Loop Calculations: Summary

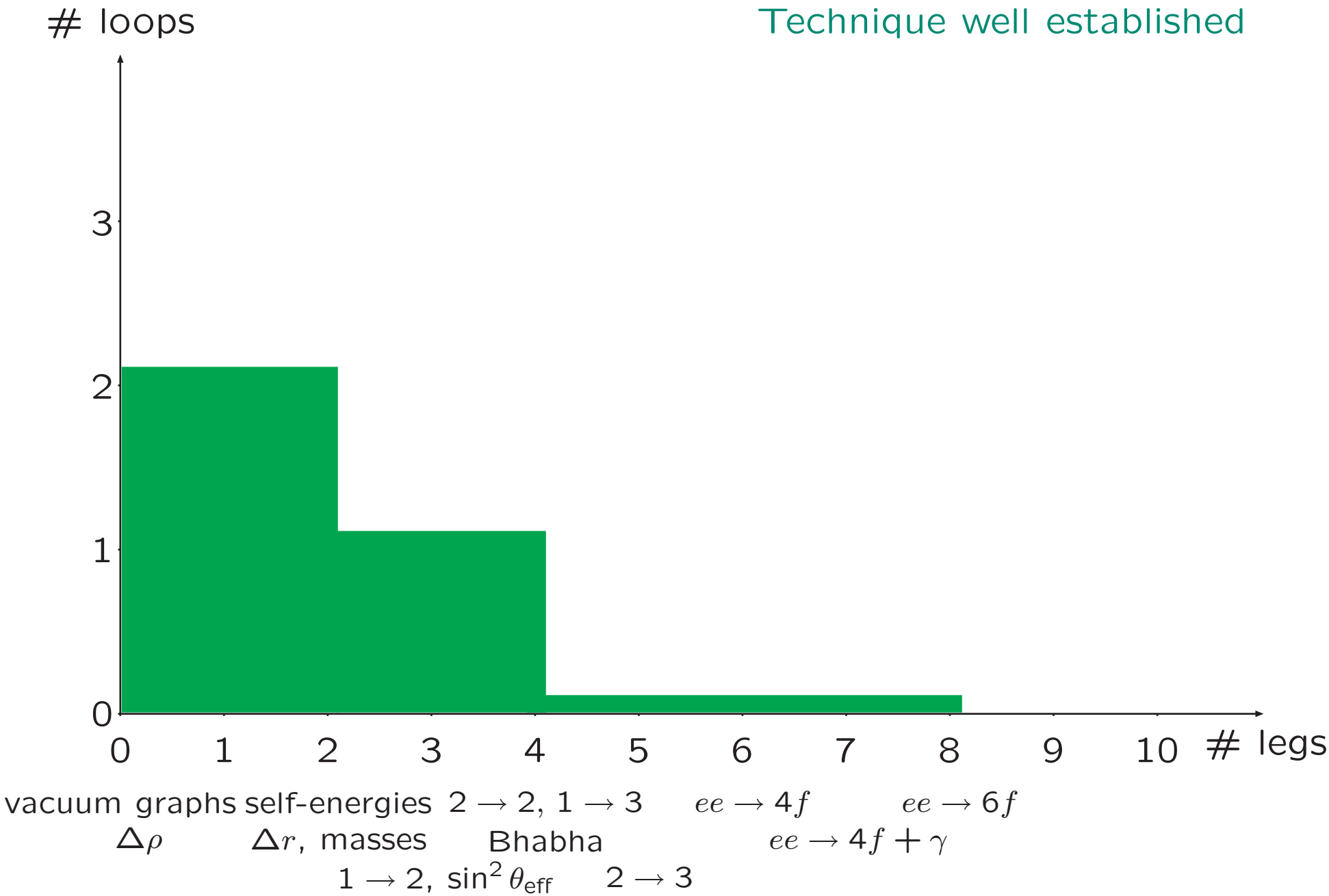
Sven Heinemeyer, CERN

Paris, 04/2004

10 Minutes (minus discussion time) $\Rightarrow$ usual apologies

- Status of the field
- Contributions at the LCWS Paris
- What is needed for the future?
- Conclusions

Technique well established



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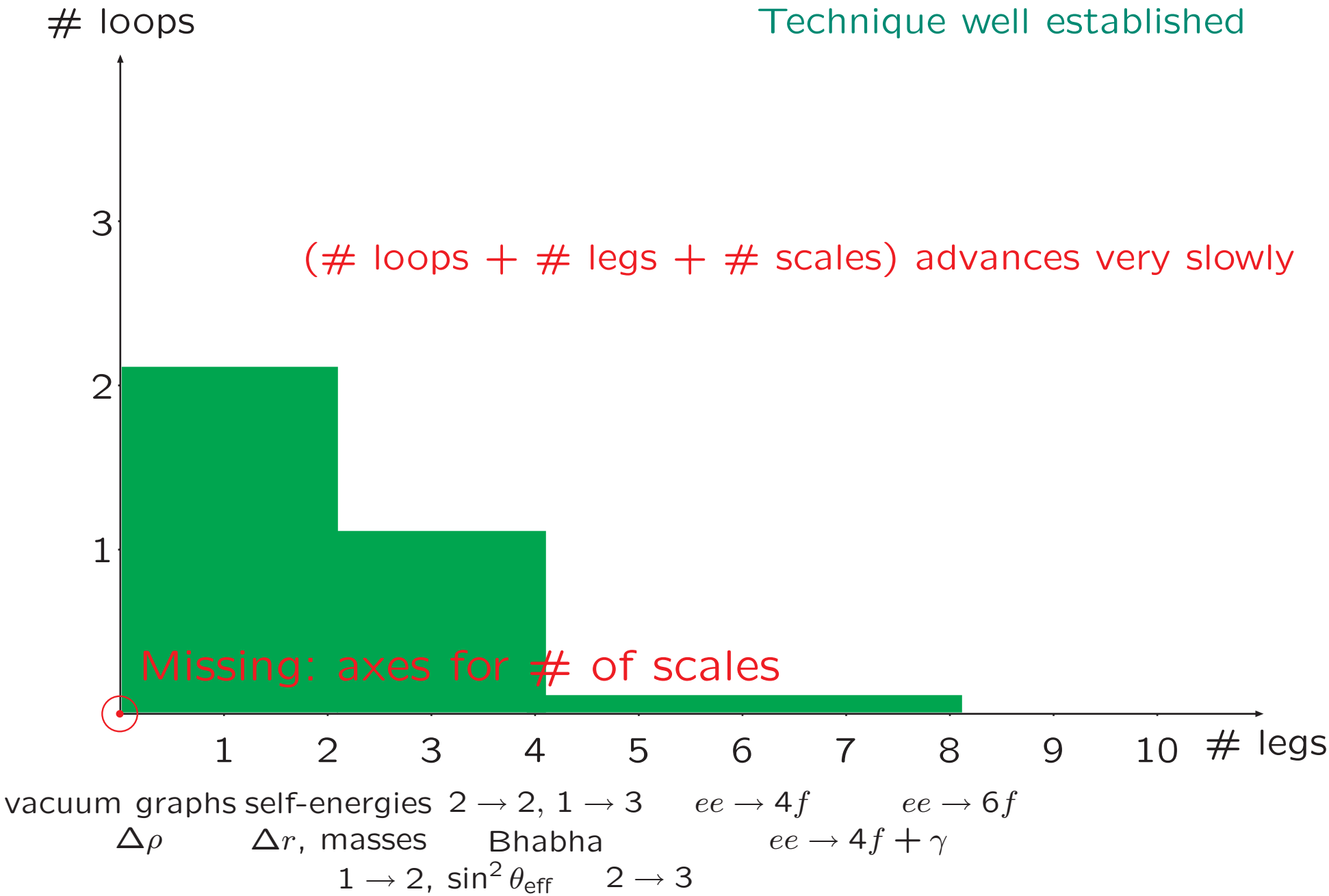

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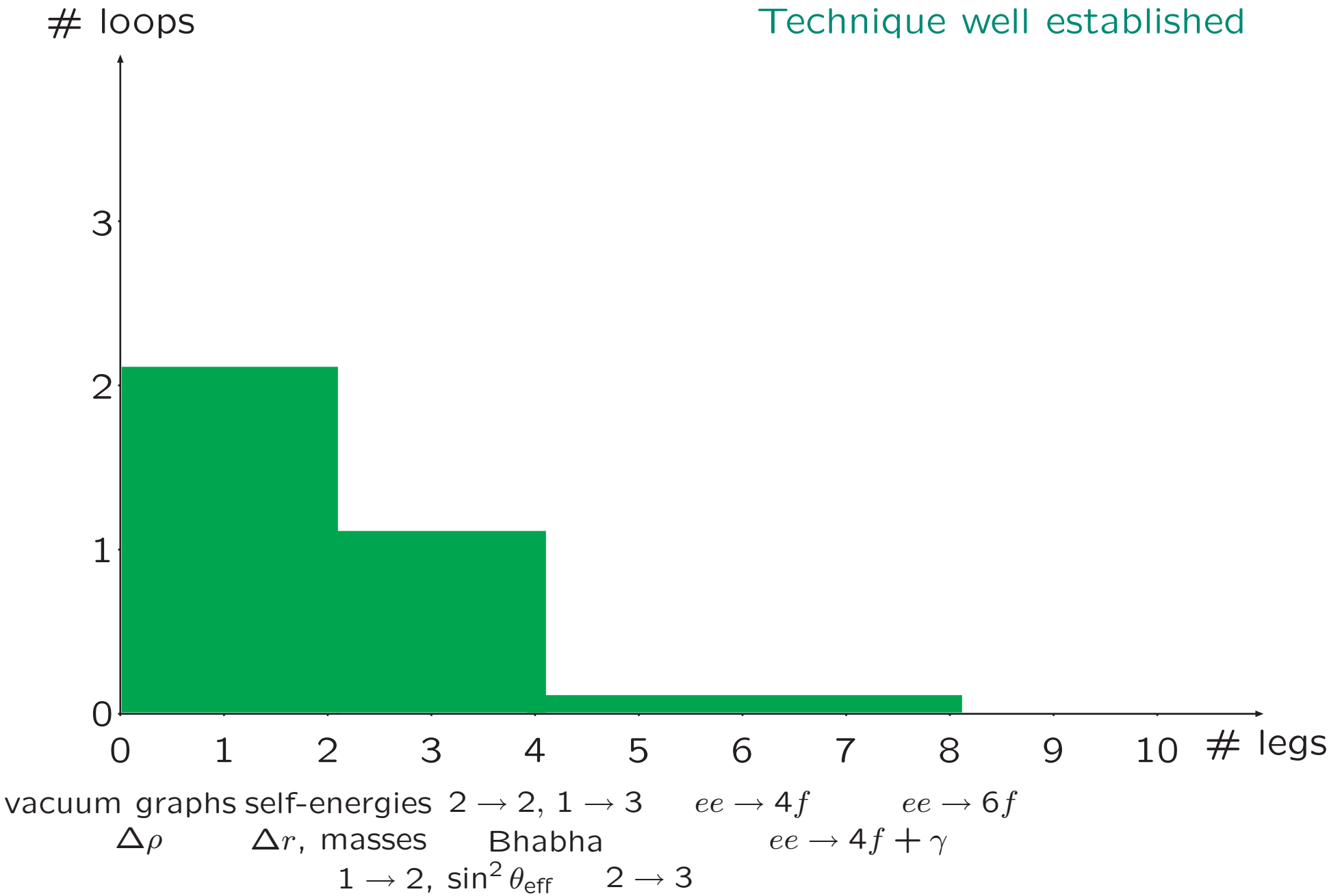

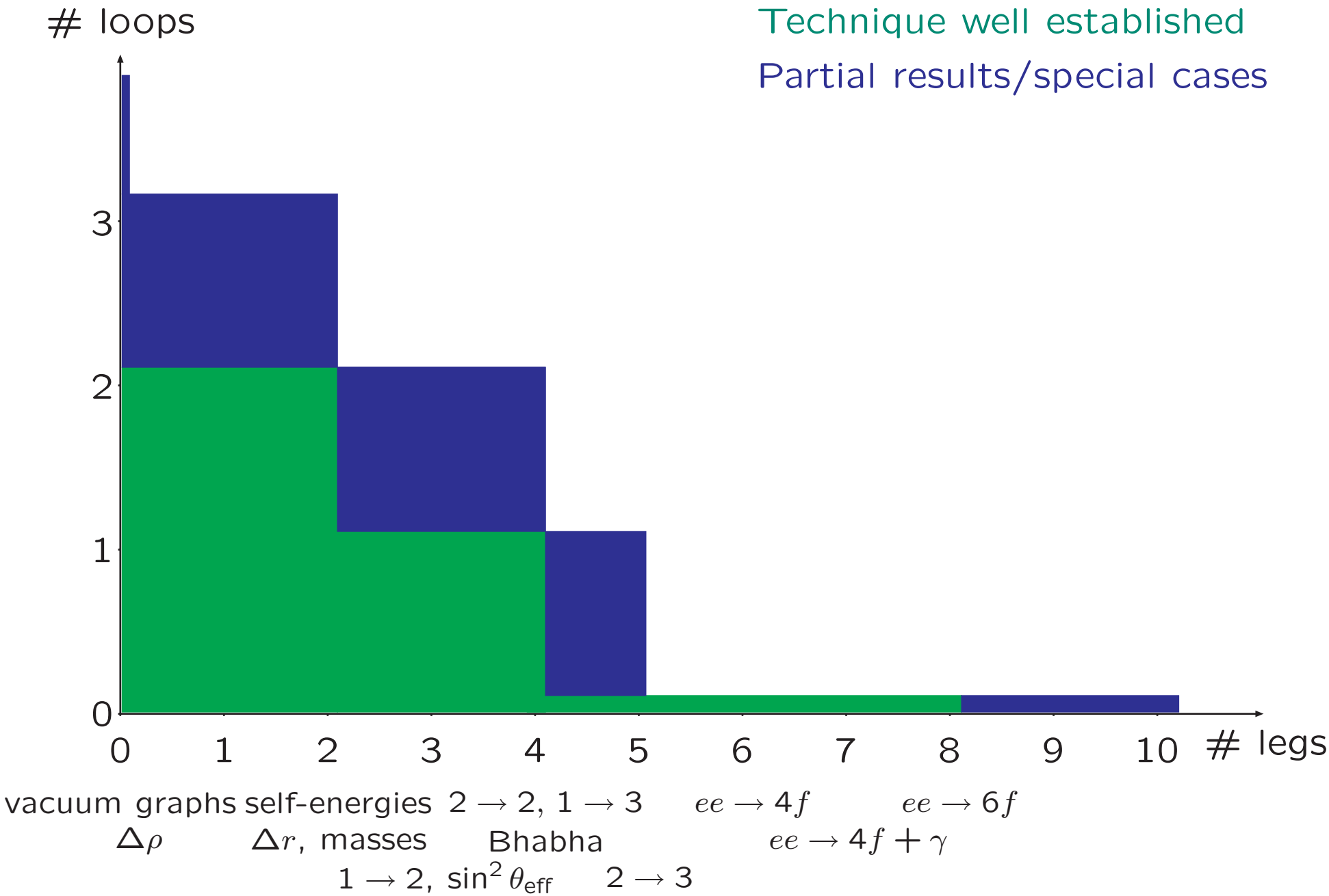
Technique well established
Partial results/special cases
loops
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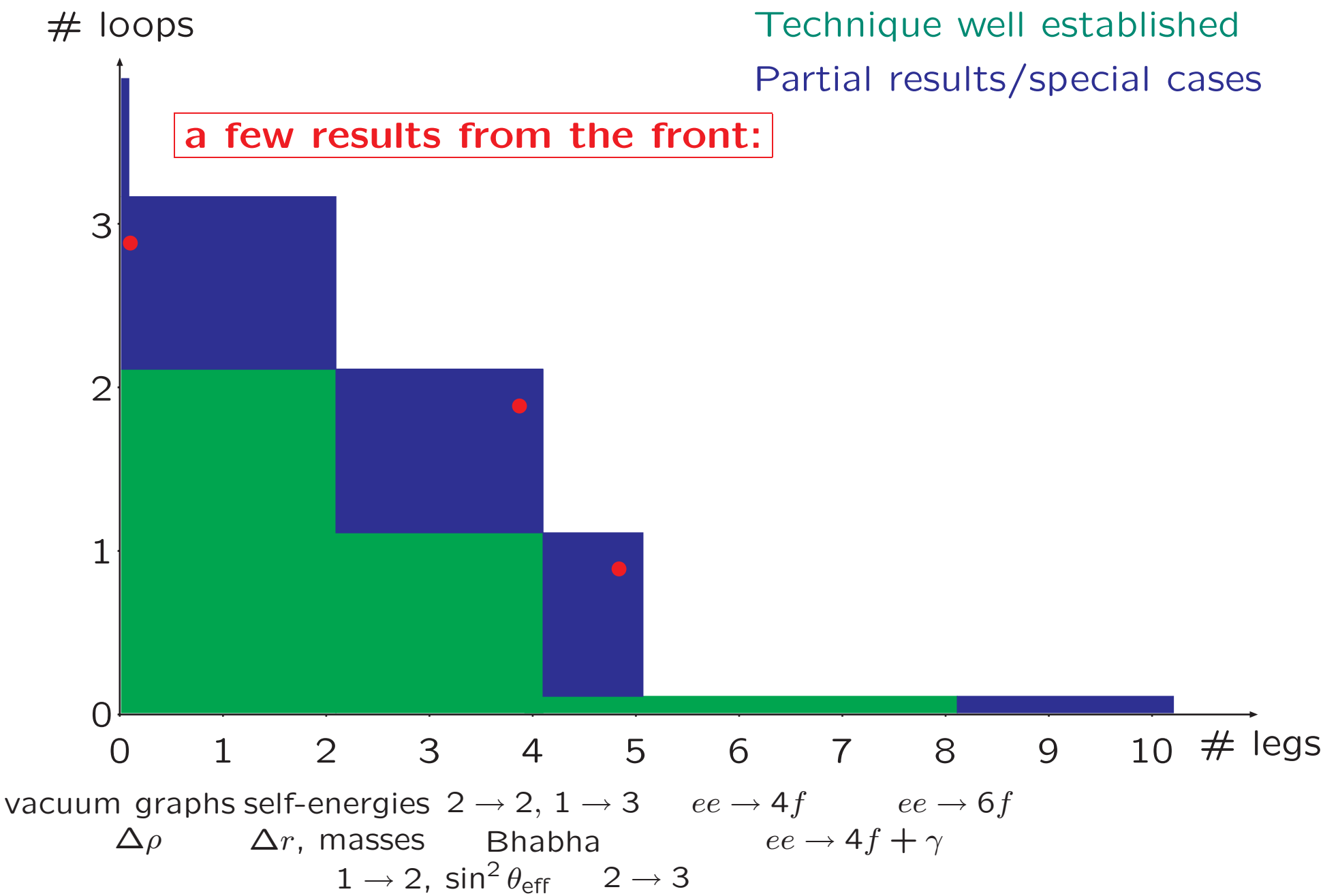
legs
vacuum graphs
self-energies
$2 \to 2,\ 1 \to 3$
$ee \to 4f$
$ee \to 6f$
$\Delta\rho$
Δr, masses
Bhabha
$ee \to 4f + \gamma$
$1 \to 2,\ \sin^2\theta_{\text{eff}}$
$2 \to 3$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Partial results/special cases
a few results from the front:
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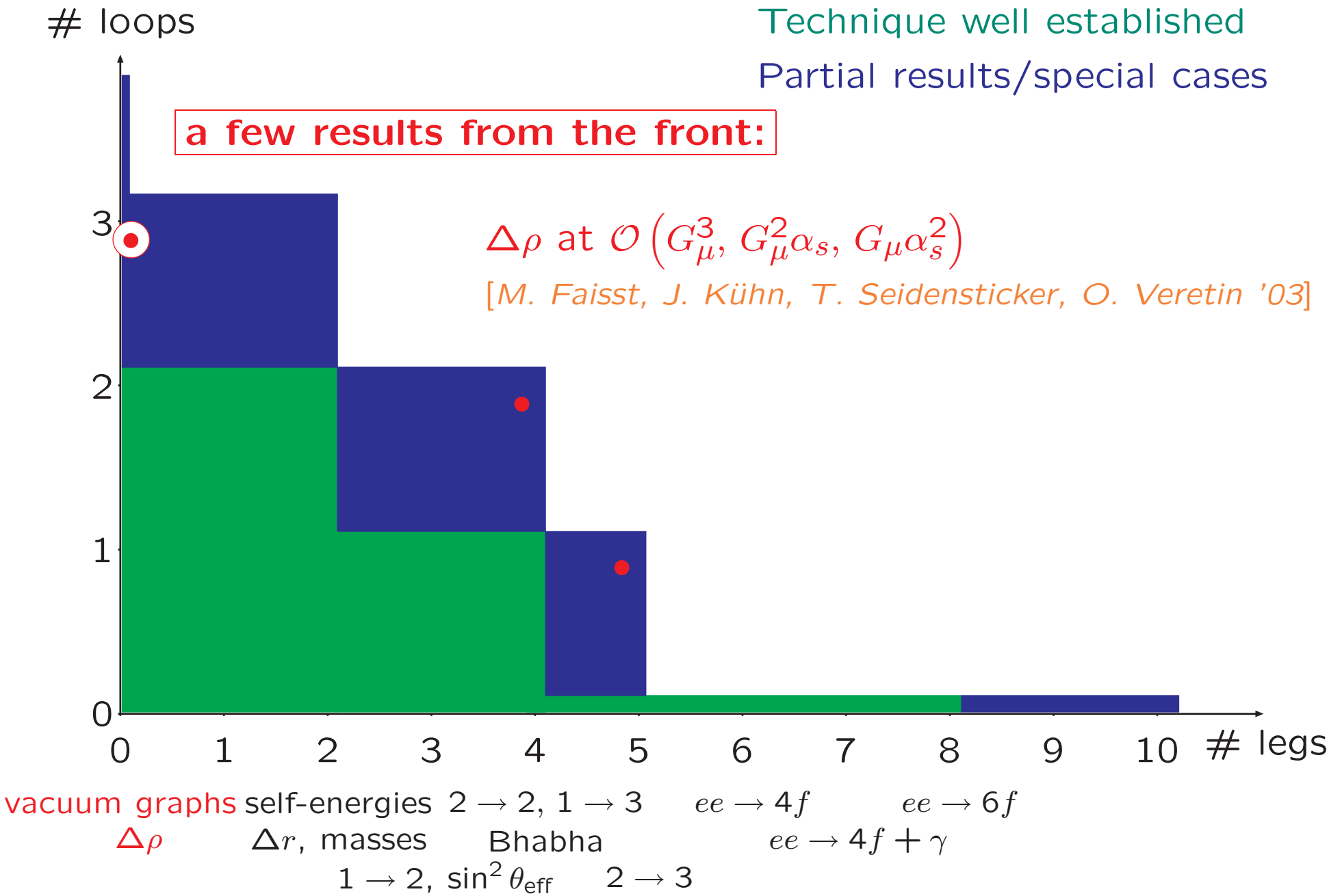
Technique well established
Partial results/special cases
a few results from the front:
$\Delta\rho$ at $\mathcal{O}\left(G_\mu^3, G_\mu^2\alpha_s, G_\mu\alpha_s^2\right)$
[M. Faisst, J. Kühn, T. Seidensticker, O. Veretin '03]
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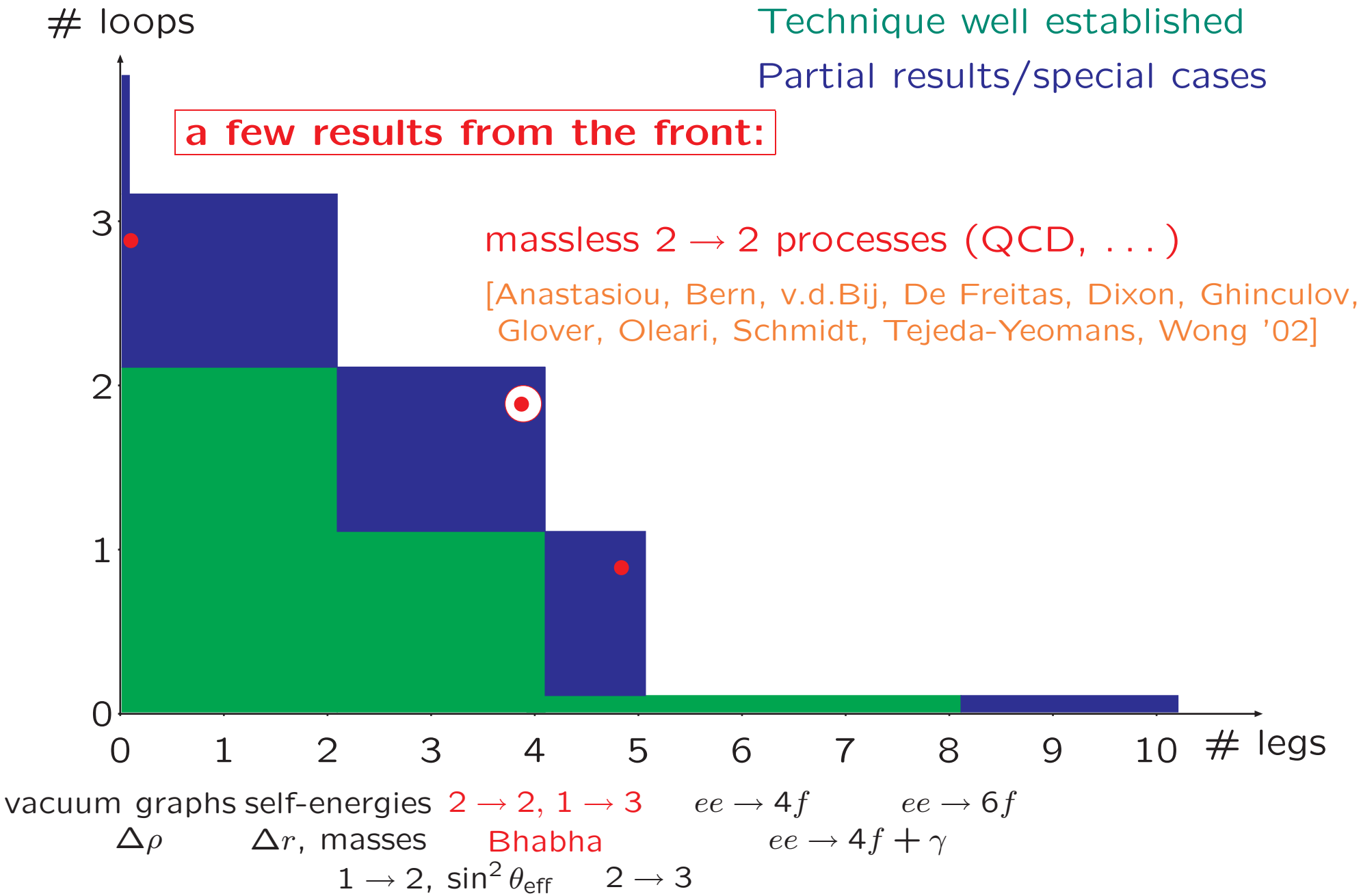
loops
Technique well established
Partial results/special cases
a few results from the front:
massless 2 → 2 processes (QCD, . . .)
[Anastasiou, Bern, v.d.Bij, De Freitas, Dixon, Ghinculov, Glover, Oleari, Schmidt, Tejeda-Yeomans, Wong '02]
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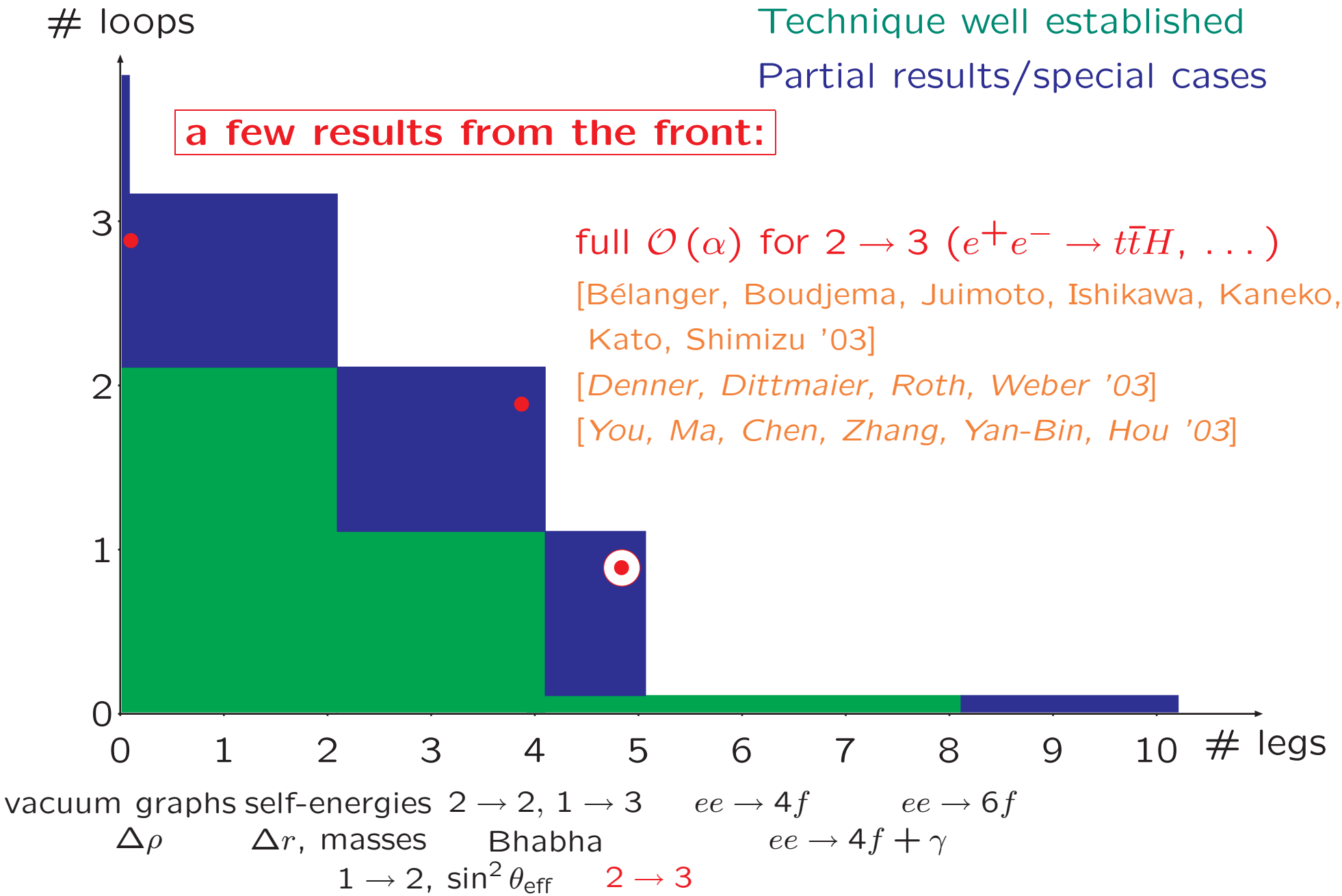
legs
vacuum graphs
self-energies
2 → 2, 1 → 3
ee → 4f
ee → 6f
Δρ
Δr, masses
Bhabha
ee → 4f + γ
1 → 2, sin²θ_eff
2 → 3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Partial results/special cases
loops
a few results from the front:
full $\mathcal{O}(\alpha)$ for $2 \to 3$ ($e^+e^- \to t\bar{t}H$, ...)
[Bélanger, Boudjema, Juimoto, Ishikawa, Kaneko, Kato, Shimizu '03]
[Denner, Dittmaier, Roth, Weber '03]
[You, Ma, Chen, Zhang, Yan-Bin, Hou '03]
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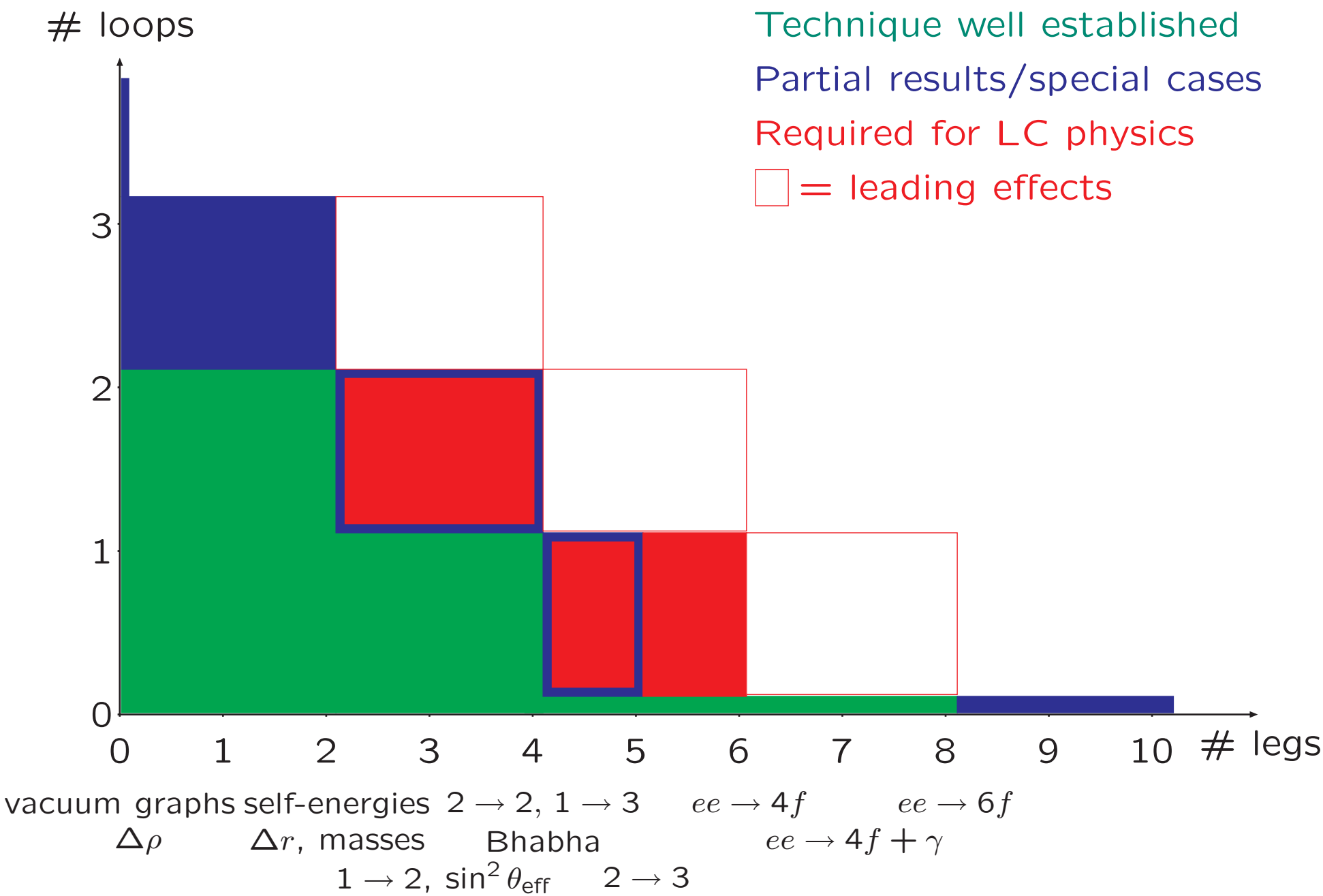
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Partial results/special cases
Required for LC physics
= leading effects
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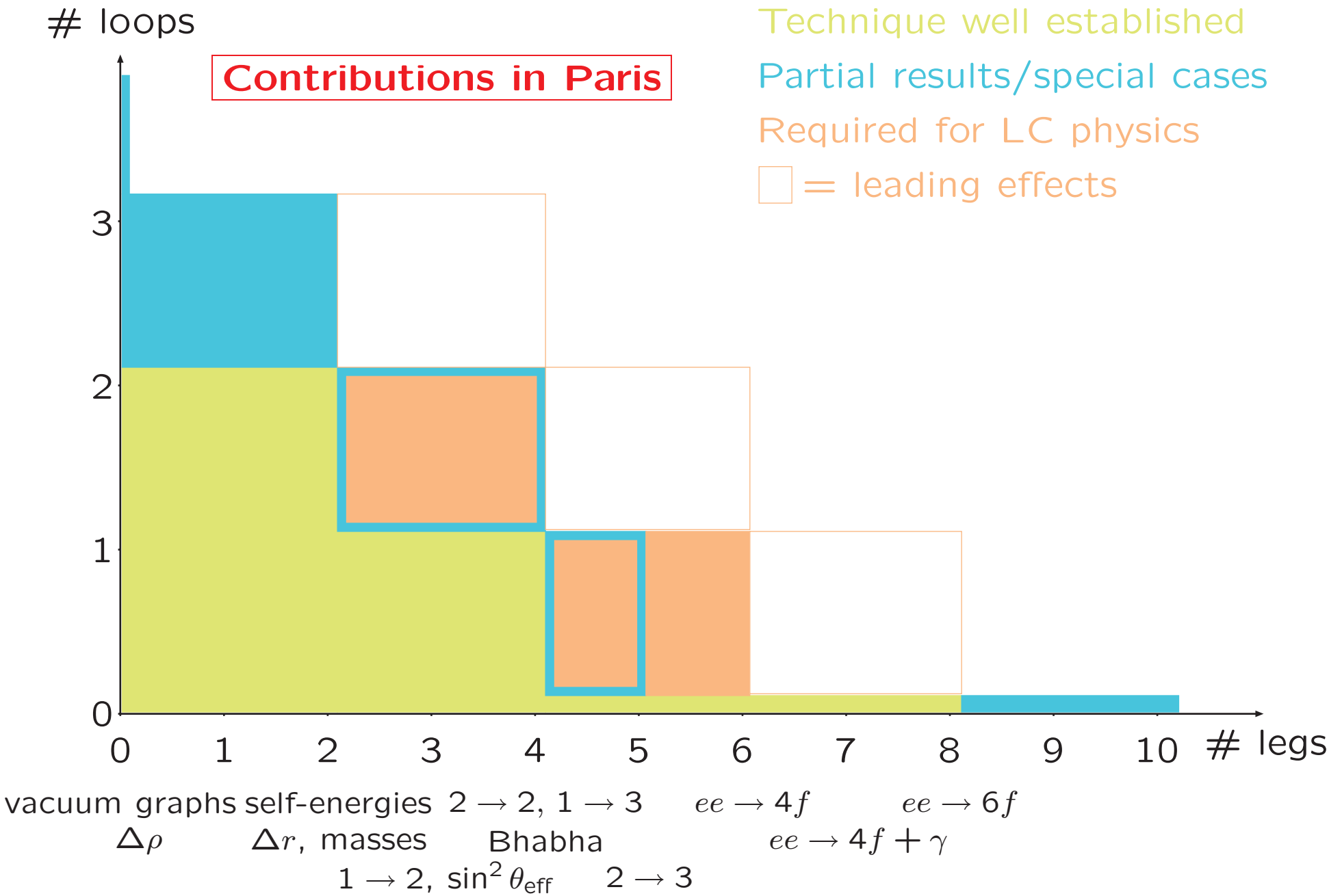
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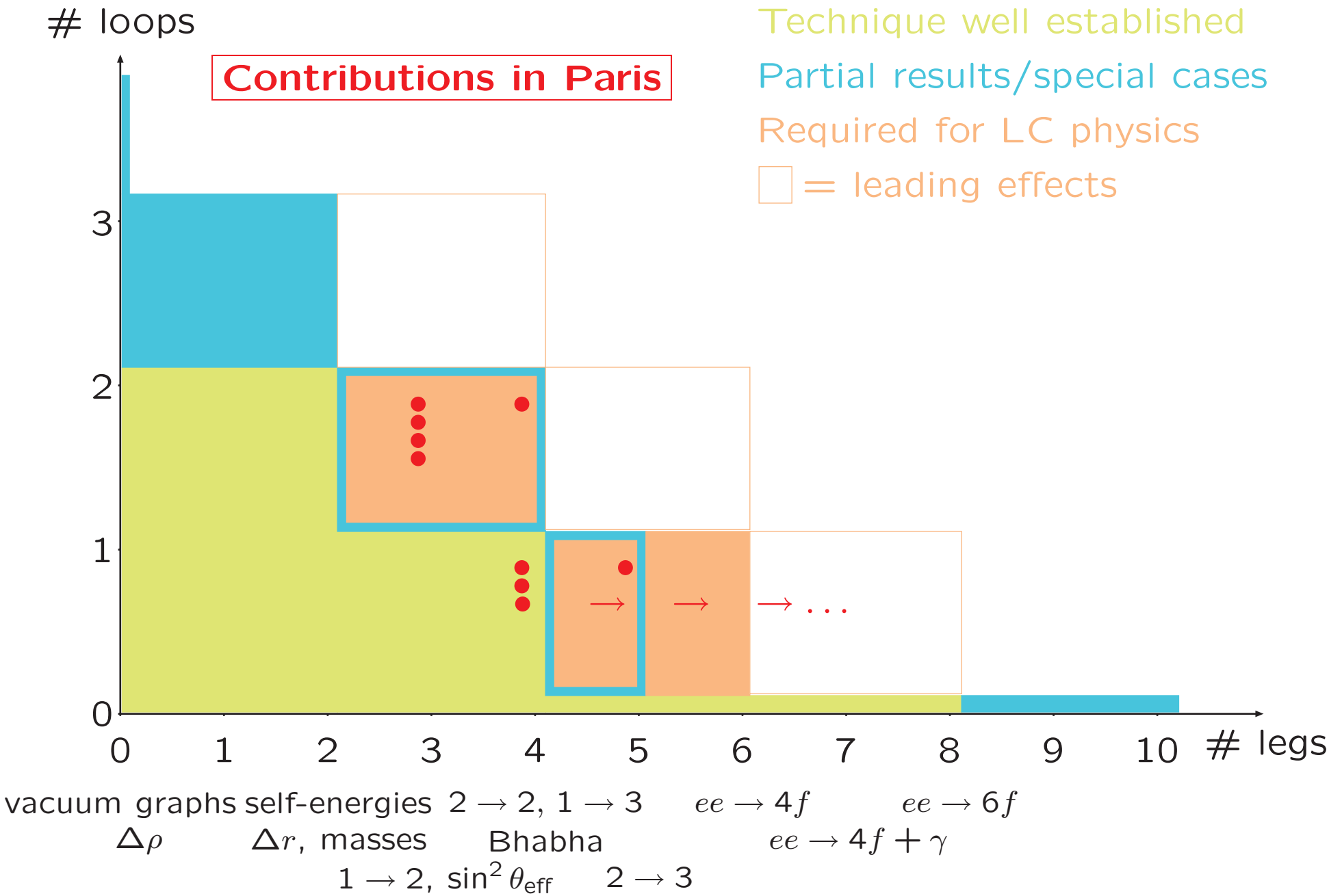
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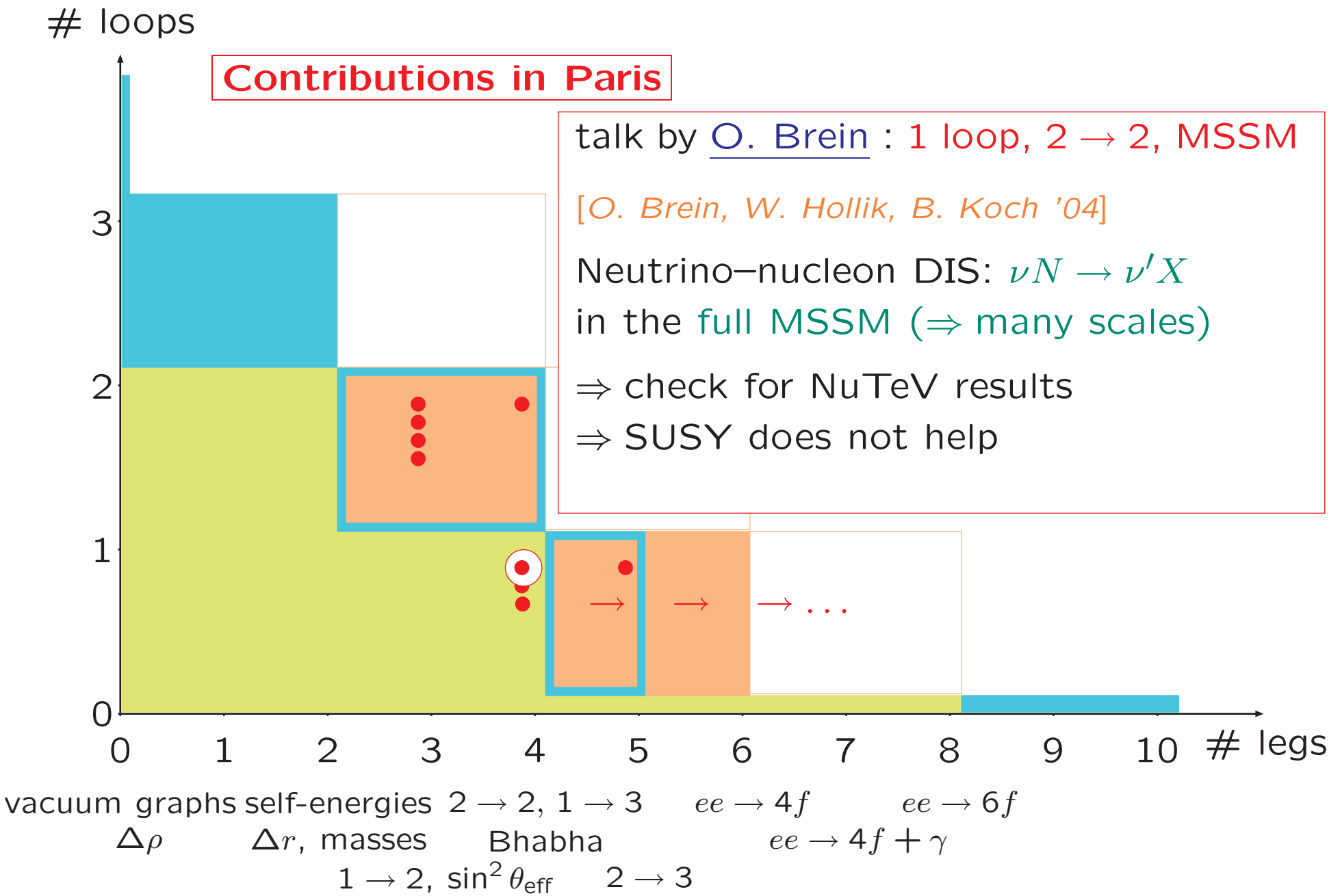
loops
Contributions in Paris
talk by O. Brein : 1 loop, 2 → 2, MSSM
[O. Brein, W. Hollik, B. Koch '04]
Neutrino–nucleon DIS: $\nu N \to \nu' X$
in the full MSSM (⇒ many scales)
⇒ check for NuTeV results
⇒ SUSY does not help
→ → → . . .
0 1 2 3
0 1 2 3 4 5 6 7 8 9 10
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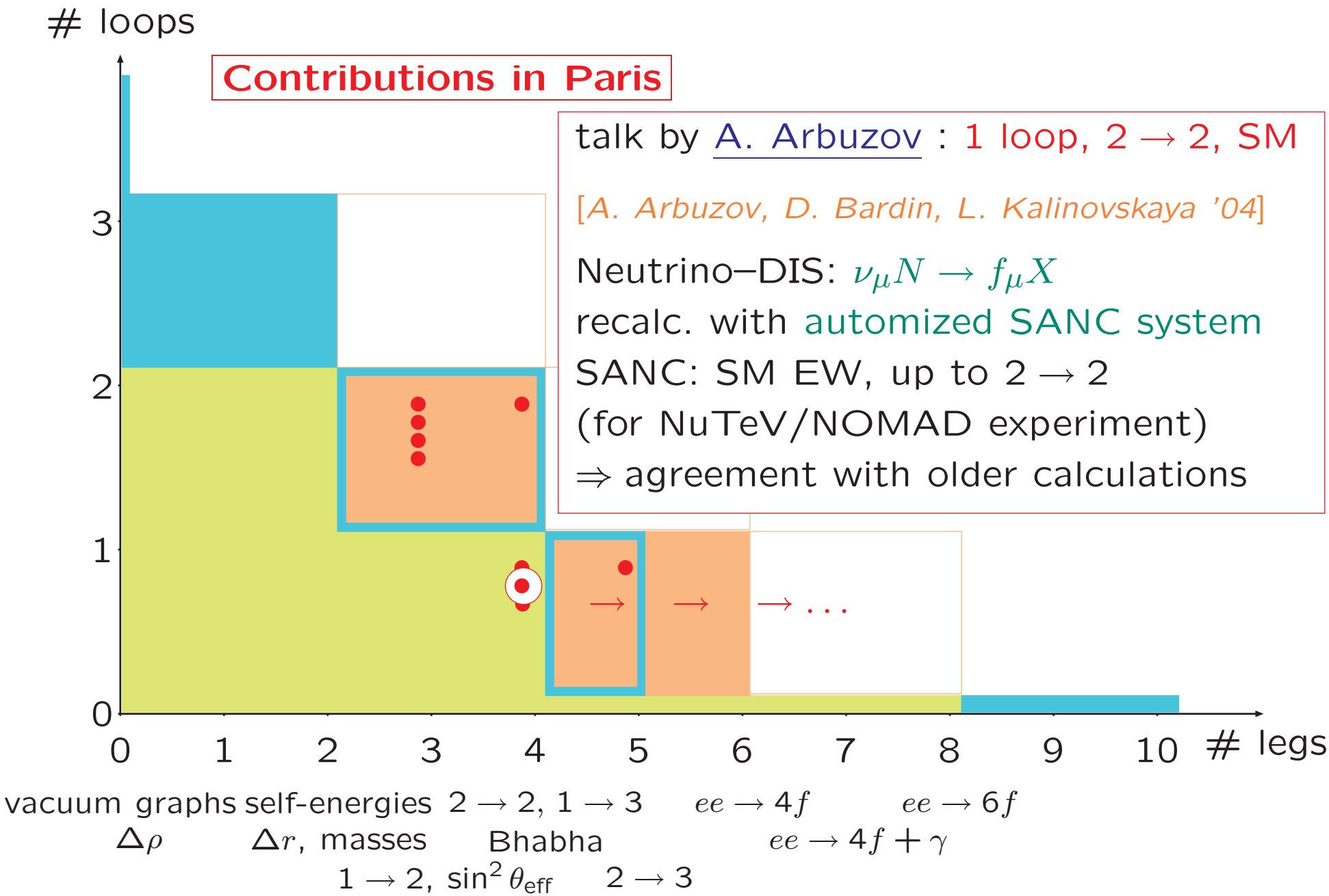
Contributions in Paris



talk by A. Arbuzov : 1 loop, $2 \to 2$, SM

[*A. Arbuzov, D. Bardin, L. Kalinovskaya '04*]

Neutrino–DIS: $\nu_\mu N \to f_\mu X$

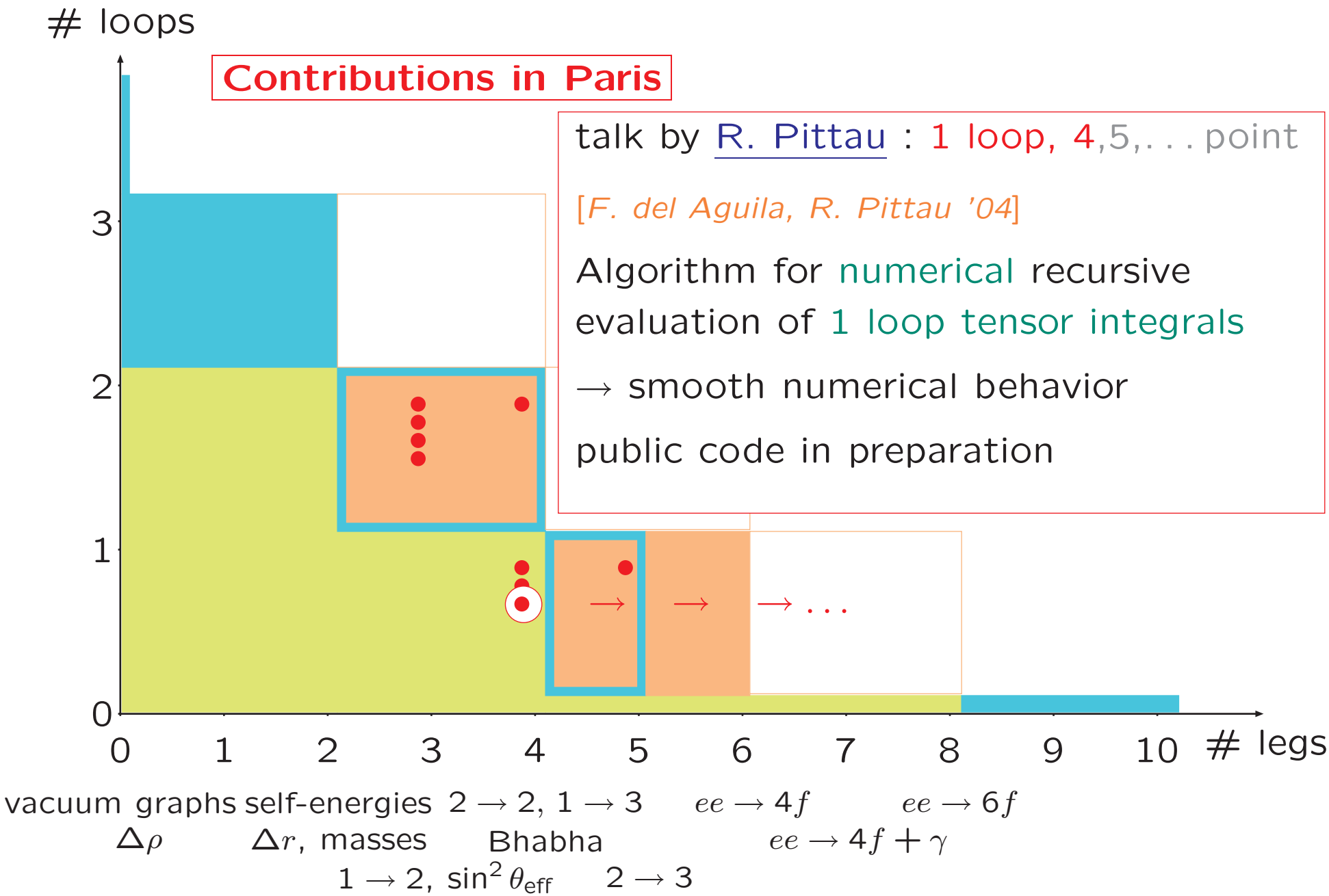
recalc. with automized SANC system

SANC: SM EW, up to $2 \to 2$

(for NuTeV/NOMAD experiment)

$\Rightarrow$ agreement with older calculations

Contributions in Paris



talk by R. Pittau : 1 loop, 4,5,. . . point

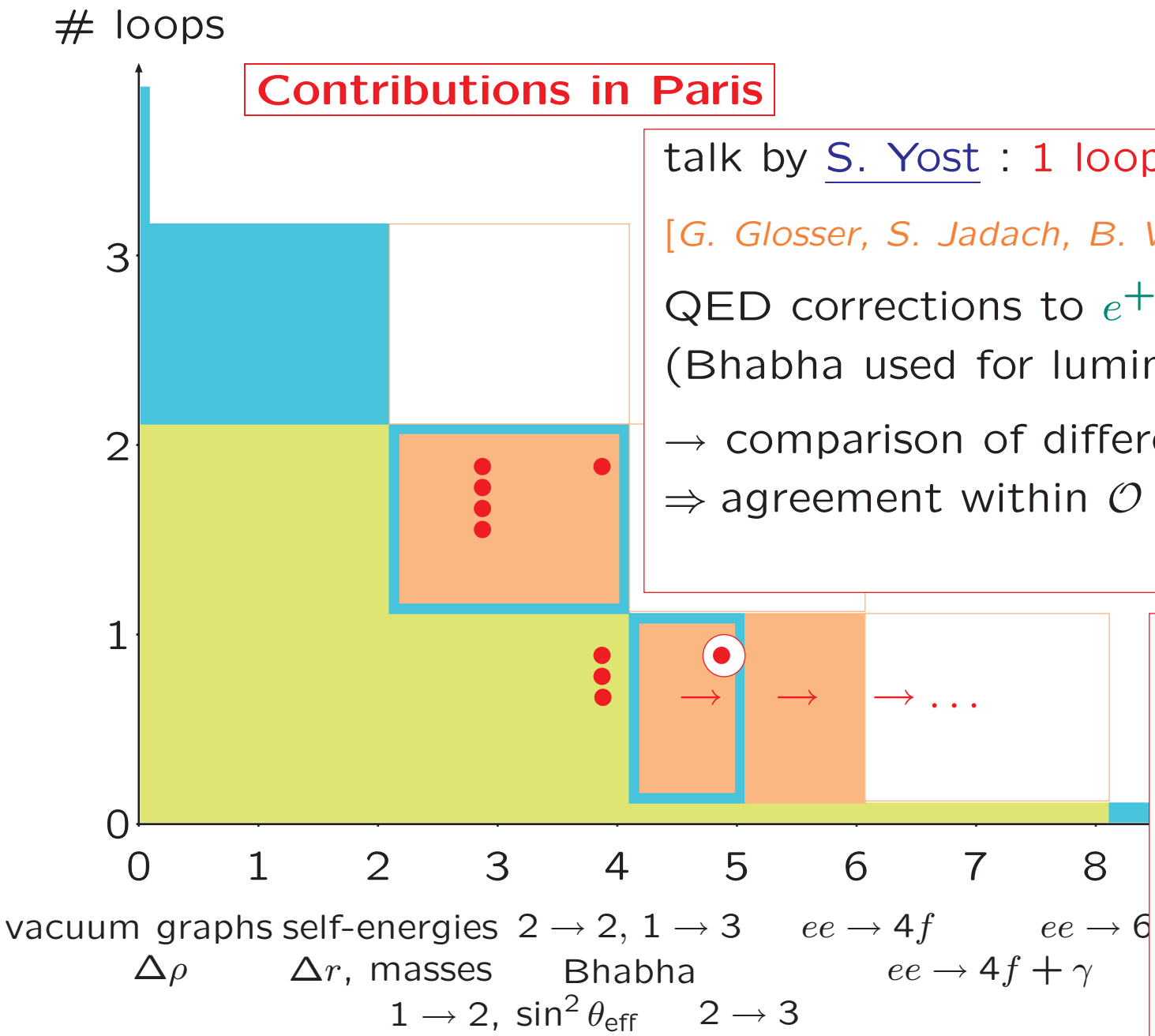
[*F. del Aguila, R. Pittau '04*]

Algorithm for numerical recursive evaluation of 1 loop tensor integrals

$\longrightarrow$ smooth numerical behavior

public code in preparation

Contributions in Paris

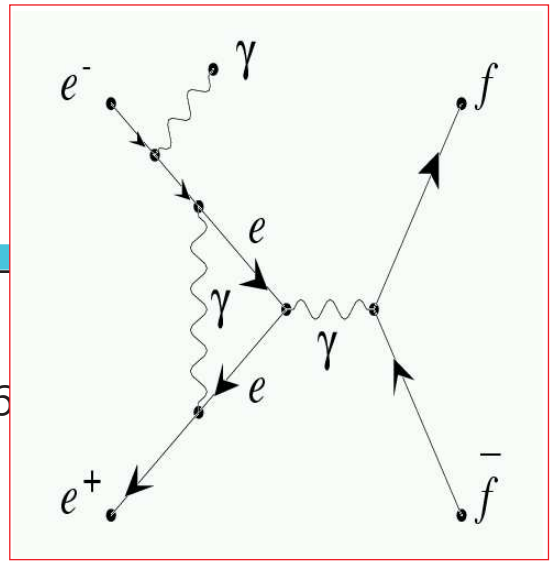


talk by S. Yost : 1 loop, $2 \to 3$, SM

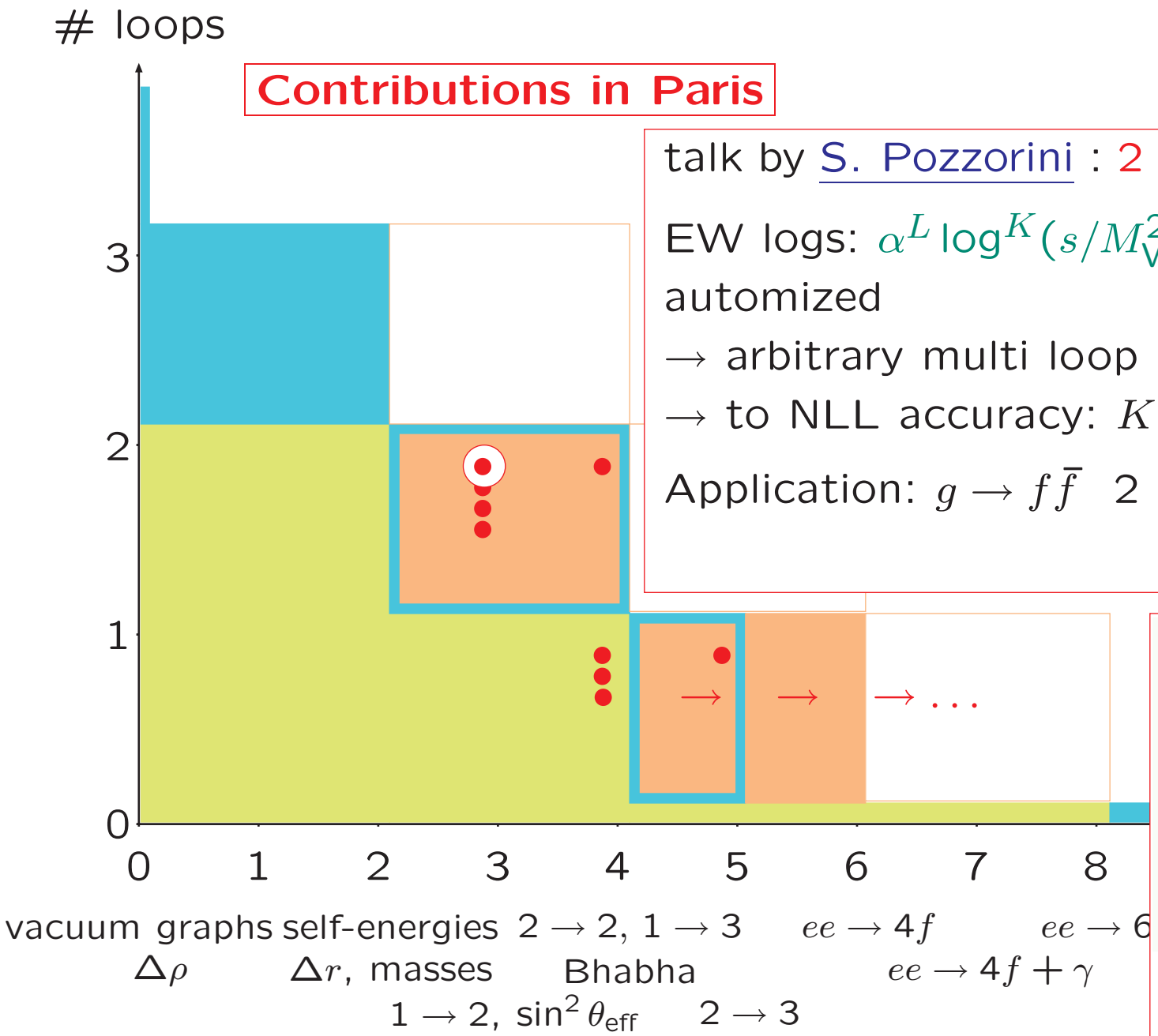
[*G. Glosser, S. Jadach, B. Ward, S. Yost '04*]

QED corrections to $e^+e^- \to 2f + \gamma$
(Bhabha used for luminosity monitor)

$\to$ comparison of different codes
$\Rightarrow$ agreement within $\mathcal{O}\left(10^{-5}\right)$



Contributions in Paris



talk by S. Pozzorini : 2 loop, $1 \to 2$, SM

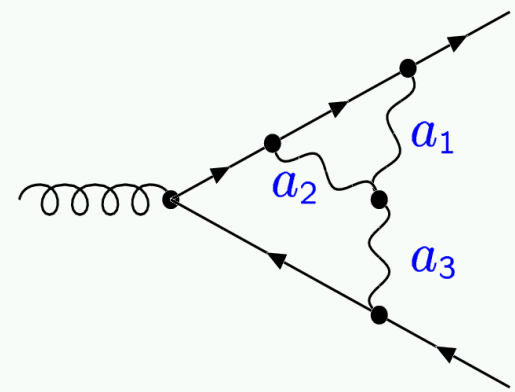
EW logs: $\alpha^L \log^K(s/M_{\rm W}^2)$, $s \gg M_{\rm W}^2$

automized

$\to$ arbitrary multi loop diagrams

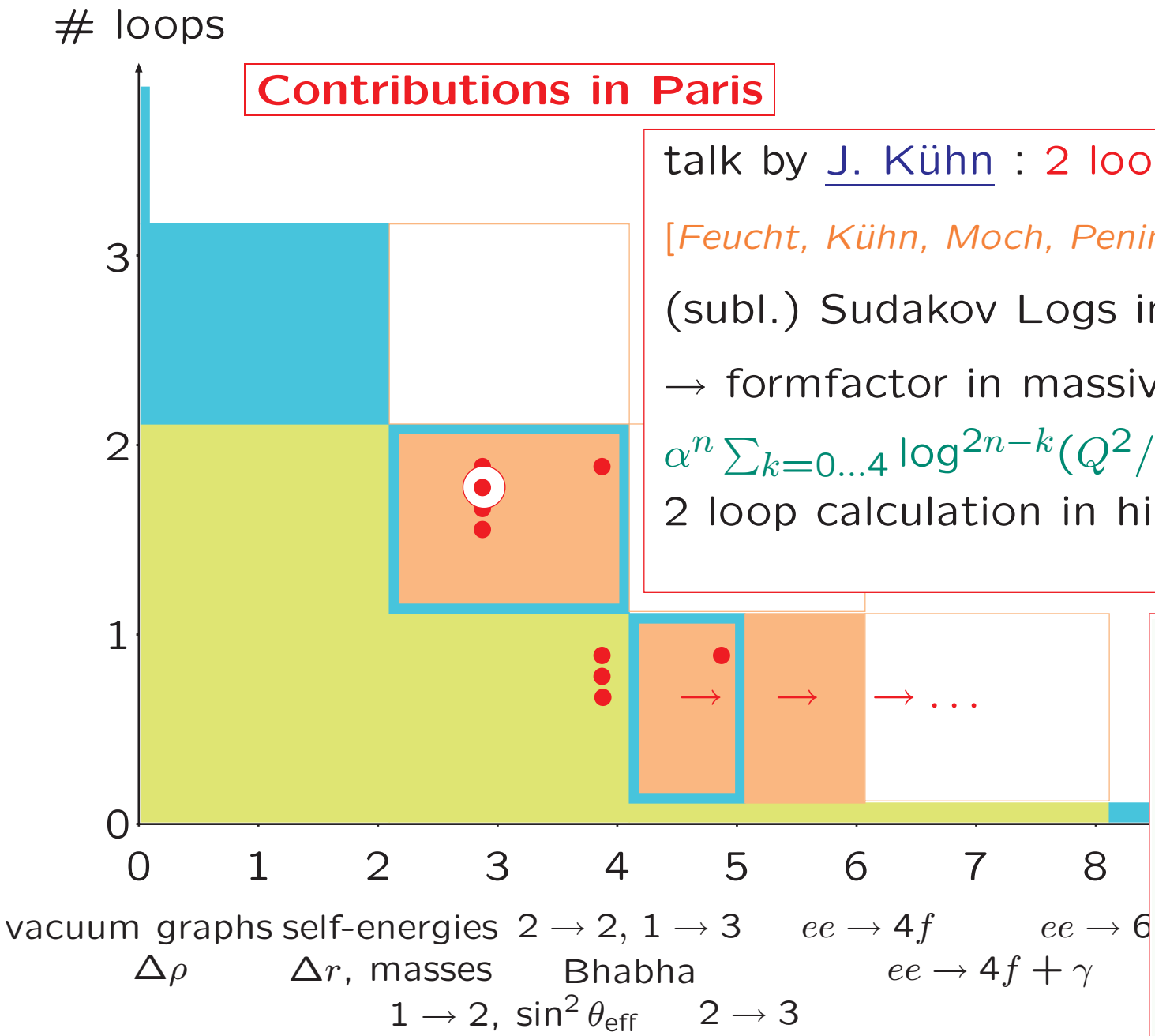
$\to$ to NLL accuracy: $K = 2L, 2L-1$

Application: $g \to f\bar{f}$ 2 loop



$a_i = \gamma, Z, W^\pm$

Contributions in Paris



talk by J. Kühn : 2 loop, $1 \to 2$, $U(1)$

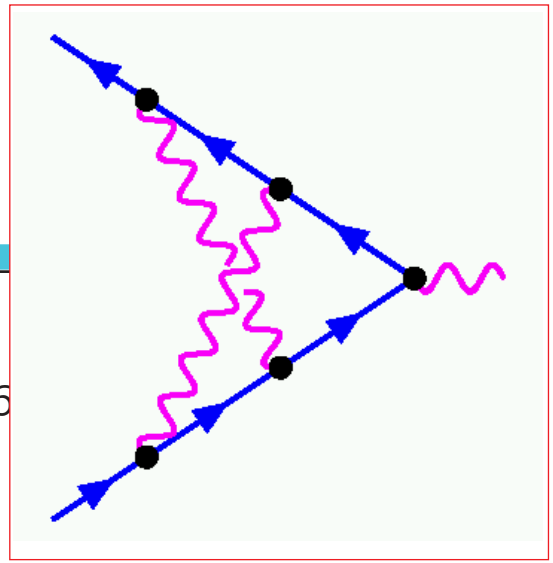
[*Feucht, Kühn, Moch, Penin, Smirnov '03,'04*]

(subl.) Sudakov Logs in EW processes

$\to$ formfactor in massive $U(1)$:

$\alpha^n \sum_{k=0\ldots4} \log^{2n-k}(Q^2/M^2) \to n = 2$

2 loop calculation in high-energy limit



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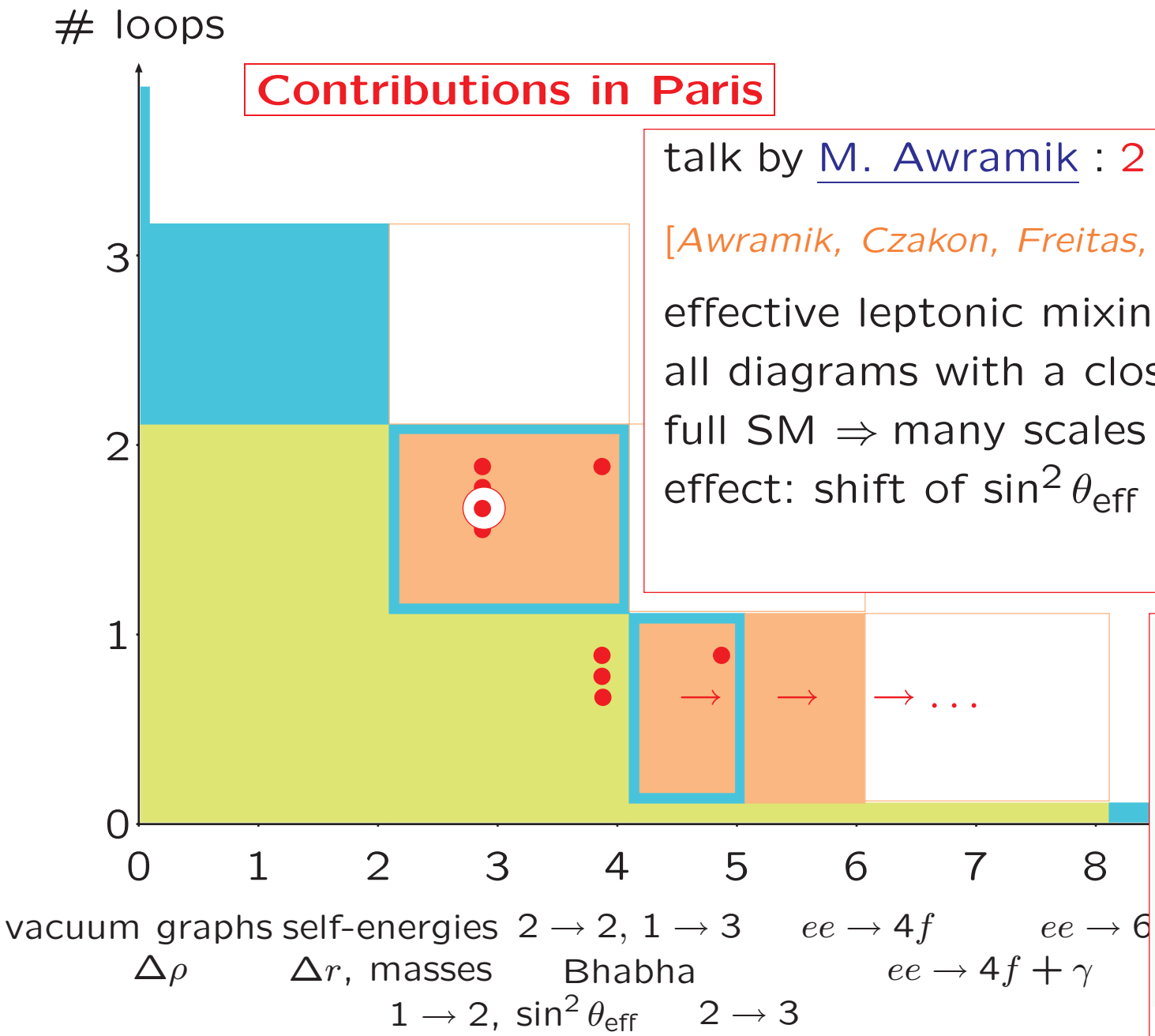


talk by M. Awramik : 2 loop, $1 \to 2$, SM

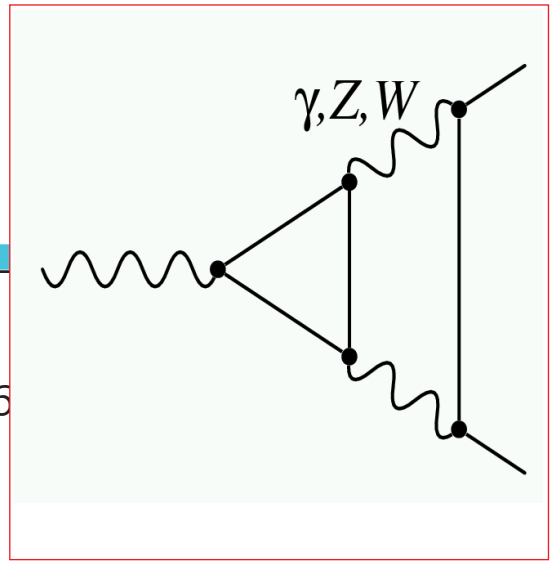
[*Awramik, Czakon, Freitas, Weiglein '04*]

effective leptonic mixing angle $\sin^2\theta_{\rm eff}$

all diagrams with a closed fermion loop

full SM $\Rightarrow$ many scales

effect: shift of $\sin^2\theta_{\rm eff}$ by $\mathcal{O}\left(10^{-4}\right)$



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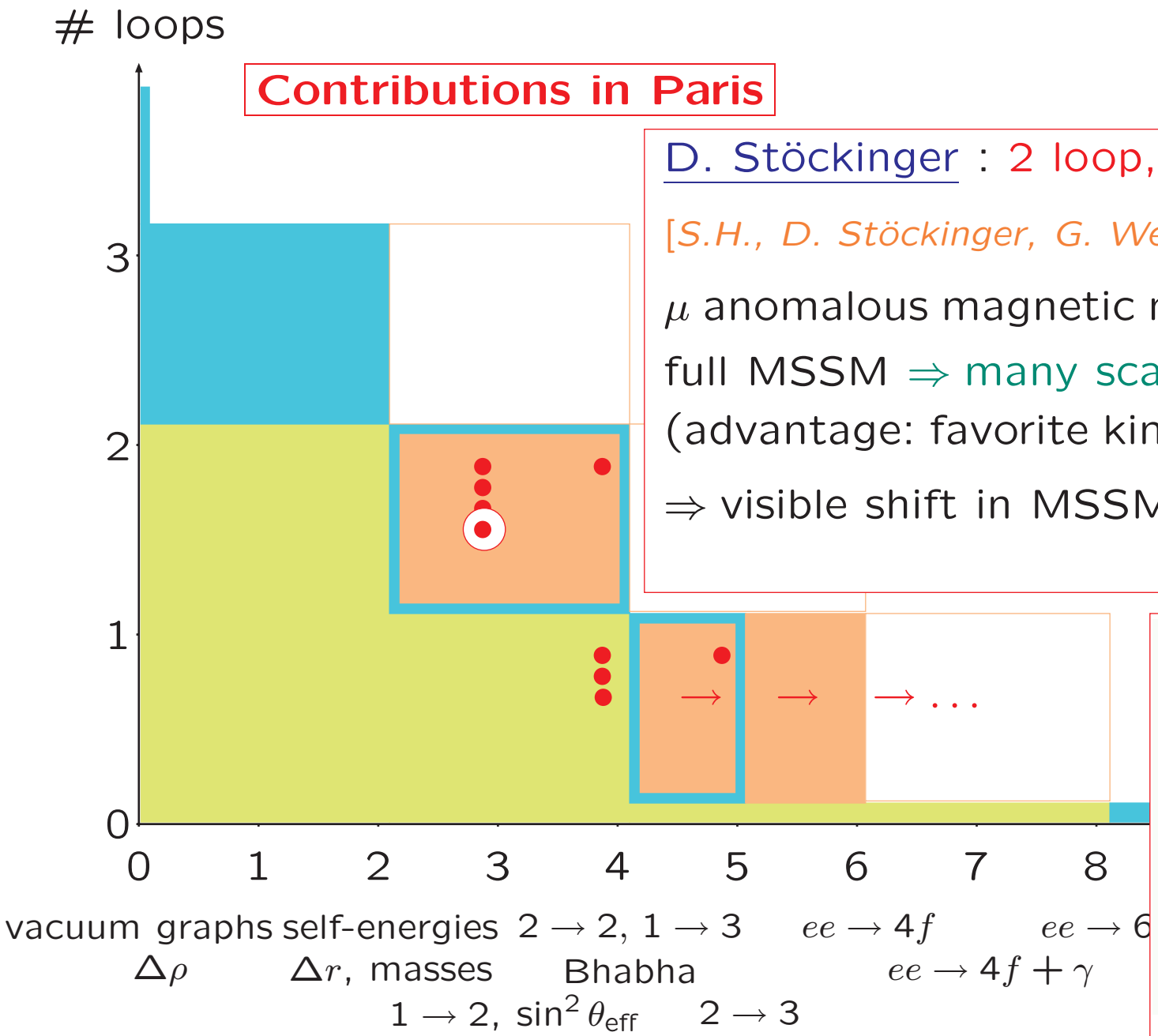


D. Stöckinger : 2 loop, $1 \to 2$, MSSM

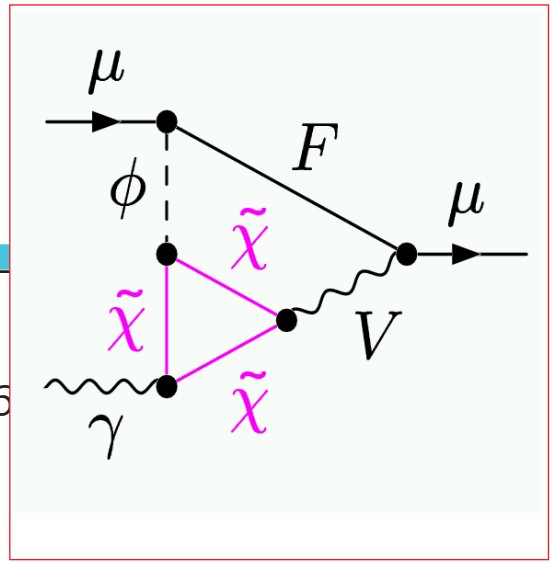
[*S.H., D. Stöckinger, G. Weiglein '04*]

μ anomalous magnetic moment: $(g-2)_\mu$

full MSSM $\Rightarrow$ many scales

(advantage: favorite kinemtic situation)

$\Rightarrow$ visible shift in MSSM prediction



Contributions in Paris

D. Stöckinger : 2 loop, $1 \to 2$, MSSM

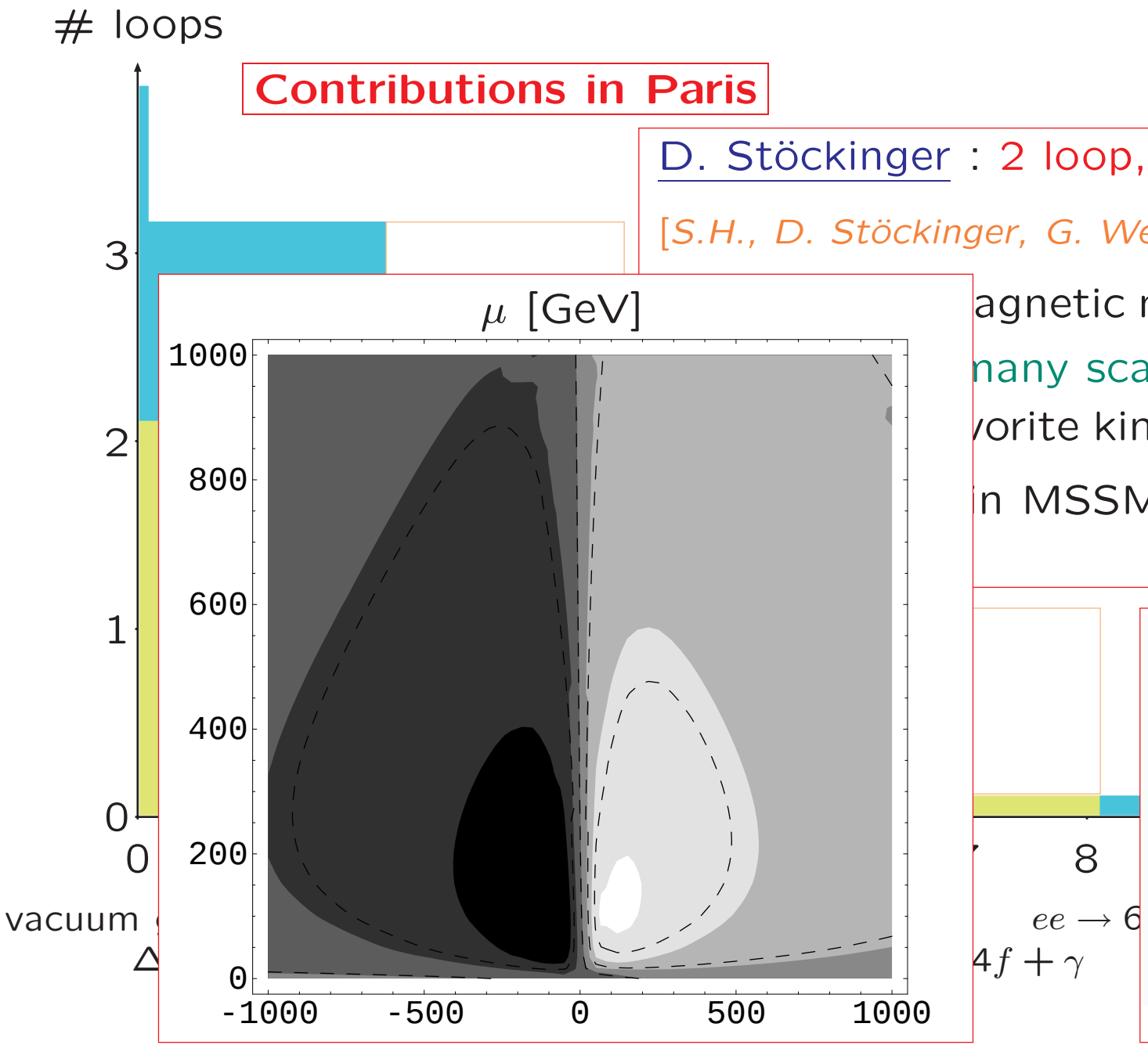
[*S.H., D. Stöckinger, G. Weiglein '04*]

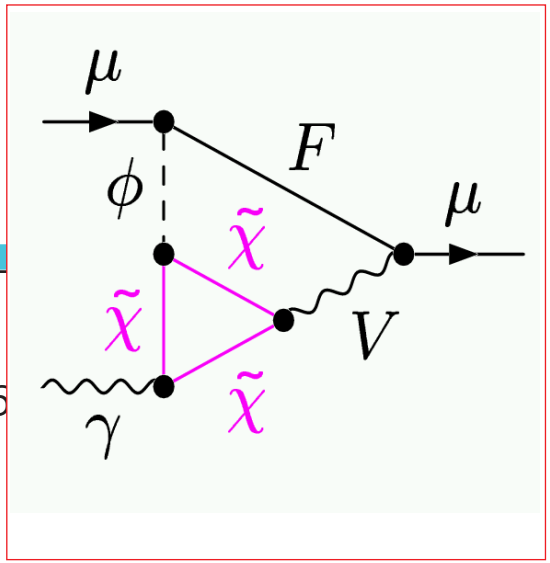
agnetic moment: $(g-2)_\mu$

nany scales

vorite kinemtic situation)

n MSSM prediction





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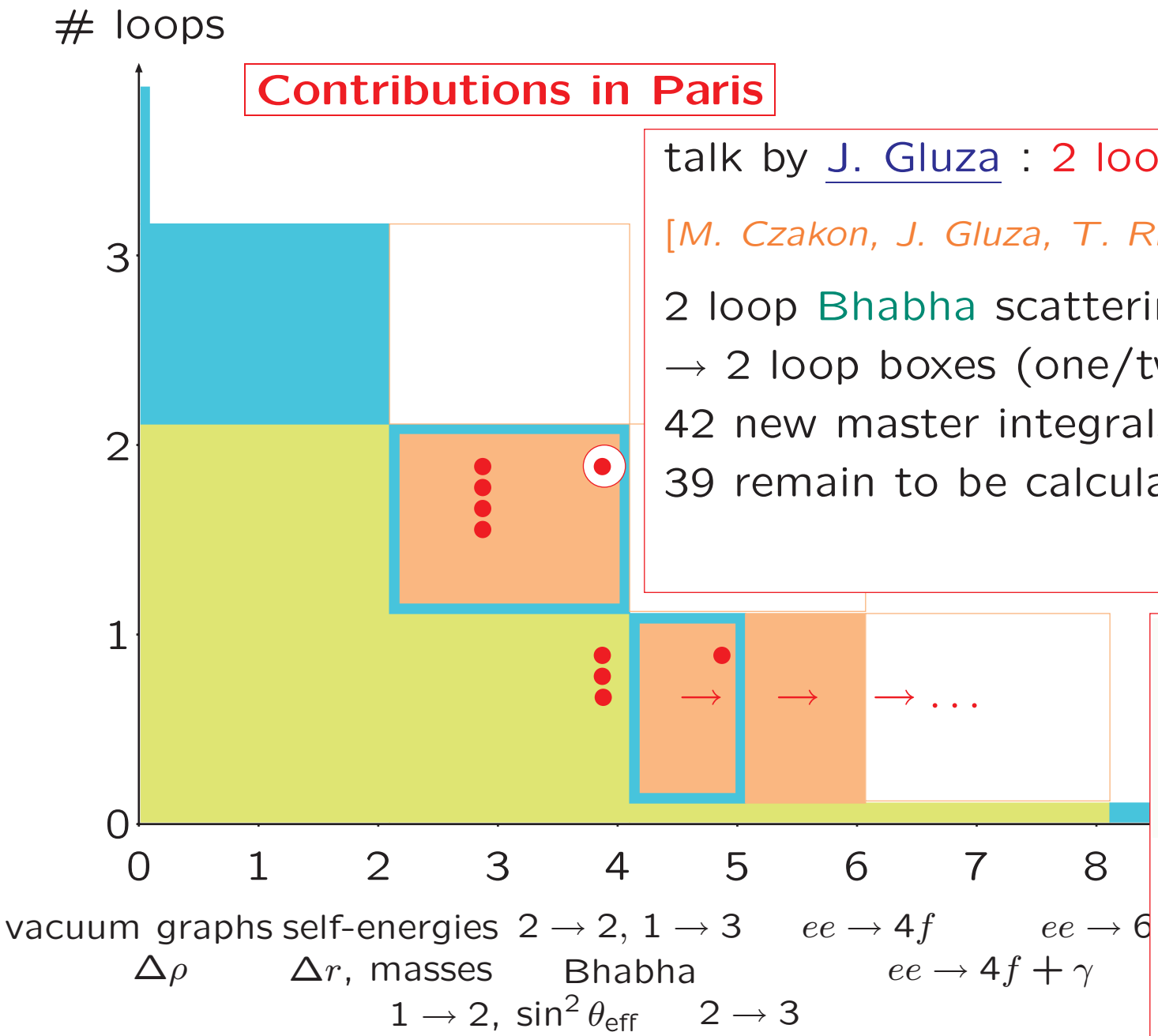


talk by J. Gluza : 2 loop, $2 \to 2$, QED

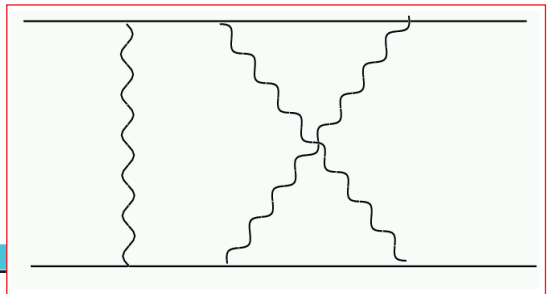
[*M. Czakon, J. Gluza, T. Riemann '04*]

2 loop Bhabha scattering in QED

$\to$ 2 loop boxes (one/two scale)

42 new master integrals

39 remain to be calculated



most complicated

Experimental situation:

Linear Collider

$\rightarrow$ provide high accuracy measurements !

Theory situation:

measured observables have to be compared with theoretical predictions (of your favourite model)

Measured data is only meaningful if it is matched with theoretical calculations at the same level of accuracy

The great LC precision would be worthless without theory calculation

We have to start **NOW** to achieve necessary accuracy in time

Theoretical calculations should be viewed as an essential part of all future High Energy Physics programs