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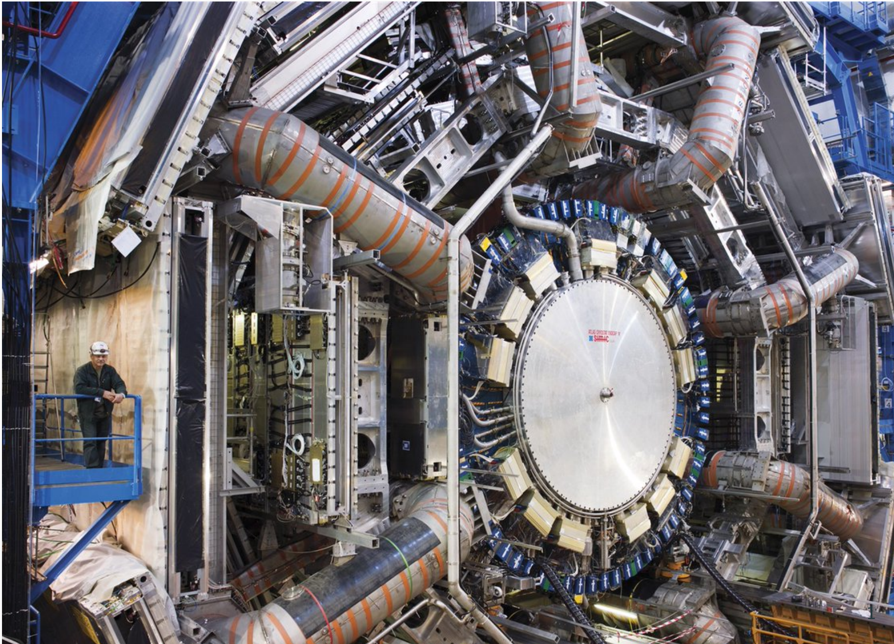
Artois University

September 29, 2017

Quantum field theory

Particle physics : $2 \sim 5$ billions €/years



N-point functions

$$< \Phi_1(x) \ldots \Phi_n(x) >$$

N-point functions

$$< \Phi_1(x) \ldots \Phi_n(x) > \quad =$$

N-point functions

$$< \Phi_1(x) \dots \Phi_n(x) > \quad = \quad \int \Phi_1(x) \dots \Phi_n(x) d\mu$$

N-point functions

$$\begin{aligned} < \Phi_1(x) \ldots \Phi_n(x) > &= \int \Phi_1(x) \ldots \Phi_n(x) d\mu \\ &= \int \Phi_1(x) \ldots \Phi_n(x) e^{-S(x)} dx \end{aligned}$$

N-point functions in maths

N-point functions in maths

Gromov-Witten

N-point functions in maths

Gromov-Witten, Jones Polynomial

N-point functions in maths

Gromov-Witten, Jones Polynomial, Mirror symetry

N-point functions in maths

Gromov-Witten, Jones Polynomial, Mirror symetry, Kontsevich knot invariant

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$$< \Phi_1(x) \dots \Phi_n(x) >$$

Problem with definition

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$\mathcal{M}$

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$$\mathcal{M} \quad =$$

Problem with definition

$$< \Phi_1(x) \ldots \Phi_n(x) > \; = \int_{\mathcal{M}} \Phi_1(x) \ldots \Phi_n(x) d\mu$$

$$\mathcal{M} \quad = \quad \textit{space of fields}$$

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$\Gamma(M, P)$

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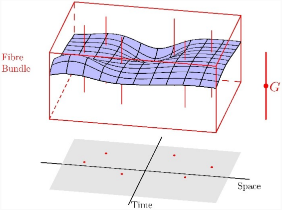
$\Gamma(M, P)$



reduction to the kinetic term

$$S(x)$$

reduction to the kinetic term

$$S(x) =$$

reduction to the kinetic term

$$S(x) = C$$

reduction to the kinetic term

$$S(x) = C +$$

reduction to the kinetic term

$$S(x) = C + a_1 x$$

reduction to the kinetic term

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reduction to the kinetic term

$$S(x) = C + a_1 x + a_2 x^2$$

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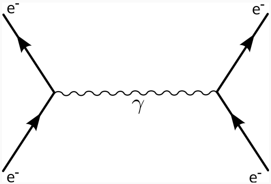
reduction to the kinetic term

$$S(x) = C + a_1 x + a_2 x^2 + \textit{ higher orders}$$

reduction to the kinetic term

$$S(x) = C + a_1 x + a_2 x^2 + \text{ } \textit{higher orders}$$



reduction to the kinetic term

$$S(x) = C + a_1 x + a_2 x^2$$

reduction to the kinetic term

$$S(x) = \qquad a_1 x + a_2 x^2$$

reduction to the kinetic term

$$S(x) = a_2 x^2$$

A 50 billion € trick

$$< \Phi_1(x) \ldots \Phi_n(x) >$$

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$$< \Phi_1(x) \dots \Phi_n(x) > \quad := \quad \int \Phi_1(x) \dots \Phi_n(x) d\mu$$

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$$
\begin{aligned}
< \Phi_1(x) \dots \Phi_n(x) > \quad &:= \quad \int \Phi_1(x) \dots \Phi_n(x) d\mu \\
&:=
\end{aligned}
$$

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&= \int \Phi_1(x) \ldots \Phi_n(x) e^{-\frac{1}{2}(X,AX)} dx
\end{aligned}
$$

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A 50 billion € trick

$$\begin{aligned} < \Phi_1(x)\ldots\Phi_n(x) > &:= \int \Phi_1(x)\ldots\Phi_n(x)d\mu \\ &:= \int \Phi_1(x)\ldots\Phi_n(x)e^{-S(x)}dx \\ &= \int \Phi_1(x)\ldots\Phi_n(x)e^{-\frac{1}{2}(X,AX)}dx \\ < x > &= \int xe^{-\frac{1}{2}(X,AX)}dx \end{aligned}$$

$$\frac{\partial}{\partial B_i} e^{(B,X)} = x_i e^{(B,X)}$$

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$$Z(B) \qquad = \int e^{-\frac{1}{2}(X,AX)+(B,X)} dx$$

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$$\frac{\partial}{\partial B_i} Z(B) = \frac{\partial}{\partial B_i} \int e^{-\frac{1}{2}(X,AX)+(B,X)} dx$$

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$$\frac{\partial}{\partial B_i} Z(B) = \int x_i e^{-\frac{1}{2}(X,AX)+(B,X)} dx$$

$$\frac{\partial}{\partial B_i} Z(B)_{|B=0} = \int x_i e^{-\frac{1}{2}(X,AX)+(B,X)} dx$$

$$\frac{\partial}{\partial B_i} Z(B)_{|B=0} = \int x_i e^{-\frac{1}{2}(X,AX)} dx$$

$$\frac{\partial}{\partial B_i} Z(B)_{|B=0} \qquad = < x_i >$$

$$\frac{\partial}{\partial B_{i_1}} Z(B) \quad = $$

$$\frac{\partial}{\partial B_{i_1}} Z(B) = \int x_{i_1} e^{-\frac{1}{2}(X,AX)+(B,X)} dx$$

$$\frac{\partial}{\partial B_{i_1}} \cdots \frac{\partial}{\partial B_{i_k}} Z(B) = \int x_{i_1} e^{-\frac{1}{2}(X,AX)+(B,X)} dx$$

$$\frac{\partial}{\partial B_{i_1}} \cdots \frac{\partial}{\partial B_{i_k}} Z(B) = \int x_{i_1} \ldots x_{i_k} e^{-\frac{1}{2}(X,AX)+(B,X)} dx$$

$$\frac{\partial}{\partial B_{i_1}} \cdots \frac{\partial}{\partial B_{i_k}} Z(B)_{|B=0} = \int x_{i_1} \ldots x_{i_k} e^{-\frac{1}{2}(X,AX)+(B,X)} dx$$

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$$\Phi_1(\frac{\partial}{\partial B}) \dots \Phi_n(\frac{\partial}{\partial B}) Z(B)_{|B=0} = \int x_{i_1} \dots x_{i_k} e^{-\frac{1}{2}(X,AX)} dx$$

$$\Phi_1(\frac{\partial}{\partial B}) \dots \Phi_n(\frac{\partial}{\partial B}) Z(B)_{|B=0} = \int \Phi_1(x) \dots \Phi_n(x) e^{-\frac{1}{2}(X,AX)} dx$$

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$$< \Phi_1(x) \ldots \Phi_n(x) > \; = \Phi_1\left(\frac{\partial}{\partial B}\right) \ldots \Phi_n\left(\frac{\partial}{\partial B}\right) Z(B)_{|B=0}$$

A 50 billion € trick

$$< \Phi_1(x) \ldots \Phi_n(x) > \; = \Phi_1(\frac{\partial}{\partial B}) \ldots \Phi_n(\frac{\partial}{\partial B}) Z(B)_{|B=0}$$

$Z(B)$

A 50 billion € trick

$$< \Phi_1(x) \dots \Phi_n(x) > \; = \Phi_1(\frac{\partial}{\partial B}) \dots \Phi_n(\frac{\partial}{\partial B}) Z(B)_{|B=0}$$

$$Z(B) \qquad =$$

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$$< \Phi_1(x) \dots \Phi_n(x) > \; = \Phi_1(\frac{\partial}{\partial B}) \dots \Phi_n(\frac{\partial}{\partial B}) Z(B)_{|B=0}$$

$$Z(B) \quad = \quad e^{\frac{1}{2}(B, A^{-1}B)} \int e^{-\frac{1}{2}(x, Ax)} dx$$

A 50 billion € trick

$$< \Phi_1(x) \ldots \Phi_n(x) > \; = \Phi_1(\frac{\partial}{\partial B}) \ldots \Phi_n(\frac{\partial}{\partial B}) Z(B)_{|B=0}$$

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A 50 billion € trick

$$< \Phi_1(x) \ldots \Phi_n(x) > \; = \Phi_1(\frac{\partial}{\partial B}) \ldots \Phi_n(\frac{\partial}{\partial B}) Z(B)_{|B=0}$$

$$Z(B)/Z(0) \quad = \quad e^{\frac{1}{2}(B,A^{-1}B)} Z(0)$$

A 50 billion € trick

$$< \Phi_1(x) \dots \Phi_n(x) > \; = \Phi_1(\frac{\partial}{\partial B}) \dots \Phi_n(\frac{\partial}{\partial B}) Z(B)_{|B=0}$$

$$Z(B)/Z(0) \qquad = \qquad e^{\frac{1}{2}(B, A^{-1}B)}$$

Symmetries

$$S(x + \epsilon V) =$$

Symmetries

$$S(x + \epsilon V) \qquad = S(x)$$

Symmetries

$$S(x + \epsilon V) - S(V) =$$

Symmetries

$$S(x + \epsilon V) - S(V) = 0$$

Symmetries

$$dS(V) = 0$$

Symmetries

$$AV \qquad\qquad = 0$$

Symmetries

$$AV = 0$$

$$A^{-1}?$$

Dictionnary

Dictionnary

fields

Dictionnary

fields words

Dictionnary

fields	words
gauge symmetry	

Dictionnary

fields	words
gauge symmetry	rewriting

Dictionnary

fields	words
gauge symmetry	rewriting
gauge fixing	

Dictionnary

fields	words
gauge symmetry	rewriting
gauge fixing	normal form

Dictionnary

fields	words
gauge symmetry	rewriting
gauge fixing	normal form
BRST/BV	

Dictionnary

fields	words
gauge symmetry	rewriting
gauge fixing	normal form
BRST/BV	Squier resolution

Gauge Fixing

If

Gauge Fixing

If

$$\mathcal{M} = G \times B$$

Gauge Fixing

If

$$\mathcal{M} = G \times B$$

f

Gauge Fixing

If

$$\mathcal{M} = G \times B$$

$f, \, dx$

Gauge Fixing

If

$$\mathcal{M} = G \times B$$

$$f,\ dx,\ G - invariants$$

Gauge Fixing

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$$\mathcal{M} = G \times B$$

$$f,\ dx,\ G - invariants$$

$$I =$$

Gauge Fixing

If

$$\mathcal{M} = G \times B$$

$$f,\ dx,\ G - invariants$$

$$I = \int_{\mathcal{M}} f(x) dx$$

Gauge Fixing

If

$$\mathcal{M} = G \times B$$

$$f,\ dx,\ G - invariants$$

$$I = \int_{\mathcal{M}} f(x)dx = \int_{\overline{\mathcal{M}}} \overline{f}(\overline{x})\overline{dx}$$

Gauge Fixing

$$\int_{\mathcal{M}} \qquad f(x) \qquad dx$$

Gauge Fixing

$$\int_{\mathcal{M}} \qquad f(x)\delta_0(F(x)) \qquad dx$$

Gauge Fixing

$$\int_{\mathcal{M}} \qquad f(x)\delta_0(F(x)) \;\; det(dF(x))dx$$

Gauge Fixing

$$\int_{\mathcal{M}} \qquad f(x)e^{i<\lambda,F(x)>}det(dF(x))dx$$

Gauge Fixing

$$\int_{\mathcal{M} \times \Gamma^*} f(x)e^{i<\lambda,F(x)>}det(dF(x))dx$$

Gauge Fixing

$$\int_{\mathcal{M} \times \Gamma^*} \qquad f(x) e^{i<\lambda, F(x)>} det(\Lambda) \qquad dx$$

Gauge Fixing

$$\int_{\mathcal{M} \times \Gamma^*} f(x) e^{i<\lambda, F(x)>} e^{<\bar{c}, \Lambda c>} \quad dx$$

Gauge Fixing

$$\int_{\mathcal{M} \times \Gamma^* \times \Pi\Gamma} f(x) e^{i<\lambda, F(x)>} e^{<\bar{c}, \Lambda c>} \quad dx$$

Gauge Fixing

$$\int_{\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*} f(x) e^{i<\lambda, F(x)>} e^{<\bar{c}, \Lambda c>} \qquad dx$$

Gauge Fixing

$$\int_{\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*} f(x) e^{i<\lambda, F(x)>} e^{<\bar{c}, \Lambda c>} \quad dx$$

$$\mathcal{F}un(\overline{\mathcal{M}})$$

Gauge Fixing

$$\int_{\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*} f(x) e^{i<\lambda, F(x)>} e^{<\bar{c}, \Lambda c>} \quad dx$$

$$\mathcal{F}un(\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*) \qquad \mathcal{F}un(\overline{\mathcal{M}})$$

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$$\int_{\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*} f(x) e^{i<\lambda, F(x)>} e^{<\bar{c}, \Lambda c>} \quad dx$$

$$\mathcal{F}un(\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*) \quad S \in \mathcal{F}un(\overline{\mathcal{M}})$$

Gauge Fixing

$$\int_{\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*} f(x) e^{i<\lambda, F(x)>} e^{<\bar{c}, \Lambda c>} \quad dx$$

$$S_F \in \mathcal{F}un(\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*) \quad S \in \mathcal{F}un(\overline{\mathcal{M}})$$

Gauge Fixing

$$\int_{\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*} f(x) e^{i<\lambda, F(x)>} e^{<\bar{c}, \Lambda c>} \quad dx$$

$$\mathcal{F}un(\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*) \qquad \mathcal{F}un(\overline{\mathcal{M}})$$

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$$\mathcal{F}un(\mathcal{M}\times\Gamma^*\times\Pi\Gamma\times\Pi\Gamma^*)\twoheadrightarrow \quad \mathcal{F}un(\overline{\mathcal{M}})$$

Gauge Fixing

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Gauge fixed action

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$$S_F = -\frac{1}{2}(X, AX) + i < \lambda, F(x) > + < \bar{c}, \Lambda c >$$

Gauge fixed action

For example, if $S = -\frac{1}{2}(X, AX)$

$$S_F = -\frac{1}{2}(X, AX) + i < \lambda, F(x) > + < \bar{c}, \Lambda c >$$

which is non-degenerate!!!!!!!!

Where are we?

Where are we?

If S non-degenerate:

Where are we?

If S non-degenerate:

$$< \Phi_1(x) \dots \Phi_n(x) > := \int_{\mathcal{M}} \Phi_1(x) \dots \Phi_n(x) e^{-S} dx$$

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Else :

S_F non degenerate on $\mathcal{M}_{BRST} := \mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*$.

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$\exists$?

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$\exists ? \delta$

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$\exists ? \delta$ on $\mathcal{F}un(\mathcal{M}_{BRST})$

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$\exists ? \delta$ on $\mathcal{F}un(\mathcal{M}_{BRST})$

$$H(\mathcal{F}un(\mathcal{M}_{BRST}))$$

Where are we?

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$\exists ? \delta$ on $\mathcal{F}un(\mathcal{M}_{BRST})$

$$H(\mathcal{F}un(\mathcal{M}_{BRST})) \simeq \mathcal{F}un(\overline{\mathcal{M}})?$$

Where are we?

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$\exists ? \delta$ on $\mathcal{F}un(\mathcal{M}_{BRST})$

$$H(\mathcal{F}un(\mathcal{M}_{BRST})) \simeq \mathcal{F}un(\overline{\mathcal{M}})?$$

Dependence on F?

BRST

BRST

Differential on $\mathcal{F}un(\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*)$?

BRST

Differential on $\mathcal{F}un(\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*)$?

$$\delta_\Gamma c^i := f^i_{jk} c^j c^k$$

BRST

Differential on $\mathcal{F}un(\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*)$?

$$\delta_\Gamma c^i := f^i_{jk} c^j c^k$$

$$\delta_\Gamma^2 = 0$$

BRST

Differential on $\mathcal{F}un(\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*)$?

$$\delta_\Gamma c^i := f^i_{jk} c^j c^k$$

$$\delta_\Gamma^2 = 0 \iff$$

BRST

Differential on $\mathcal{F}un(\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*)$?

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$$\delta_\Gamma^2 = 0 \iff \textit{Jacobi}$$

BRST

Differential on $\mathcal{F}un(\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*)$?

$$\delta_\Gamma c^i := f^i_{jk} c^j c^k$$
$$\delta_\mathcal{M} f := c^i L_{X_{e_i}} f$$

$$\delta_\Gamma^2 = 0 \iff \textit{Jacobi}$$

BRST

Differential on $\mathcal{F}un(\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*)$?

$$\delta_\Gamma c^i := f^i_{jk} c^j c^k$$
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$\delta_\mathcal{M}$

BRST

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$$\delta_\Gamma c^i := f^i_{jk} c^j c^k$$
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$$\delta_\Gamma^2 = 0 \iff \textit{Jacobi}$$

$(\delta_\mathcal{M} + \delta_\Gamma)$

BRST

Differential on $\mathcal{F}un(\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*)$?

$$\delta_\Gamma c^i := f^i_{jk} c^j c^k$$
$$\delta_\mathcal{M} f := c^i L_{X_{e_i}} f$$

$$\delta_\Gamma^2 = 0 \iff Jacobi$$

$$(\delta_\mathcal{M} + \delta_\Gamma)^2 = 0$$

BRST

Differential on $\mathcal{F}un(\mathcal{M} \times \Gamma^* \times \Pi\Gamma \times \Pi\Gamma^*)$?

$$\delta_\Gamma c^i := f^i_{jk} c^j c^k$$
$$\delta_\mathcal{M} f := c^i L_{X_{e_i}} f$$

$$\delta_\Gamma^2 = 0 \iff \textit{Jacobi}$$
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$$\delta_{\mathcal{M}+\Gamma} f = 0 \iff f \ invariant$$

BRST

BRST

δ_λ?

BRST

$\delta_\lambda ? \delta_{\overline{c}} ?$

BRST

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Proposition

$\delta_\lambda ? \delta_{\overline{c}} ?$

Proposition

$\int \quad e^{-S_F}$

BRST

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$\int e^{-S_F}$ *does not depend on* F.

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BRST

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Proposition

$\int g e^{-S_F}$ does not depend on F.   ..if $div(\delta) = 0$, g and S invariants.

$$S_F = S + \delta \Psi_F$$

$$\frac{d}{dt} \int e^{-S_{F_t}} = 0$$