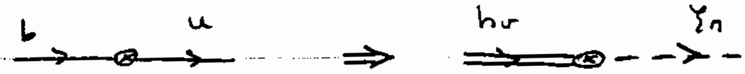
## Currents

e.g. QCD $b \to u e \nu$ $\quad J = \bar{u}\,\Gamma\, b \qquad \Gamma = \gamma^\mu(1-\gamma_5)$

if $u$ energetic match onto SCET (& HQET for b)

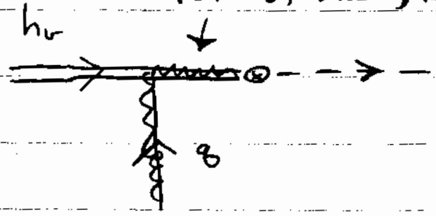
$$J^{eff} = \bar{\xi}_n\, \Gamma\, h_v$$




↑ dashed for collinear

for offshell, $k^\mu = m_b v^\mu + \frac{n^\mu}{2}\,\bar{n}\cdot q + \ldots$

Consider




$k^2 = m_b^2 + n\cdot v\, m_b\, \bar{n}\cdot q$

$k^2 - m_b^2 \sim m_b^2$

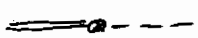
for $\bar{n}\cdot q \sim m_b$

$\bar{n}\cdot A_n \sim \lambda^0 \leftarrow$ no power suppression for these gluons

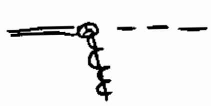
Find
$$\bar{\xi}_n\, \Gamma\, \frac{i(\not{k}+m_b)}{k^2-m_b^2}\, i g T^A \gamma^\mu\, h_v = -g\, \bar{\xi}_n \Gamma \frac{\left(\cancel{m_b}(1+\not{v}) + \cancelto{0}{\frac{\not{n}}{2}\bar{n}\cdot q}\right)\frac{\not{\bar{n}}}{2}\bar{n}^\mu T^A h_v}{n\cdot v\, \cancel{m_b}\, \bar{n}\cdot q}.$$

$$= \frac{-g\,\bar{n}^\mu}{\bar{n}\cdot q}\, \bar{\xi}_n\, \Gamma\, T^A \frac{\left(\cancelto{0}{-\frac{\not{\bar{n}}}{2}(1-\not{v})} + \cancel{n\cdot v}\right)}{\cancel{n\cdot v}}\, h_v \qquad \not{v}\, h_v = h_v$$

ie



$= \Gamma$



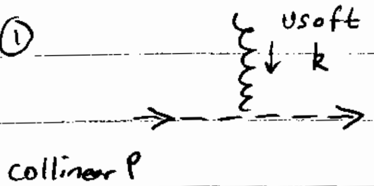
$= \dfrac{-g\,\bar{n}^\mu}{\bar{n}\cdot q}\,\Gamma\, T^A$

same order in $\lambda$

(add more gluons later)

Which fields can interact in a local way?

(1)

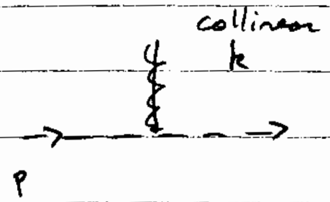



$p+k = \frac{n^\mu}{2}\,\bar{n}\cdot p + \frac{\bar{n}^\mu}{2}\,n\cdot(p+k) + p_\perp + \ldots$

still collinear

$\therefore$ local

(2)

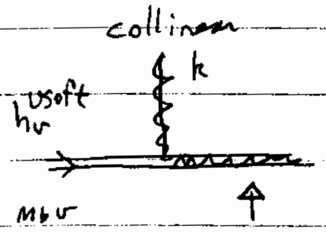



$p+k = \frac{n^\mu}{2}\,\bar{n}\cdot(p+k) + \frac{\bar{n}^\mu}{2}\,n\cdot(p+k) + p_\perp + k_\perp$

still collinear

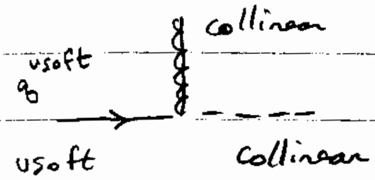
$\therefore$ local

(3)




offshell integrate it out (prev. eg.)

(4)




OK, local

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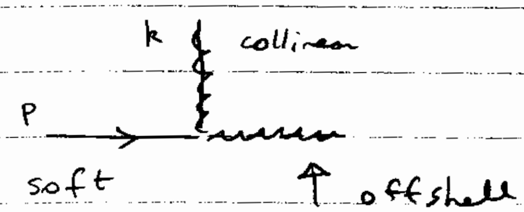
(5)




in $SCET_{II}$

$p+k = \frac{n^\mu}{2}\,\bar{n}\cdot p + \frac{\bar{n}^\mu}{2}\,n\cdot k + \ldots$

$(p+k)^2 = \bar{n}\cdot p\; n\cdot k \sim Q^2\lambda \gg Q^2\lambda^2$

UV    IR d.o.f.

Fields which mediate interactions in $SCET_{II}$ are offshell making it more complicated so we postpone further discussion to after developing $SCET_I$

skip to 201

# More on Power Counting

Separate $Q$, $Q\lambda$, $Q\lambda^2$ moments

| | | | | label | | residual | |
|---|---|---|---|---|---|---|---|
| Analogy | b: | HQET | $p^\mu =$ | $m_b v^\mu$ | $+$ | $k^\mu$ | $h_v(x)$ |
| | u: | SCET | $p^\mu =$ | $p^\mu$ | $+$ | $k^\mu$ | $\xi_{n,p}(x)$ |
| | | | | $\uparrow (1,\lambda)$ terms | | $\uparrow \lambda^2$ terms | |

<u>Mode Expn</u>

$$\psi(x) = \int d^4p\ \delta(p^2)\ \theta(p^0)\left[ u(p)\, a(p)\, e^{-ip\cdot x} + v(p)\, b^+(p)\, e^{ip\cdot x}\right]$$
$$= \psi^+ + \psi^-$$

expand & Write

$$\psi^+(x) = \sum_p e^{-ip\cdot x}\, \psi^+_{n,p}(x) \qquad \alpha\, \psi^\pm_{n,p} = 0$$
$$\psi^-(x) = \sum_p e^{ip\cdot x}\, \psi^-_{n,p}(x)$$

$\uparrow$ both have $\theta(\bar n\cdot p)$

Now define $\quad \xi_{n,p}(x) \equiv \psi^+_{n,p}(x) + \psi^-_{n,-p}(x)$

$\bar n\cdot p > 0$ particles $\quad E = \frac{\bar n\cdot p}{2} > 0$

$\bar n\cdot p < 0$ antiparticles $\quad E = -\frac{\bar n\cdot p}{2} > 0$

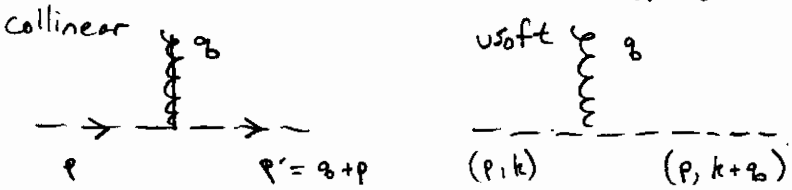
Similiar for Gluons $\quad A^\mu_{n,q}$ destroy

$\qquad A^{\mu *}_{n,q} = A^\mu_{n,-q}$ create

In HQET label $v^\mu$ was conserved by gluons

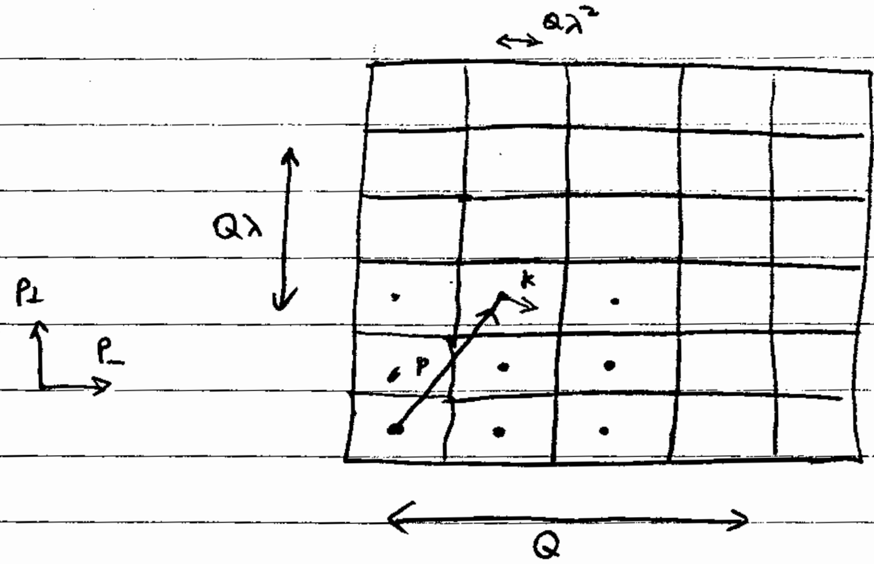
In SCET labels are changed by collinear gloons

" are conserved by usoft gloons




(label, residual)

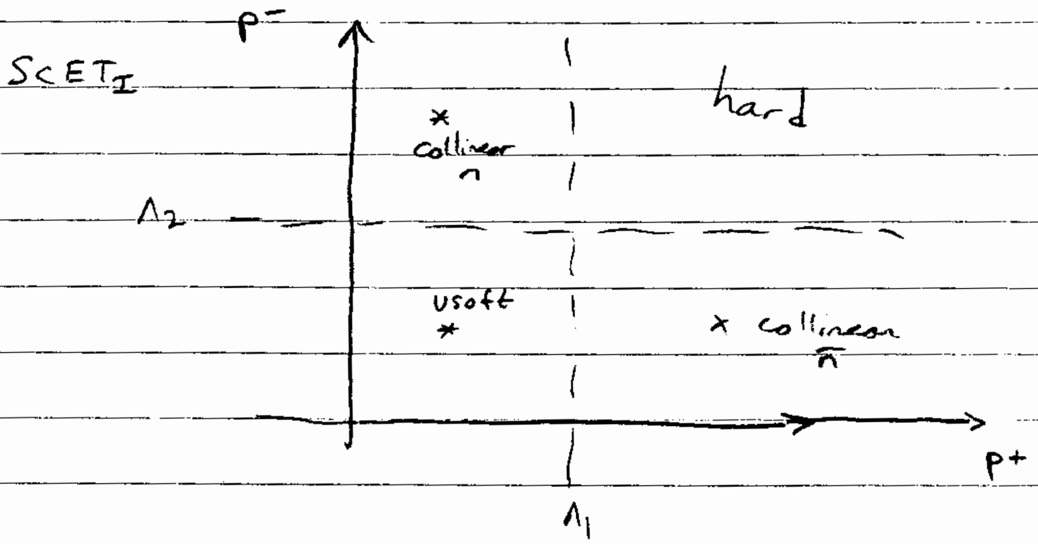
# Page with SCET Grid




large momentum $\mathcal{P}^- = p^- + k^-$

$\uparrow p^- \neq 0$

small momentum $\mathcal{P}^- = k^-$ , $p^- = 0$ , zero-bin




See hep-ph/0605001 for information on the details that we discussed in lecture

See hep-ph/0605001 for information on the details that we discussed in lecture

Introduce Label Operator for $p^\mu$ momenta

$$\mathcal{P}^\mu \left( \phi^\dagger_{q_1} \phi^\dagger_{q_2} \cdots \phi_{p_1} \phi_{p_2} \cdots \right) = \left( p_1^\mu + p_2^\mu + \cdots - q_1^\mu - q_2^\mu \right) \left( \phi^\dagger_{q_1} \cdots \phi_{p_1} \cdots \right)$$

eigenvalue eqtn

"derivative" for labels $\mathcal{P}^\mu$

derivative for residual $i\partial^\mu$

$$i\partial^\mu \sum_p e^{-ip\cdot x} \phi_{n,p}(x) = \sum_p e^{-ip\cdot x} \left( \mathcal{P}^\mu + i\partial^\mu \right) \phi_{n,p}(x)$$

$$= \sum_p e^{-ix\cdot\mathcal{P}} \left( \mathcal{P}^\mu + i\partial^\mu \right) \phi_{n,p}(x)$$

in products of fields this makes labels conserved

residual momentum conserved

5/3/06

## Summary

| Type | $(p^+, p^-, p^\perp)$ | Fields | | Field Scaling |
|---|---|---|---|---|
| collinear | $(\lambda^2, 1, \lambda)$ | $\xi_{n,p}(x)$ | | $\lambda$ |
| | | $(A^+_{n,p}, A^-_{n,p}, A^\perp_{n,p})$ | | $(\lambda^2, 1, \lambda)$ |
| soft | $(\lambda, \lambda, \lambda)$ | $q_{s,p}$ | essentially Fourier transform | $\lambda^{3/2}$ |
| | | $A^\mu_{s,p}$ | | $\lambda$ |
| usoft | $(\lambda^2, \lambda^2, \lambda^2)$ | $q_{us}$ | | $\lambda^3$ |
| | | $A^\mu_{us}$ | | $\lambda^2$ |