

# Recursive relations in MadGraph

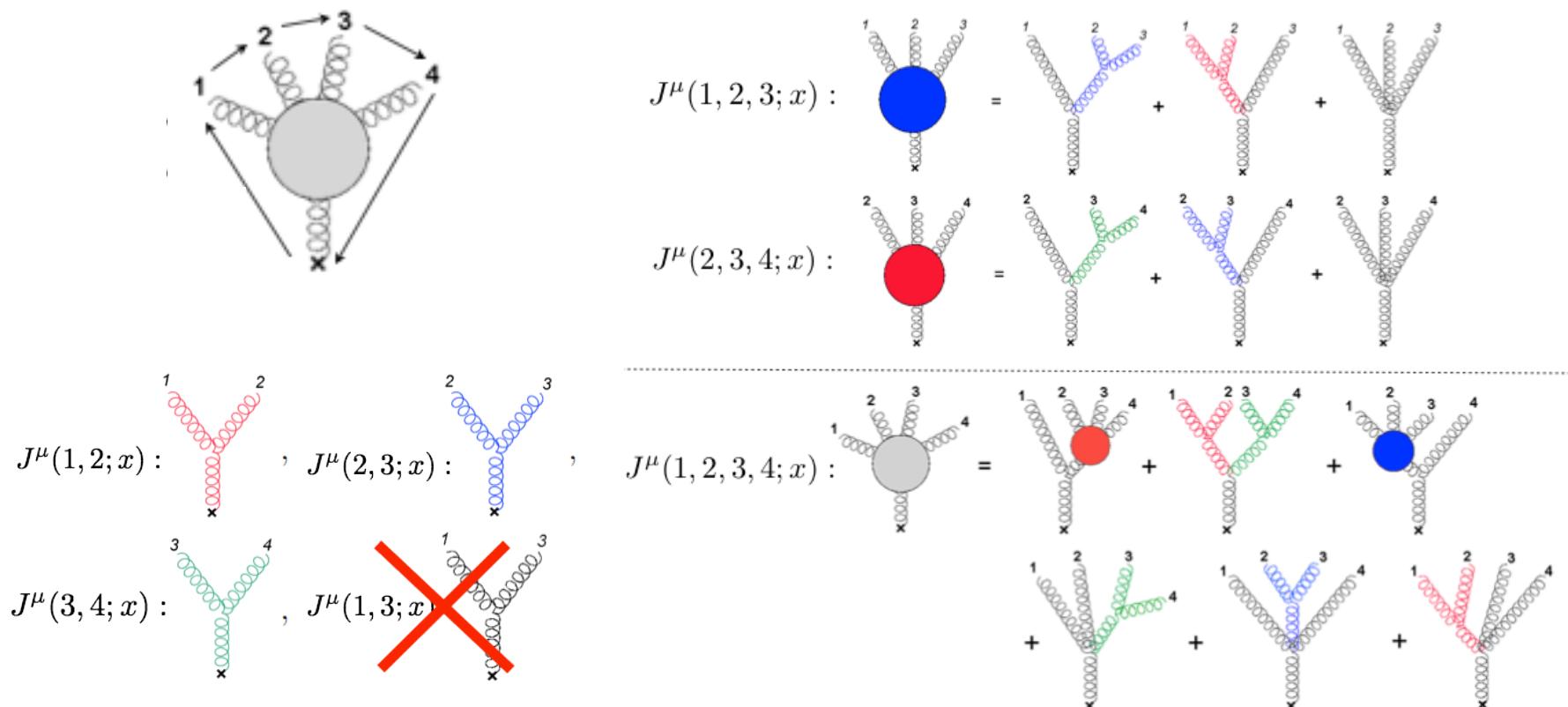


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# What is the Recursive Relation

Off-shell R.R. for gluons in fixed color-order



# Why do we use R.R. ?

# MG5 is Fantastic!

Matrix Element  
generation:

Process	MADGRAPH 4	MADGRAPH 5	Subprocesses	Diagrams
$pp \rightarrow jjj$	29.0 s	54.4 s	34	307
$pp \rightarrow jjl^+l^-$	341 s	258 s	108	1216
$pp \rightarrow jjje^+e^-$	1151 s	654 s	141	9012
$u\bar{u} \rightarrow e^+e^-e^+e^-e^+e^-$	772 s	175 s	1	3474
$gg \rightarrow ggggg$	2788 s	1049 s	1	7245
$pp \rightarrow jj(W^+ \rightarrow l^+\nu_l)$	146 s	70 s	82	304
$pp \rightarrow t\bar{t} + \text{full decays}$	5640 s	22 s	27	45
$pp \rightarrow \tilde{q}/\tilde{g} \tilde{q}/\tilde{g}$	222 s	286 s	313	475
7 particle decay chain	383 s	5.2 s	1	6
$gg \rightarrow (\tilde{g} \rightarrow u\bar{u}\tilde{\chi}_1^0)(\tilde{g} \rightarrow u\bar{u}\tilde{\chi}_1^0)$	70 s	5.5 s	1	48
$pp \rightarrow (\tilde{g} \rightarrow jjj)$				11008

More Efficient than MG4

Matrix Element  
evaluation  
(Fortran):

Process	MG 4	MG 5	MG 4	MG 5
$u\bar{u} \rightarrow e^+e^-$	8	8	< 6μs	< 6μs
$u\bar{u} \rightarrow e^+e^-e^+e^-$	110	80	0.22 ms	0.14 ms
$u\bar{u} \rightarrow e^+e^-e^+e^-e^+e^-$	6668	3775	46.5 ms	19.0 ms
$u\bar{u} \rightarrow d\bar{d}$	6	6	< 4μs	< 4μs
$u\bar{u} \rightarrow d\bar{d}g$	16	16	27 μs	27 μs
$u\bar{u} \rightarrow d\bar{d}gg$	85	67	0.42 ms	0.31 ms
$u\bar{u} \rightarrow d\bar{d}ggg$	748	515	10.8 ms	6.75 ms
$u\bar{u} \rightarrow u\bar{u}gg$	160	116	1.24 ms	0.80 ms
$u\bar{u} \rightarrow u\bar{u}ggg$	1468	960	35.7 ms	17.2 ms
$u\bar{u} \rightarrow d\bar{d}dd\bar{d}$	42	33	84 μs	83 μs
$u\bar{u} \rightarrow d\bar{d}dd\bar{d}g$	310	197	1.88 ms	1.15 ms
$u\bar{u} \rightarrow d\bar{d}dd\bar{d}gg$	3372	1876	141 ms	34.4 ms
$u\bar{u} \rightarrow d\bar{d}dd\bar{d}dd\bar{d}$	1370	753	42.5 ms	6.6 ms

from Johan's talk

# BUT still not satisfied!

Because

For some processes, Generated HELAS codes

**cannot** be

**compiled** and **calculated...**

$$gg \rightarrow 5g$$

$$qg \rightarrow q5g$$

$$qq \rightarrow qq4g$$

Especially for

Multi-parton QCD processes

Why codes for

$$\sum_{color} |\mathcal{M}|^2$$

cannot be evaluated?

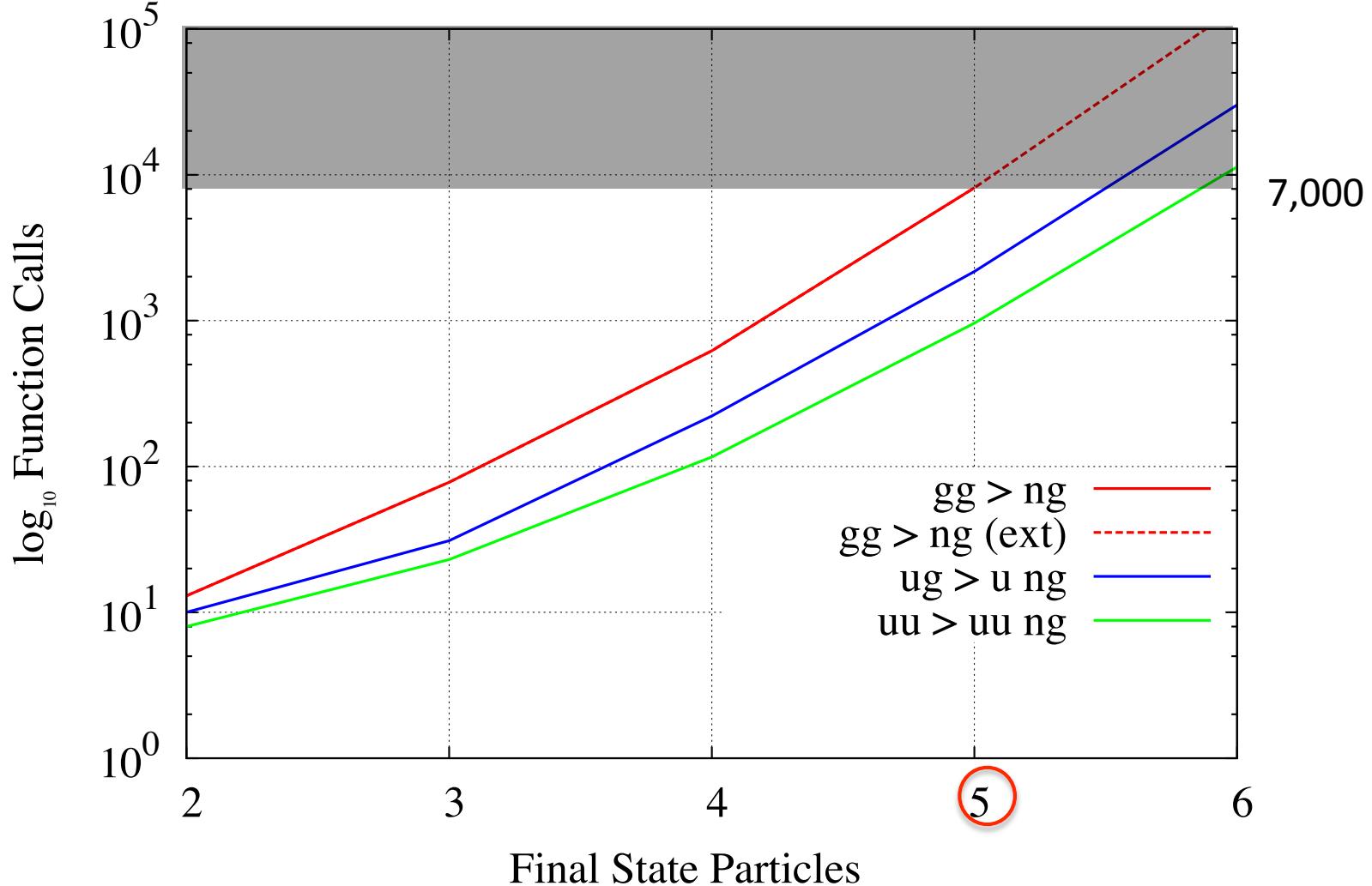
because of

# of diagrams (Function Calls)

QCD processes with

~~$\geq 7,000$~~

AMPs cannot be compiled







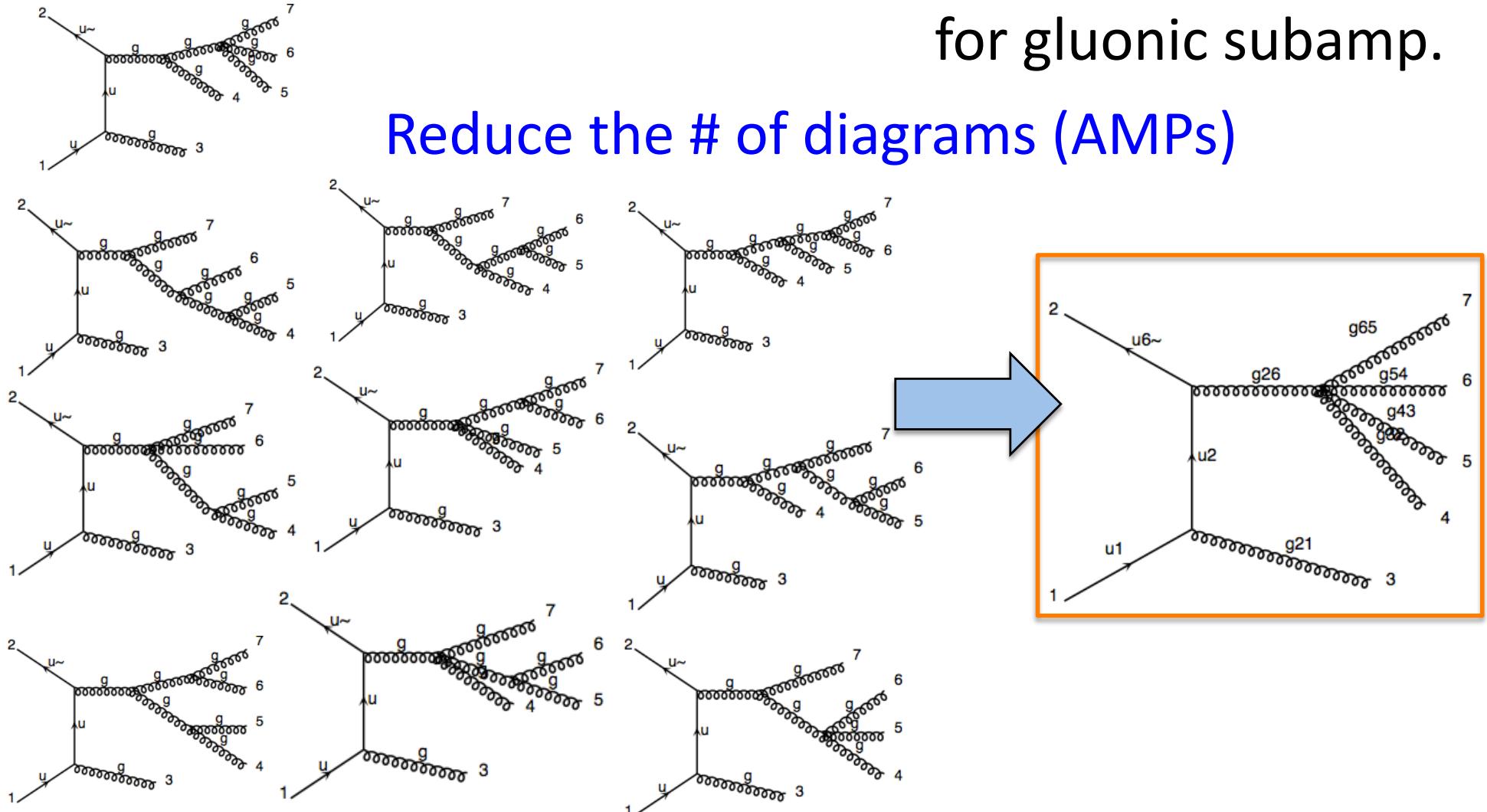
How can we go further?

from Johan's talk

# Recursive relation

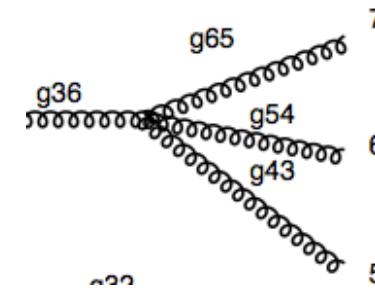
for gluonic subamp.

Reduce the # of diagrams (AMPs)

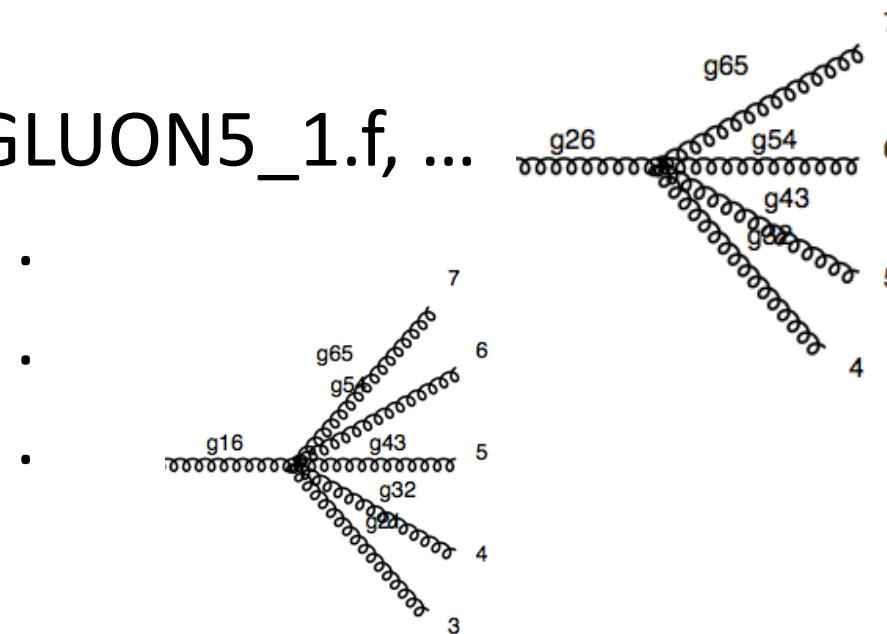


# We added n-point off-shell R.R. subroutines to HELAS Library

GLUON4\_0.f, GLUON4\_1.f, ...

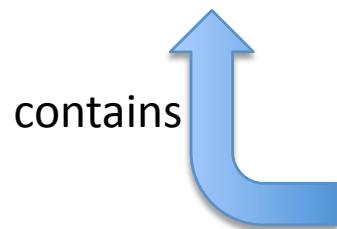
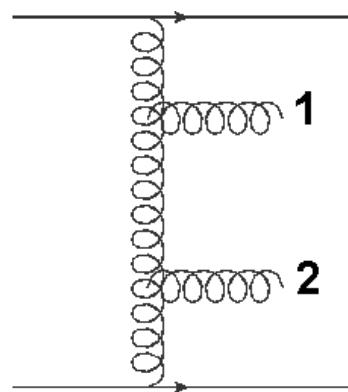


GLUON5\_0.f, GLUON5\_1.f, ...

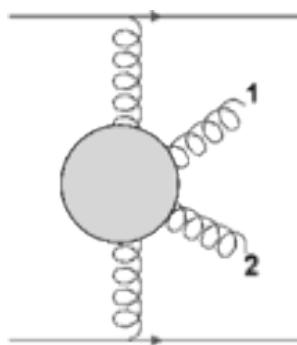


We also **forbid gluon propagator** between multi-gluon vertices to avoid double counting.

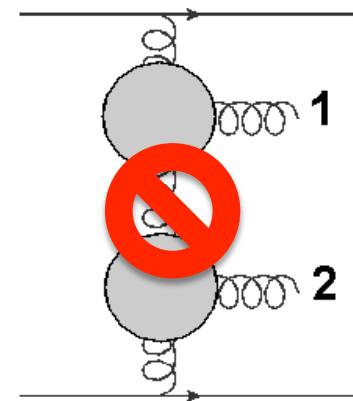
For example,



is also made by



4-point R.R. current



2×(3-point R.R. currents).



Double counting

Using those off-shell R.R. subroutines,  
We calculate JAMPs.



$$gg \rightarrow 5g$$



$$gg \rightarrow 6g$$



$$gg \rightarrow 7g \text{ (OK but slow..)}$$

# Conclusion

- Generated Codes by MG5 for multi-parton QCD process cannot be compiled for more than 5 final states processes.
- Off-shell recursive relations helps us to reduce the # of AMPs and the size of the codes.
- We proposed a way to calculate  $gg > 5g, 6g, 7g$  processes by making use of the R.R. .

# Future works

- Apply to processes with quarks,  
 $qg \rightarrow q \text{ ng}$ ,  $qq \rightarrow qq \text{ ng}$
- Phase space integration and event generation

Dank u ze

MERCI  
BEAUCOUP!

감사합니다!

DANKE SCHÖN!

**Thank you very much!**

Grazie mille!

どうもありがとうございました！

谢谢