renormalization condition for the operator is given by

$$Z_{\mathcal{O}} = (Z_q^{RI/SMOM})^2 \frac{1}{P^{ij,kl}_{\alpha\beta,\gamma\delta}\Lambda^{ij,kl}_{B,\alpha\beta,\gamma\delta}},$$

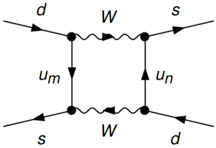
where $\Lambda^{ij,kl}_{B,\alpha\beta,\gamma\delta}$ is the bare amputated four-point Greens function for the $d(p_1)\bar{s}(p_2) \to \bar{d}(p_3)s(p_4)$ transition and $P^{ij,kl}_{\alpha\beta,\gamma\delta}$ is the projection operator.

- All relevant master integrals for the two-loop vertex correction



Matthew Leak, Martin Gorbahn

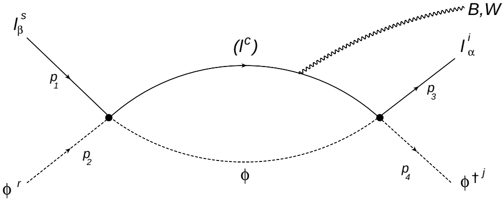
Neutral Meson Oscillations



- Calculate $\mathcal{O}(\alpha_s^2)$ corrections to Wilson coefficient η_{tt}
- Matching calculation requires 3-loop integrals with masses M_W, m_t
- Expansion by regions (Smirnov)

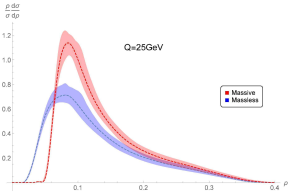
SMEFT ADM to two loops

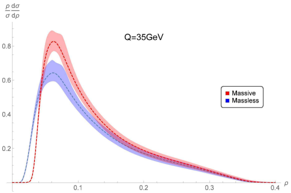
- 59 dim-6 operators of Warsaw basis mix under renormalisation $\rightarrow$ calculate renormalisation constants and ADM
- Calculate mixing of double dim-5 operator into dim-6 operators (ADT)



- Apply to lepton-flavour violating processes (with Sacha Davidson)

HJM Distribution - Primary Massive Quark Effects

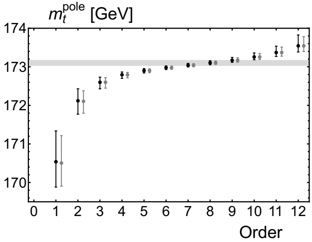




- Started in Master Thesis:
  - $e^+e^- \rightarrow$ Hadrons: Differential cross section w.r.t. event shape "Heavy Jet Mass".
  - Usage of EFT required to sum logs of ratios of scales in problem:
    - Hard, Jet, Soft $\rightarrow$ SCET.
  - Known quite well for massless primary quarks.
    - Computed effects of primary massive quarks (e.g. bottom).

- Now:
  - Generalize Calculation for massive top quark.
    - Finite width effects, instability, scale hierarchies w.r.t mass, ...

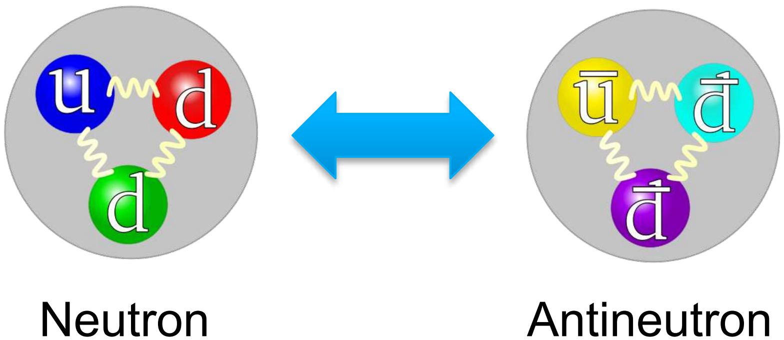
Heavy Quark Pole Mass Properties



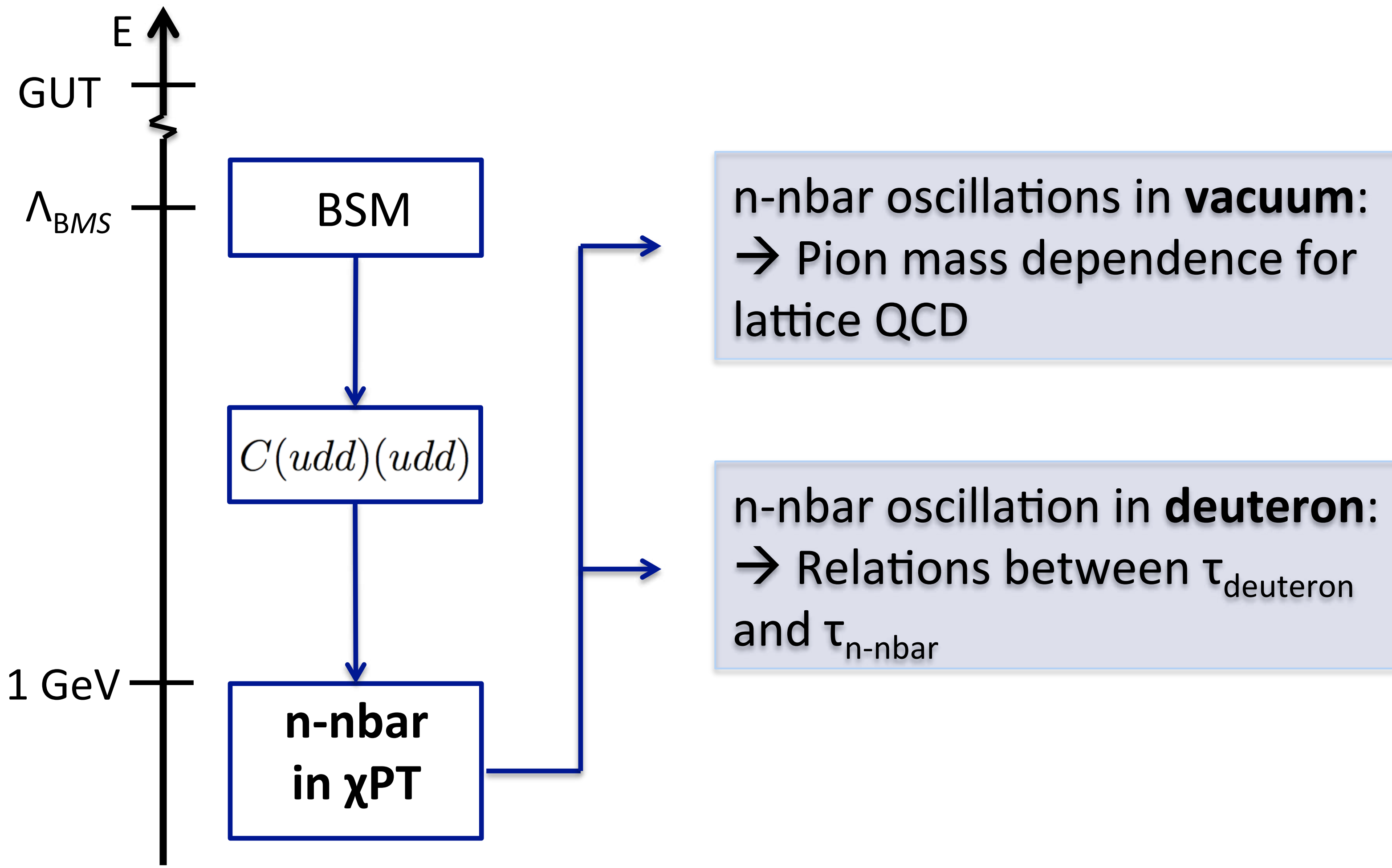
- Pole mass of heavy quarks:
  - Linearly sensitive to small momenta (including non-perturbative regimes) $\rightarrow$ "$\mathcal{O}(\Lambda_{\rm QCD})$ Renormalon".
    - Bad perturbative behavior (even diverging high-order behavior), intrinsic ambiguity of pole mass value of $\mathcal{O}(\Lambda_{\rm QCD})$.
  - Studied influence and structure of lighter massive quarks (e.g. bottom, charm in top) on high order behavior and ambiguity $\rightarrow$ RG-formalism.
    - Relevant since virtual missive loops change IR-structure.
    - Several applications: Higher order prediction of mass corrections, pole mass differences, pole mass ambiguity $\rightarrow$ 250 MeV(!), ...

Neutron-antineutron oscillations in chiral perturbation theory

Femke Oosterhof
With: J. de Vries, U. van Kolck, R. Timmermans



$$|\Delta B| = 2$$



Next:

- Baryon oscillations with heavier flavors?
- T violation (EDMs)?

- **HEP**: vector portal prospects on SHiP experiment at CERN (**1504.04855**)

$$L_{CS} = c_1 \epsilon^{\mu\nu\alpha\beta} X_\mu (c_1 Z_\nu F^Z_{\alpha\beta} + c_2 W_\nu F^W_{\alpha\beta} + c_3 Z_\nu F^A_{\alpha\beta})$$

- **Cond-mat**: investigating the analytical structure of the graphene state density function (**1705.08120**)

$$H_{\text{sub-lattice}} = v_F \sigma \cdot \mathbf{p}, \quad v_F \approx c/300$$

- **Cosmology**: generation of primordial magnetic fields by axion-like particle dark matter (**in progress**)

$$L_\theta = \frac{1}{2}(\partial_\mu \theta)^2 - V(\theta) + \frac{\theta}{f_\gamma} \epsilon^{\mu\nu\alpha\beta} F^{\text{EM}}_{\mu\nu} F^{\text{EM}}_{\alpha\beta}$$

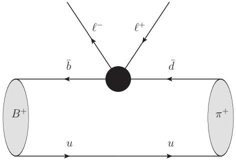
Hadronic effects and observables in the semileptonic B-meson decays

Aleksey Rusov

University of Siegen, Germany

Supervisors: Alexander Khodjamirian
Thomas Mannel

$$\mathcal{H}_{\rm eff}^{b\to q} = \frac{4G_F}{\sqrt{2}}\left(\lambda_u^{(q)}\sum_{i=1}^{2} C_i\,\mathcal{O}_i^u + \lambda_c^{(q)}\sum_{i=1}^{2} C_i\,\mathcal{O}_i^c - \lambda_t^{(q)}\sum_{i=3}^{10} C_i\,\mathcal{O}_i\right)$$



- Precise Calculation of the Dilepton Invariant-Mass Spectrum and the Decay Rate in $B^\pm \to \pi^\pm\mu^+\mu^-$ in the SM

  A. Ali, A. Parkhomenko, AR (2014). arXiv: 1312.2523

- Hadronic effects and observables in $B \to \pi\ell^+\ell^-$ decay at large recoil

  Ch. Hambrock, A. Khodjamirian, AR (2015). arXiv: 1506.07760

- $B_s \to K\ell\nu_\ell$ and $B_{(s)} \to \pi(K)\ell^+\ell^-$ decays at large recoil and CKM matrix elements

  A. Khodjamirian, AR (2017). arXiv: 1703.04765

- Higher-Twist Effects in Light-Cone Sum Rule for the $B \to \pi$ Form Factor

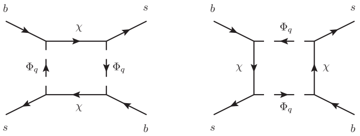
  AR (2017). arXiv: 1705.01929

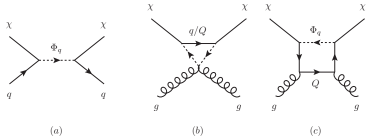
- Inclusive Semitauonic B Decays to Order $\mathcal{O}(\Lambda^3_{QCD}/m_b^3)$

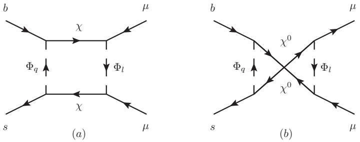
  Th. Mannel, AR, F. Shahriaran (2017). arXiv: 1702.01089 [poster]

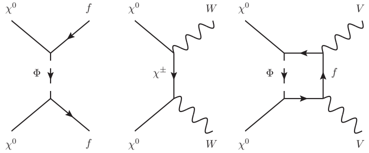
Introduce "slepton" Φ_l, "squark" Φ_q and "neutralino" χ. Also introduce new flavour symmetries $G_F = A_4 \times Z_3 \times U(1)_{\text{FN}}$

$$\mathcal{L}_{\text{int}} = g_i^q \bar{\chi}_R Q_L^i \Phi_q + g_i^l \bar{\chi}_R L_L^i \Phi_l + \text{h.c.} \tag{1}$$

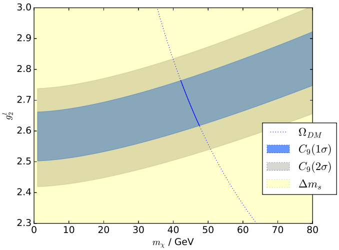


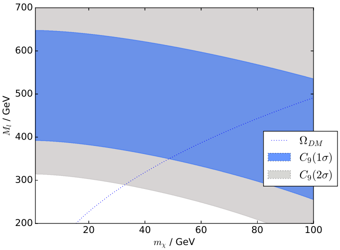






Exclusions





- recent direct limits give $M_q = 950$ GeV (2017), $M_l = 300$ GeV (2014)
- no bounds from direct detection (here 4 orders lower than experiment) or B-mixing (within 1σ)
- only $\sim 20\%$ of $(g-2)_\mu$ can be accommodated by the Bino-like χ
- Wino-like χ is excluded by $\chi^\pm$-limits to serve the flavour anomalies

Cosmology of Mirror Twin Higgs

with Nathaniel Craig & Seth Koren 1611.07977

- Duplicate the SM with a mirror parity. Sectors only mix through large Higgs portal.

$$V \propto \lambda\Big(|H_A|^2 + |H_B|^2 - \frac{f^2}{2}\Big)^2$$

- Higgs is a pseudo-Goldstone boson of a SSB accidental global $SU(4)$ - but have to align vacua to make it dominantly “A” type.
- Mirror parity must be softly broken for pGB to be mostly SM-like.

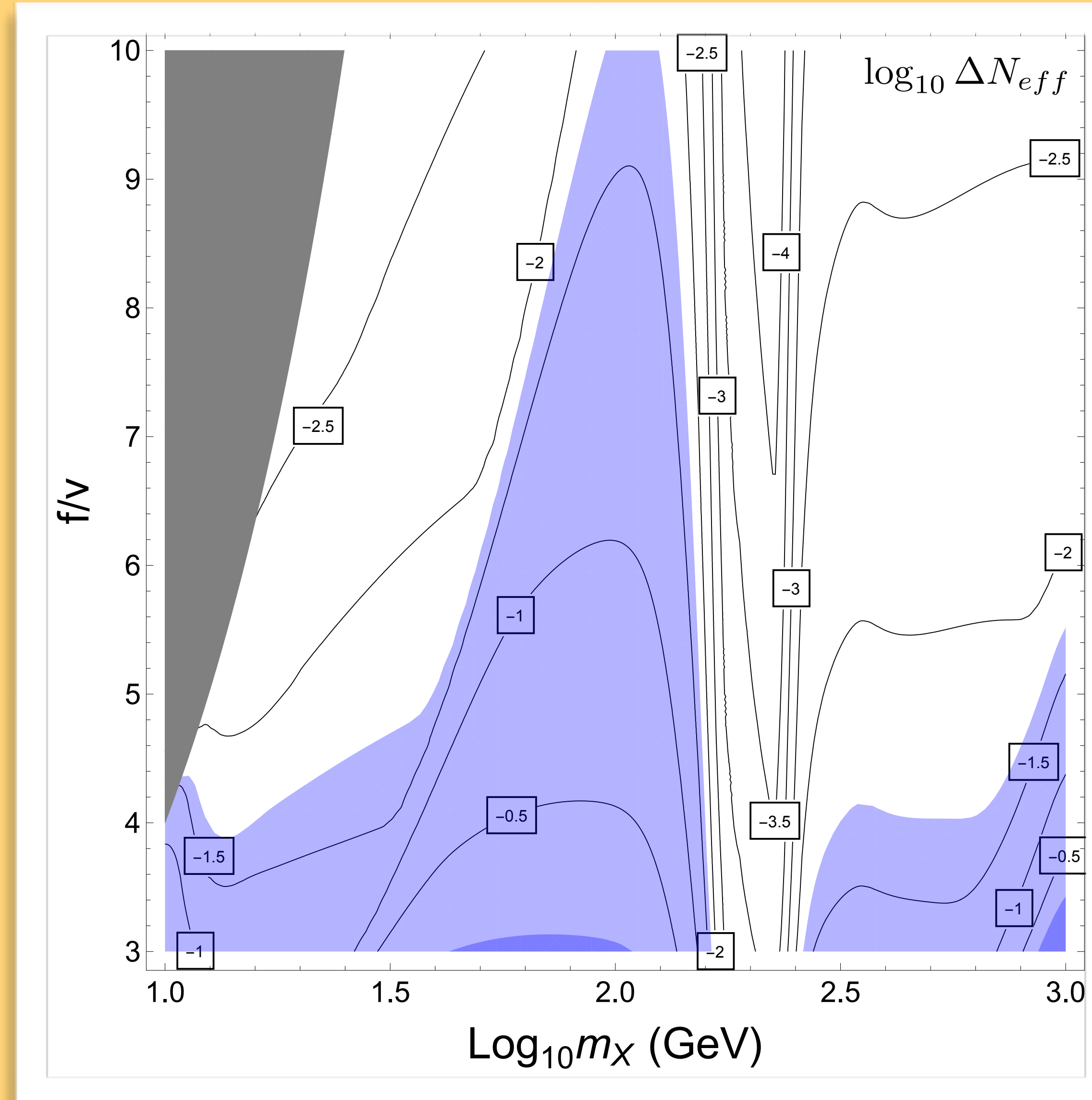
$$v \approx v_A \ll v_B \approx f$$

BUT

- Double the light particles $\Longrightarrow$ double the radiation density of the early universe, ruled-out by CMB.

- Investigated asymmetric dilution mechanisms related to the asymmetry in the Higgs potential.
- E.g. A long-lived modulus reheats the universe below the temperature of sector decoupling (~1 GeV). Decay rate asymmetry inherited from $\mathbb{Z}_2$-breaking. Twin particles are diluted by entropy transfer mostly into the SM:

$$\Delta N_{eff} \propto \frac{Br(X \to Twin)}{Br(X \to SM)} \propto \frac{v^2}{f^2}$$



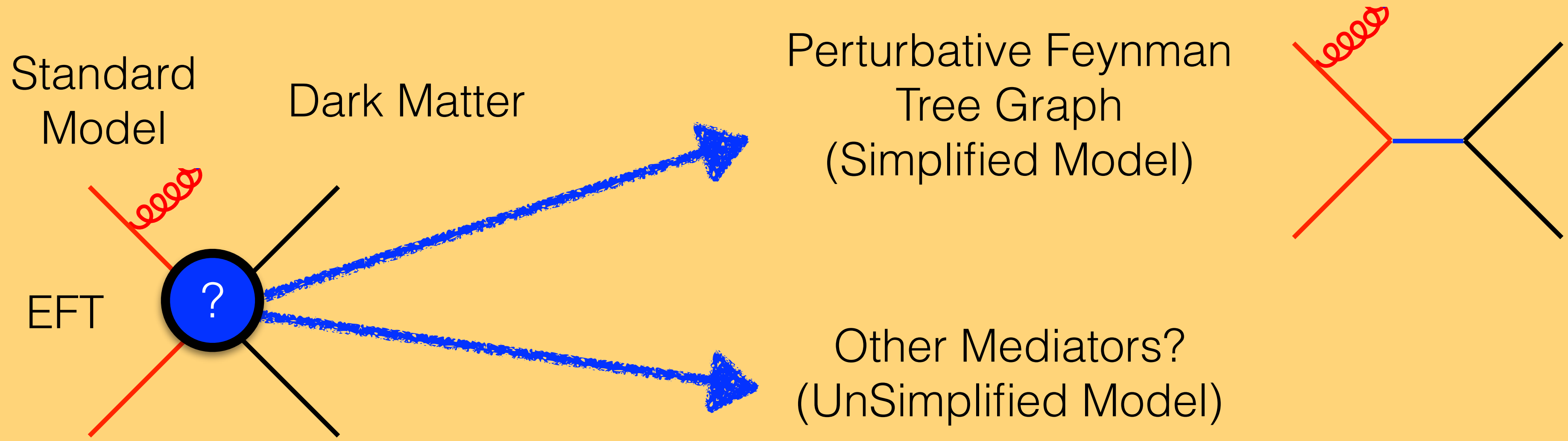
↑ f/v ↑ E/W Tuning

↓ f/v ↑ ΔN_{eff}

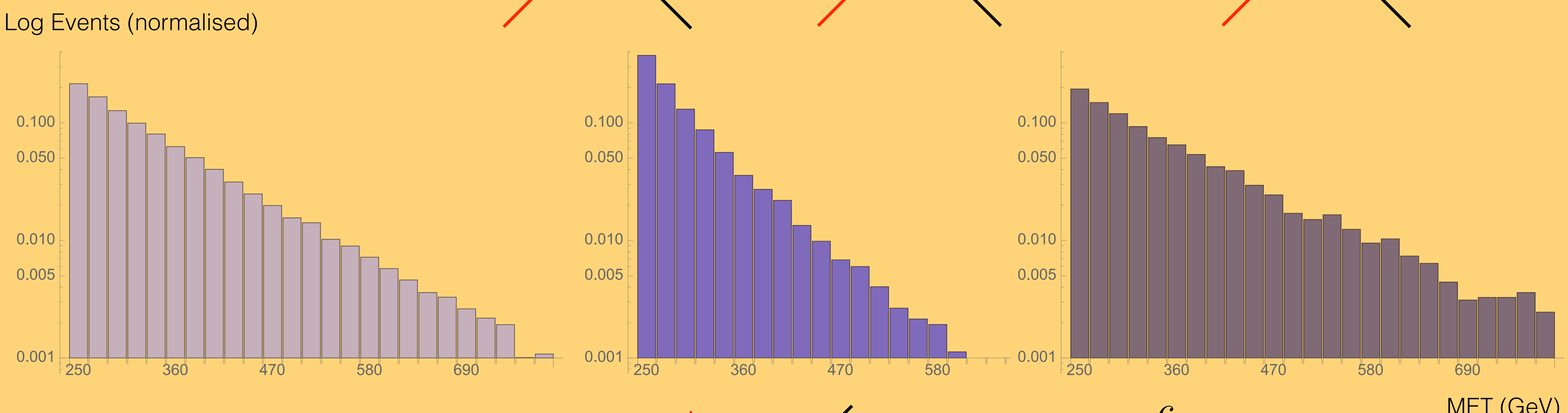
UnSimplified Models

with Nathaniel Craig, Aidan Herderschee, Zachary Johnson & Seth Koren (in progress)

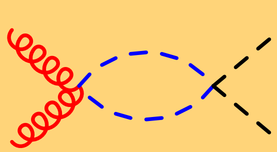
Testing the coverage of the Simplified Model framework of the LHC dark matter program.

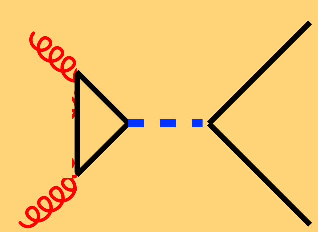


Testing ability of the MET spectrum to characterize the mediator sector.



E.g. Gluphilic dark matter
R. M. Godbole, et. al.
1605.04756





Simplified Model

$$\frac{c}{M^2} G^{\mu\nu} G_{\mu\nu} \chi^* \chi$$

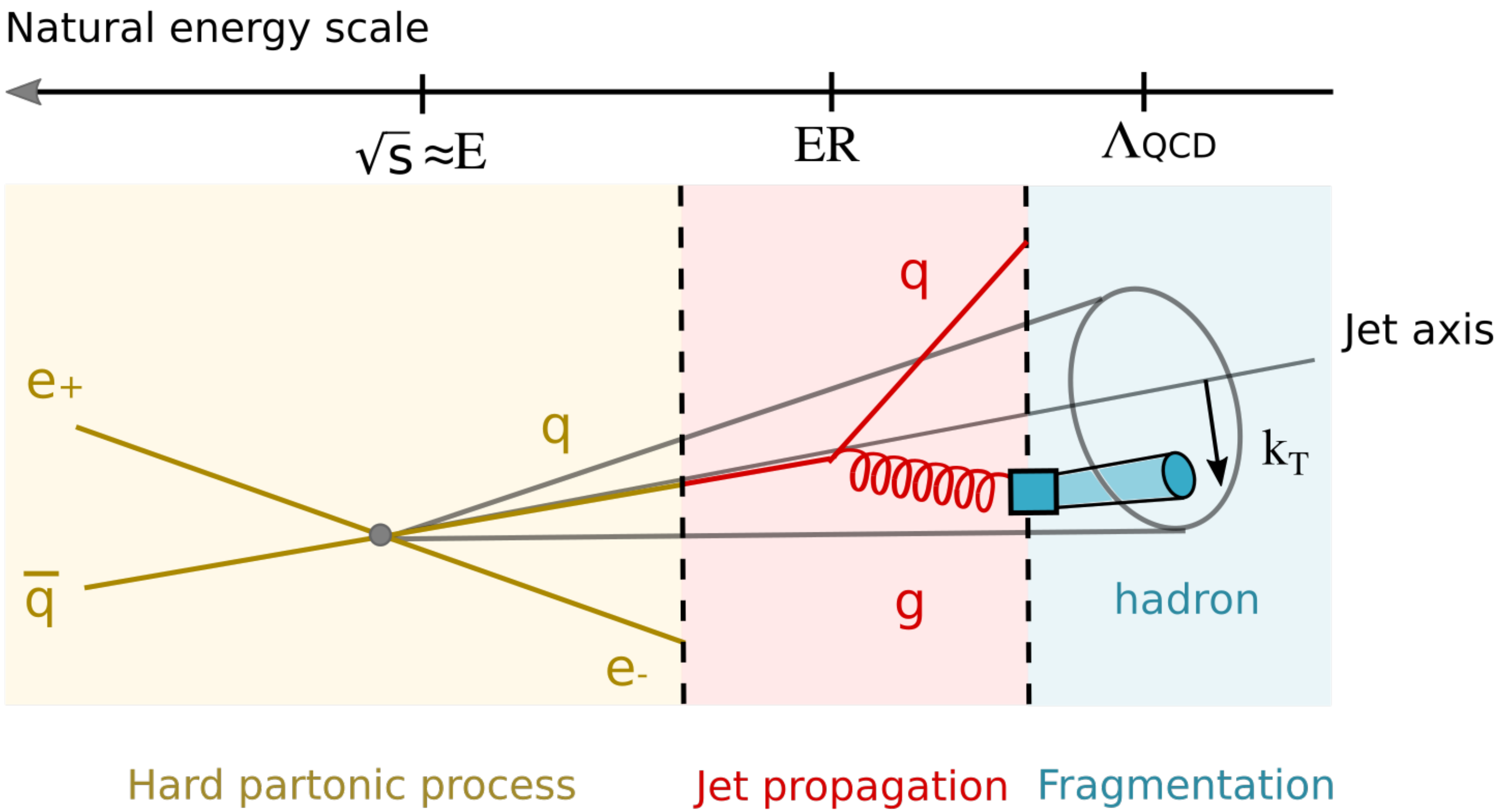
Effective Operator

Jong Min Yoon **Advisor: M. Peskin**
SLAC / Stanford University

- Standard Model treats Electroweak symmetry breaking only in a phenomenological way.
- It would be nice to have a theory in which the Higgs potential is calculable.
- There is an approach to this problem based on the following ideas.
  1) Higgs as a composite Goldstone boson
  2) Randall-Sundrum geometry as a dual formulation of a strongly interacting theory
  3) Phase transition and competing forces of fermion condensation
- We would like to advance this theory and make it more predictive.

- Gauge-Higgs Unification
  - In the dual picture, Goldstone boson in 4D becomes the fifth component A5 of 5D gauge fields.
  - For massless fermions of opposite chirality, it is energetically favorable for those to pair up and become massive.
  - The Coleman-Weinberg potential of A5 can break EW symmetry
  - We can calculate the relations between resonance masses and Top&Higgs couplings.

- Current focus – Little Hierarchy
  - No new particles at the scale of Higgs vev.
  - Can we separate the scale of new physics far above 246 GeV without fine-tuning?



$$\left(\frac{d\sigma}{d^2k_T}\right)_{e^+e^-\to jet(hadron)} = H_{e^+e^-\to i} \otimes B_{ij} \otimes C_{jk}(k_T) \otimes D_{k\to hadron}$$