

## Guage Covariant Derivative & 4-Derivative

(-+++ convention used

$$QFTMetric = \begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix};$$

COORD = {x0, x1, x2, x3};

Bar[A\_] := Transpose[Conjugate[A]].γ0

GDer[A\_] := i (γ0. (D[A, x0]) + γ1. (D[A, x1]) + γ2. (D[A, x2]) + γ3. (D[A, x3]));

(\*If EM is included need to put in EM potential terms\*)

FourDer[A\_] := D[A, x0] + D[A, x1] + D[A, x2] + D[A, x3];

FourDerSQ[A\_] :=

Sum[Sum[QFTMetric[[i, i]] ((D[A, COOD[[i]]])^2), {i, 1, 4}][[j]], {j, 1, 4}][[1]]

FourLap[A\_] := Sum[ $\frac{1}{\sqrt{\text{Abs}[\text{Det}[QFTMetric]]}}$  D[ $\sqrt{\text{Abs}[\text{Det}[QFTMetric]]}$  QFTMetric[[i, i]] D[A[[i]], COOD[[i]], COOD[[i]], {i, 1, 4}][[1]]];

FourLap2[A\_] := Sum[ $\frac{1}{\sqrt{\text{Abs}[\text{Det}[QFTMetric]]}}$  D[ $\sqrt{\text{Abs}[\text{Det}[QFTMetric]]}$  QFTMetric[[i, i]] D[A[[i]], COOD[[i]], COOD[[i]], {i, 1, 4}];

(\* Metric = metric in 4D Spacetime

FourLapGen[A\_] :=

Sum[ $\frac{1}{\sqrt{\text{Abs}[\text{Det}[Metric]]}}$  D[ $\sqrt{\text{Abs}[\text{Det}[Metric]]}$  Metric[[i,i]] D[A[[i]],COOD[[i]],COOD[[i]], {i,1,4}][[1]]];\*)

## GR Math Stuff

### Metrics

$$a = \frac{J}{M};$$

$$\rho = r^2 + (a \cos[\theta])^2;$$

$$\Delta = r^2 - r_s r + a^2 + (r_0)^2;$$

KNMetric =

$$\begin{pmatrix} -L^2 (1 + (r^2)) & 0 & 0 & 0 \\ 0 & (L^2) (r^2) & 0 & 0 \\ 0 & 0 & (L^2) (r^2) (\sin[\alpha]^2) & 0 \\ 0 & 0 & 0 & (L^2) (1 + (r^2))^{(-1)} \end{pmatrix};$$

COORD = {x0, x1, x2, x3};