Fast Matrix-Element Resummations with Sector Showers

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Peter Z. Skands
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Higgs Hunting. July 2011

Motivation

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- Signal/Backgrounds for LHC Physics require **accurate** and **fast** Monte Carlo simulation of (exclusive) events.
  For example, searches for the Higgs boson.

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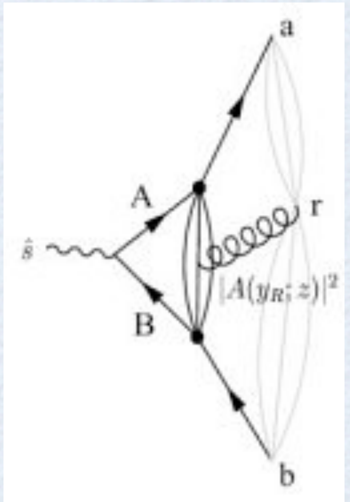
  For example, searches for the Higgs boson.
- **Hard jets**: **matching to MEs required**
- **Computationally expensive**: traditional multijet matching schemes are orders of magnitude slower than "pure" showers

UNDERLYING THEORY

Kosower, D. A. Phys.Rev. D57 (1998) 5410-5416 ; Gehrmann-De Ridder, A. et al. JHEP 0509 (2005) 056 ; G. Gustafson Phys.Lett. B175 (1986) 453



- Dipole-antenna formalism (2 -> 3)
  IR divergences structure of QCD.
  - Double-logs (soft) over single-logs (collinear) singularities.
  - Exact momentum-conserving Lorenz-invariant on-shell phase-space factorization.

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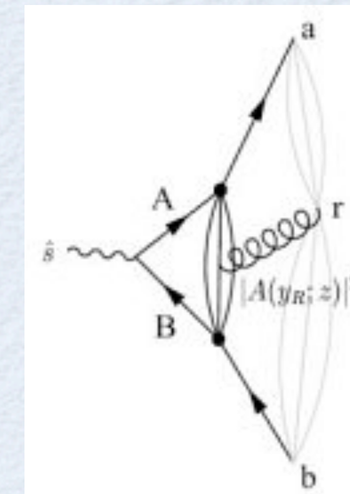

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  IR divergences structure of QCD.
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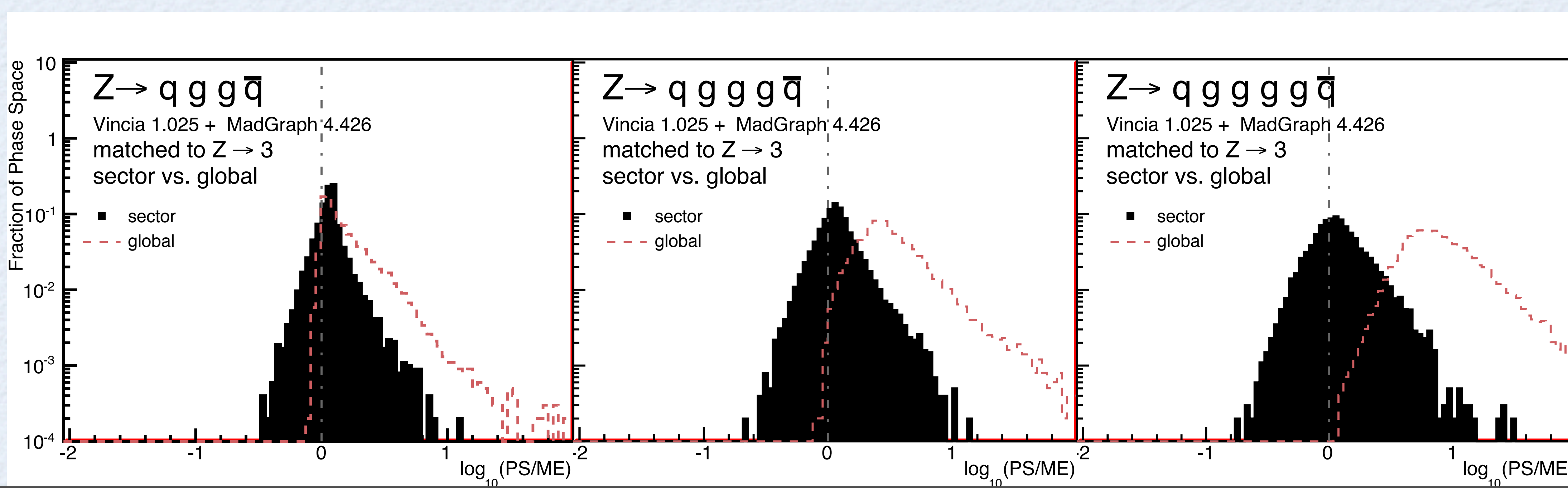
- Two types:
  - Global $|M^{(n)}|^2 \sim \sum_{i \in \mathrm{ant.}} a_i |M_i^{(n-1)}|^2$ for any P.S. point
  - Sector $|M^{(n)}|^2 \sim \sum_{i \in \mathrm{ant.}} \tilde{a}_i |M_i^{(n-1)}|^2 \, \Theta_i(\mathrm{P.S.}) \sim \tilde{a}_j |M_j^{(n-1)}|^2$ for some ant. j



VINCIA

Giele, Kosower, Skands: arXiv:1102.2126

- VINCIA (http://projects.hepforge.org/vincia/)
  Shower based on antenna factorization and universality
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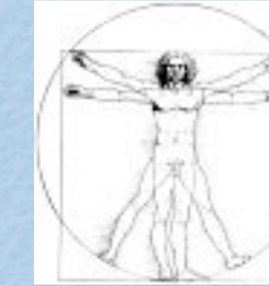
	"Traditional" parton shower	Vincia Markov global antenna shower	Vincia Markov sector antenna shower
# of terms produced in the shower	$2^N N!$	N	1

N = number of emitted partons

VINCIA



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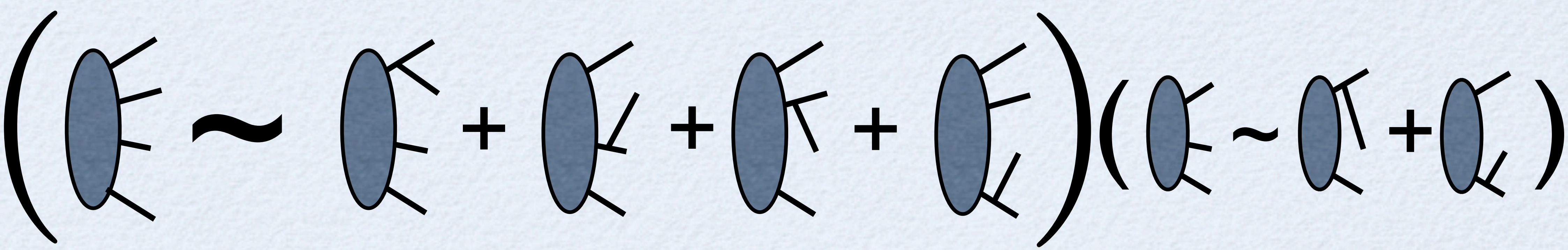
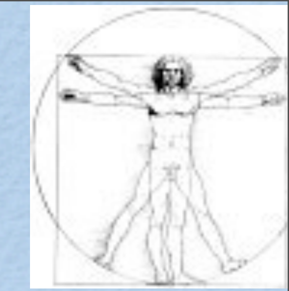
N = 2
$2 \rightarrow 4$



$3 \rightarrow 4$
$\rightarrow$ 4 terms

$2 \rightarrow 3$
$\rightarrow$ 2 terms

VINCIA



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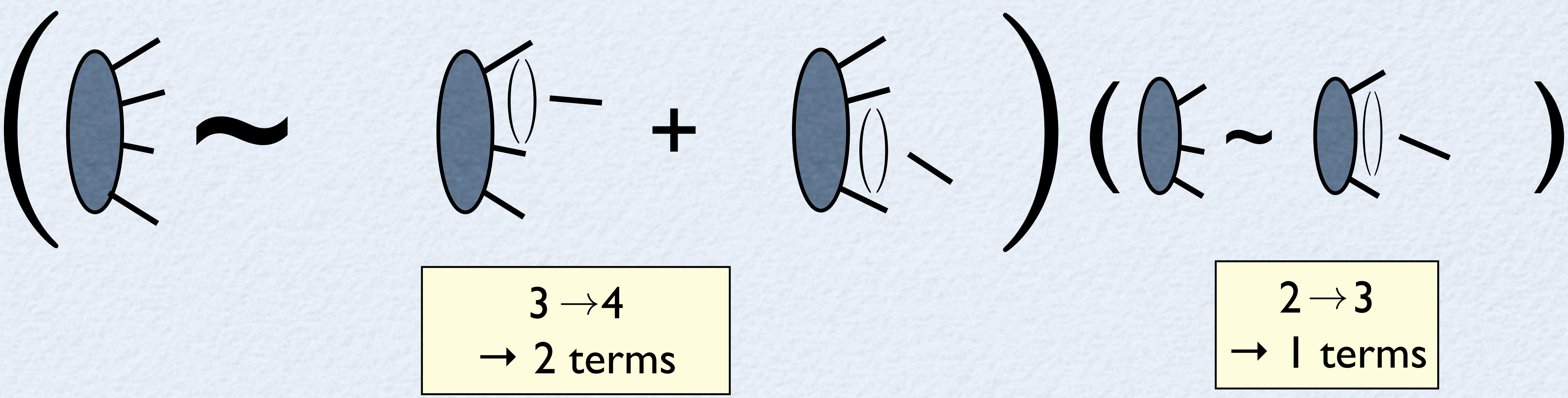

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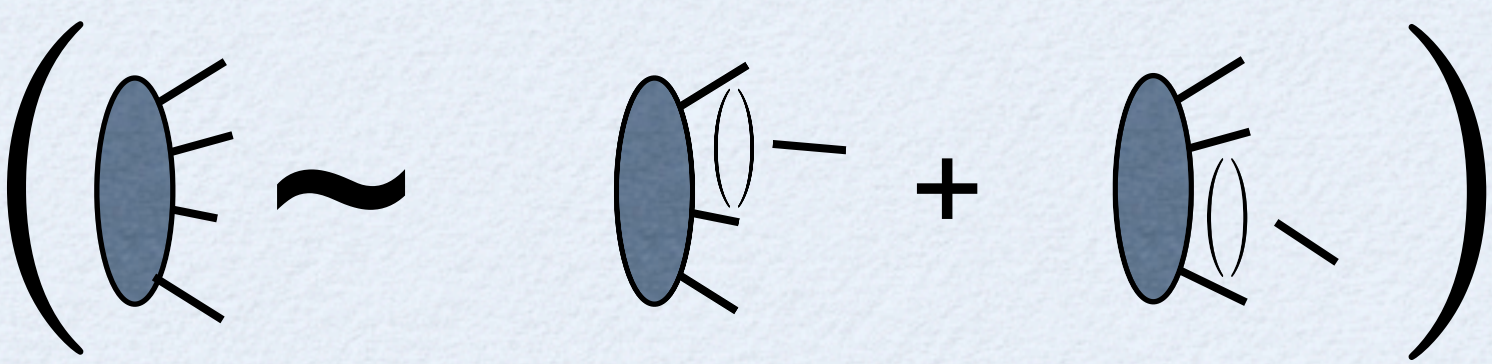

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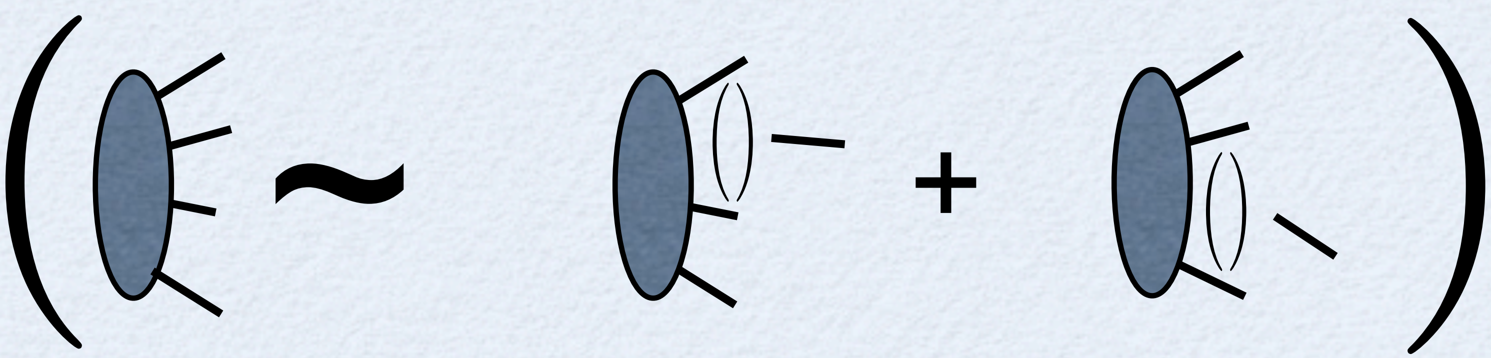

$3 \to 4$
$\to$ 2 terms

Global FSR shower implemented
-> **Sector shower**

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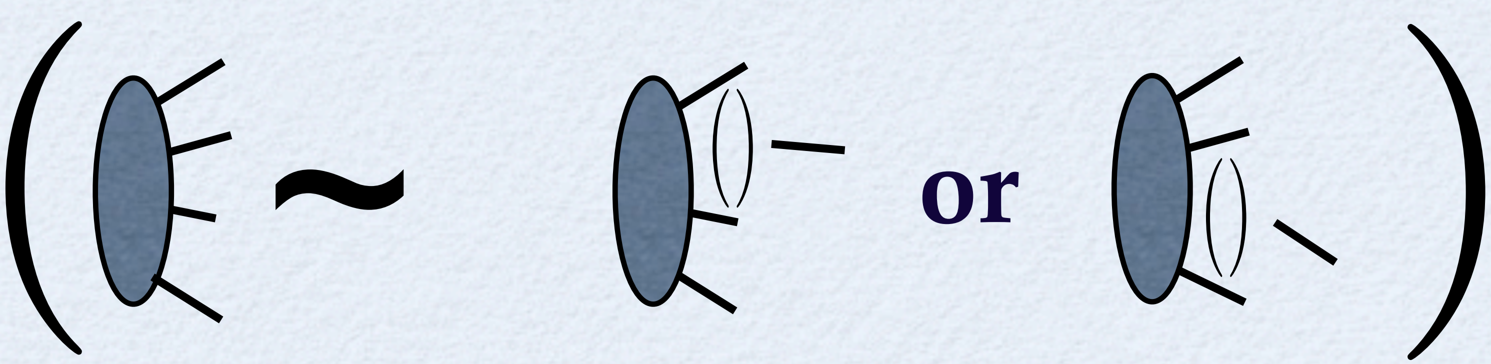

$3 \rightarrow 4$
$\rightarrow$ 1 term

Global FSR shower implemented
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Sector implementation

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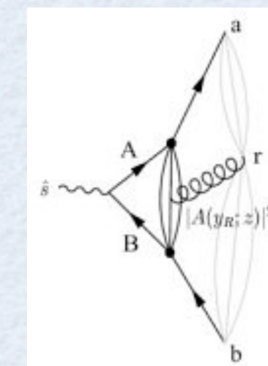
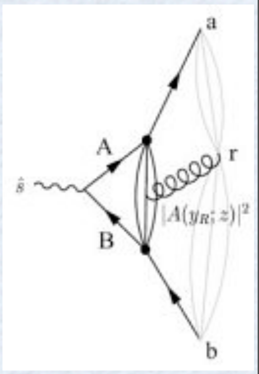
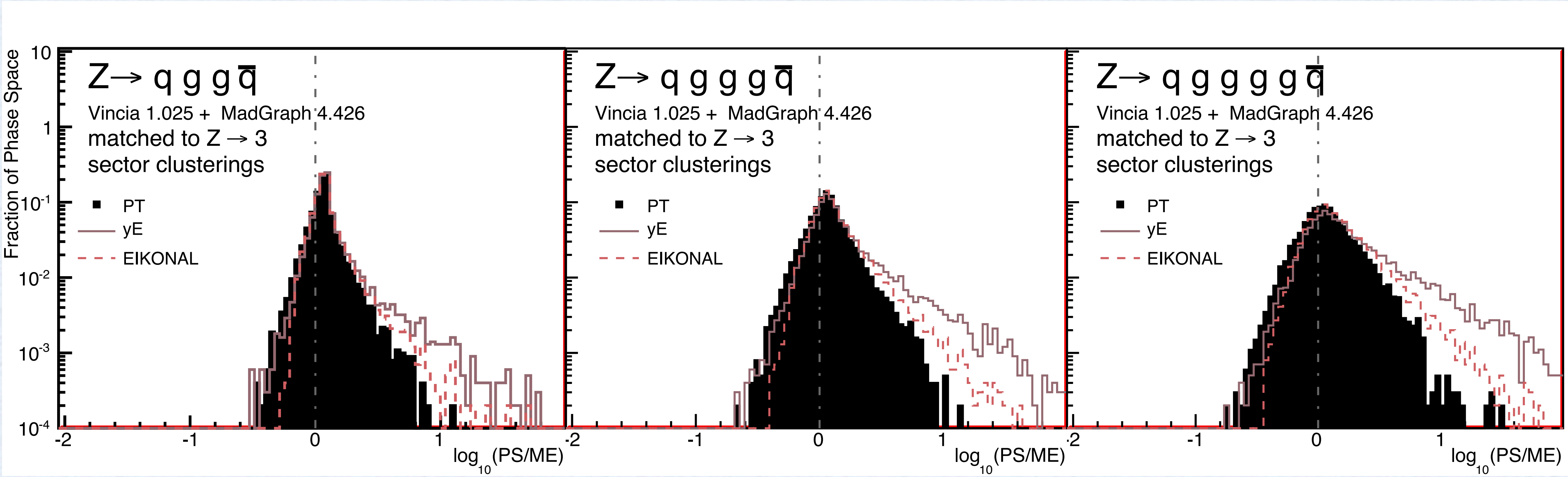
- Antenna functions are different than in the global case.
  -> Challenges



Sector implementation

- Implementation based on the global shower setup.
- Antenna functions are different than in the global case.
  -> Challenges
- Different criteria for separating sectors in phase space
  Looking for "best" sub-LL behavior.

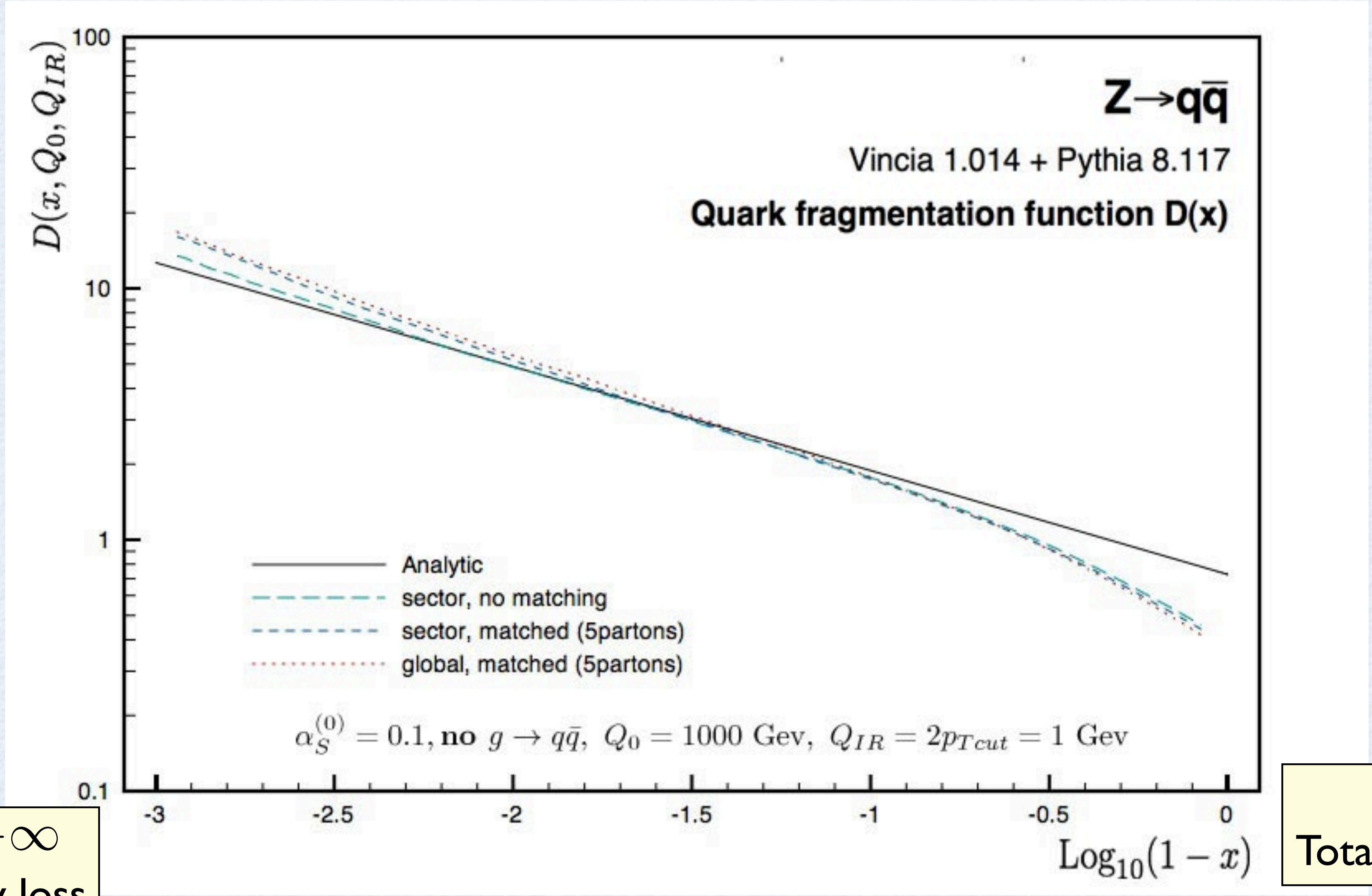




RESULTS->FF

Skands, Weinzierl: Phys.Rev.D79 (2009) ; Nagy, Zoltan et al. JHEP 0905 (2009) 088

Test: fragmentation function for a quark



$x \to -\infty$
No energy loss

$x = 0$
Total energy loss

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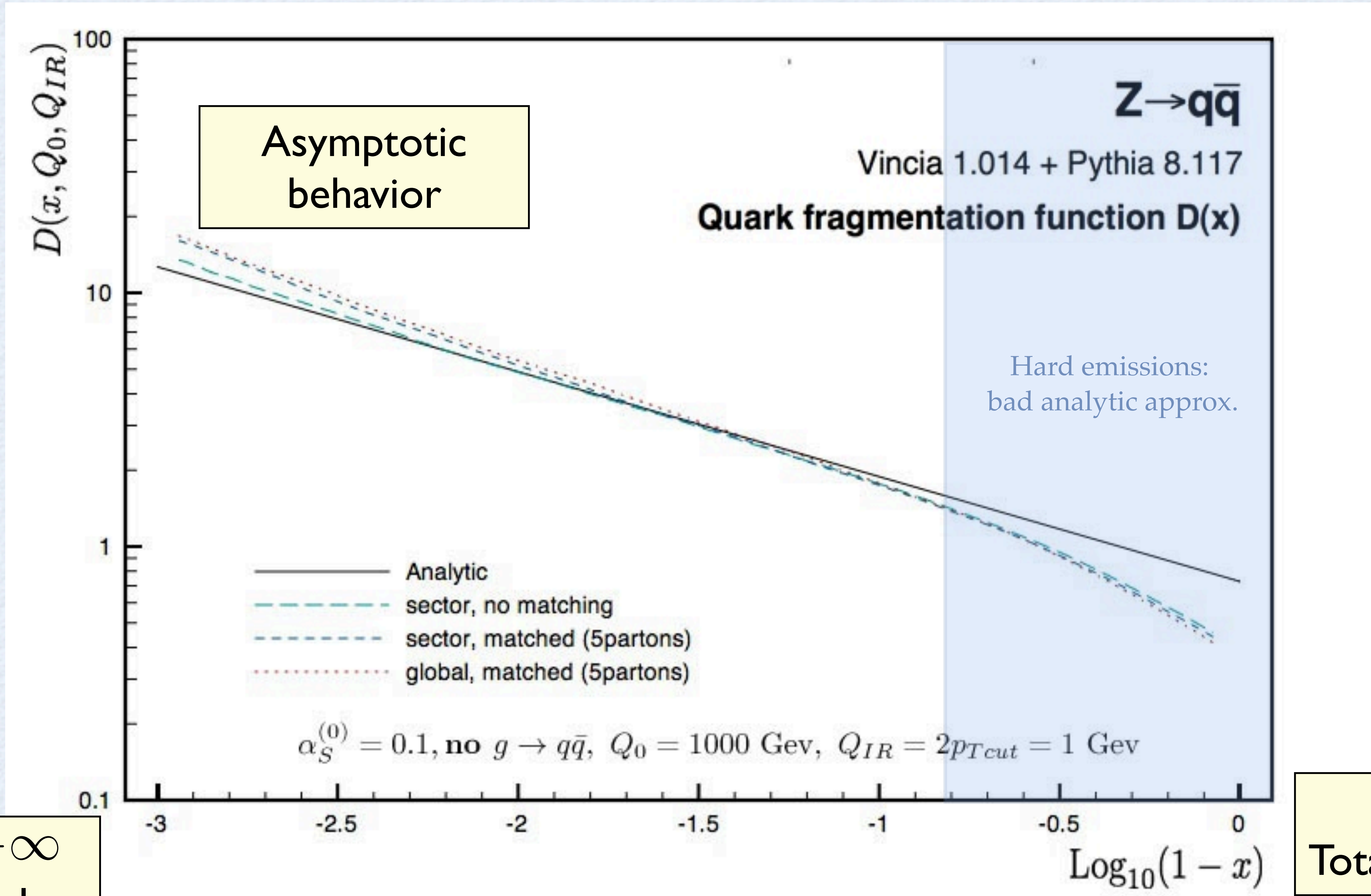

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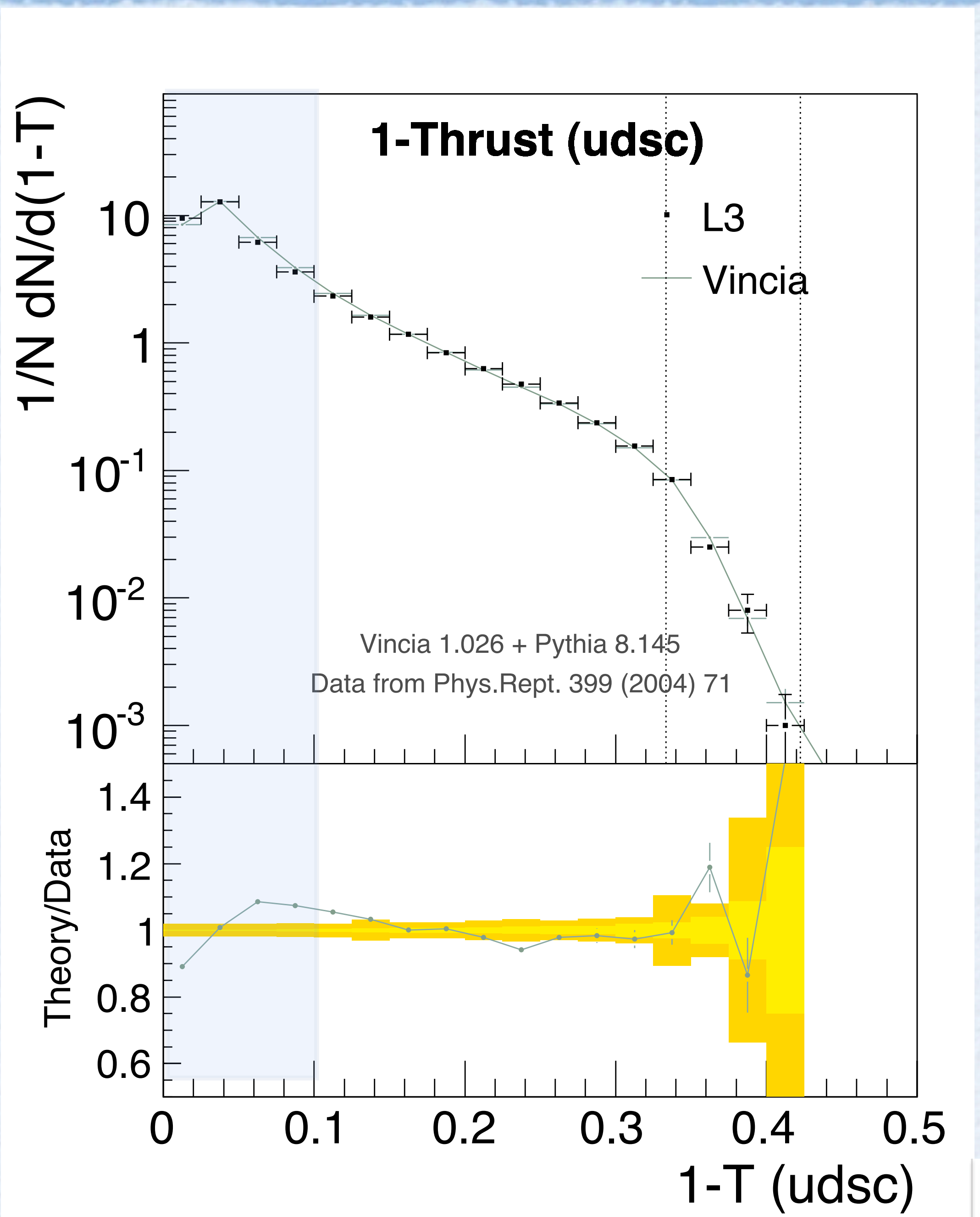
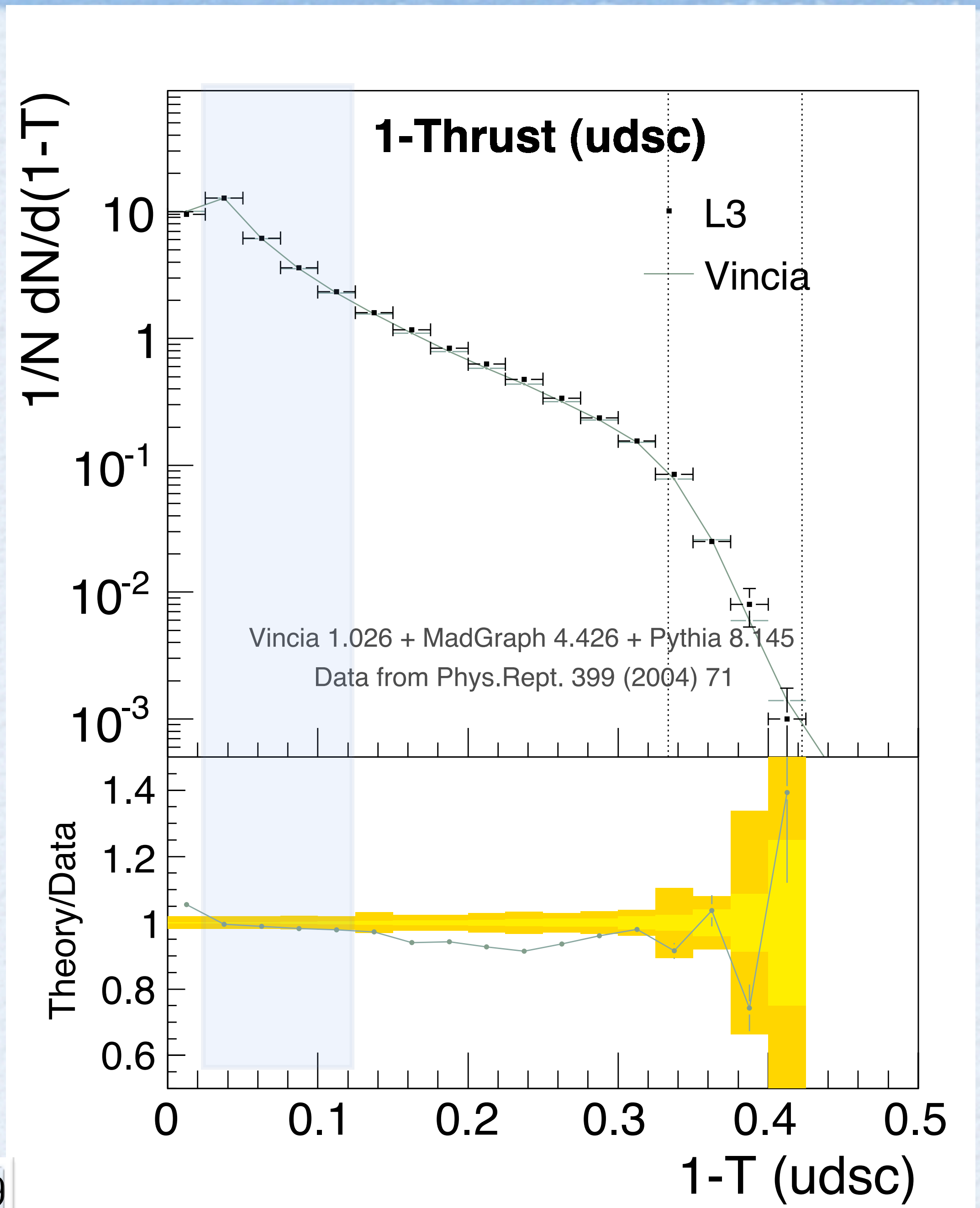
Results->Event Shape(s)





$\alpha_s^{LO}(m_z) = 0.139$

Not matched : 10^6 events

Matched to $Z \to 5$ partons : $2\text{x}10^6$ events

* Collaborating with summer student B. Bravi for tuning to LEP data

Results -> Speed

Matched through:	Z→3	Z→4	Z→5	Z→6
Pythia 6	0.20	ms/event Z→qq *(q=udscb)* + shower. Matched and unweighted. Hadronization off *gfortran/g++ with gcc v.4.4 -O2 on single 3.06 GHz processor with 4GB memory*		
Pythia 8	0.22			
Vincia Global	0.30	0.77	6.40	130.00
Vincia Sector	0.27	0.63	6.90	52.00
Vincia Global *(Q_{match} = 5 GeV)*	0.29	0.60	2.40	20.00
Vincia Sector *(Q_{match} = 5 GeV)*	0.26	0.50	1.40	6.70
Sherpa *(Q_{match} = 5 GeV)*	5.15*	53.00*	220.00*	400.00*
* + *initialization time*	1.5 minutes	7 minutes	22 minutes	2.2 hours

Generator Versions: Pythia 6.425 *(Perugia 2011 tune)*, Pythia 8.150, Sherpa 1.3.0, Vincia 1.026 *(without uncertainty bands, NLL/NLC=OFF)*

J.J. Lopez-Villarejo & Peter Z. Skands. "Fast matrix-elements resummations with sector showers":

Arxiv to be...

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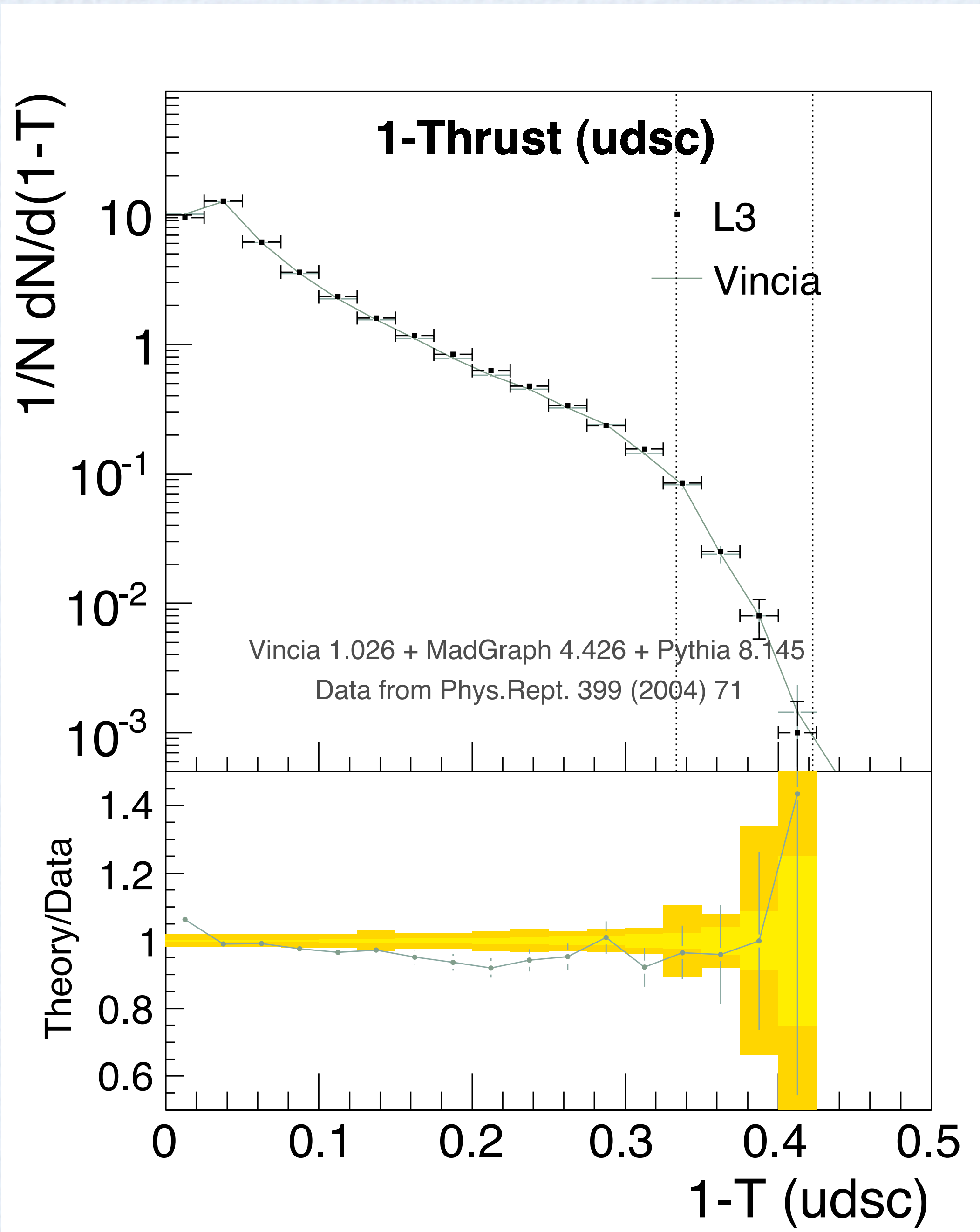
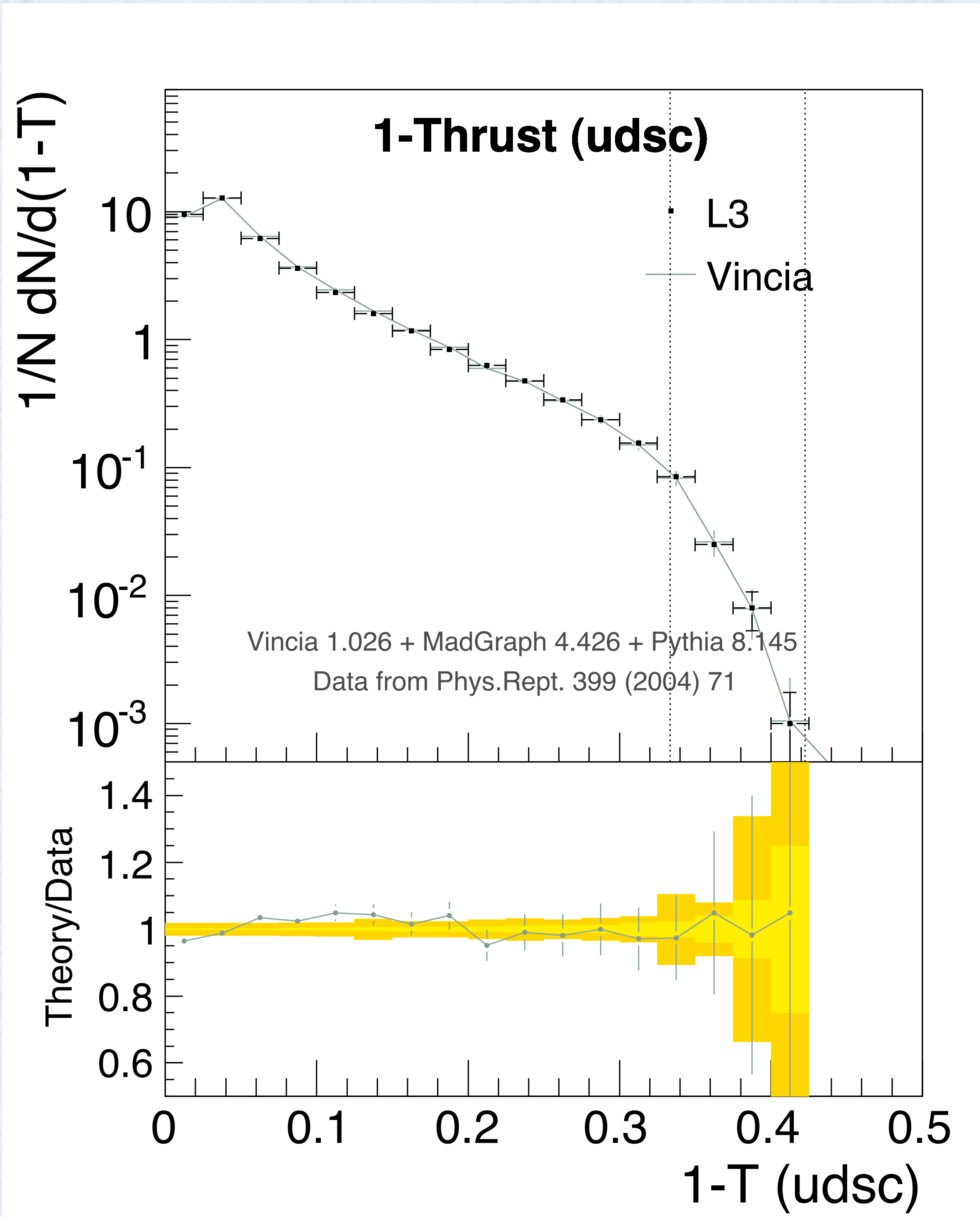
Next steps: ISR, polarization...

Backup

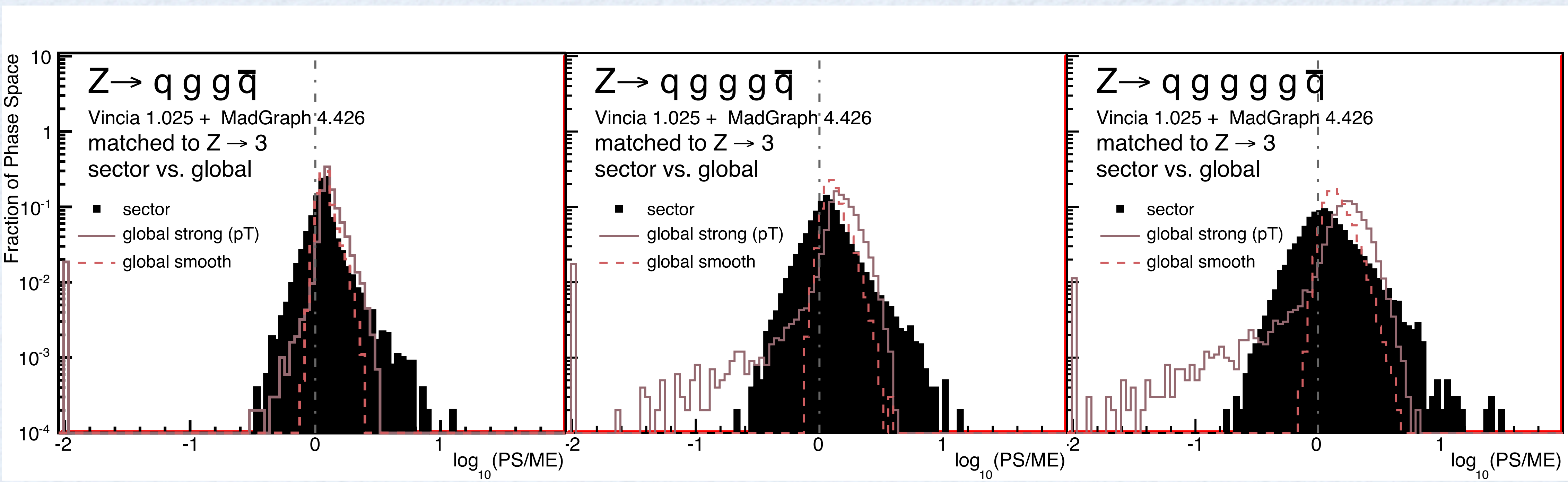


Test (1.000.000 events)



Global (100.000 events)

BACKUP



Fraction of Phase Space
$Z \rightarrow q\,g\,g\,\bar{q}$
Vincia 1.025 + MadGraph 4.426
matched to $Z \rightarrow 3$
sector vs. global
sector
global strong (pT)
global smooth
$Z \rightarrow q\,g\,g\,g\,\bar{q}$
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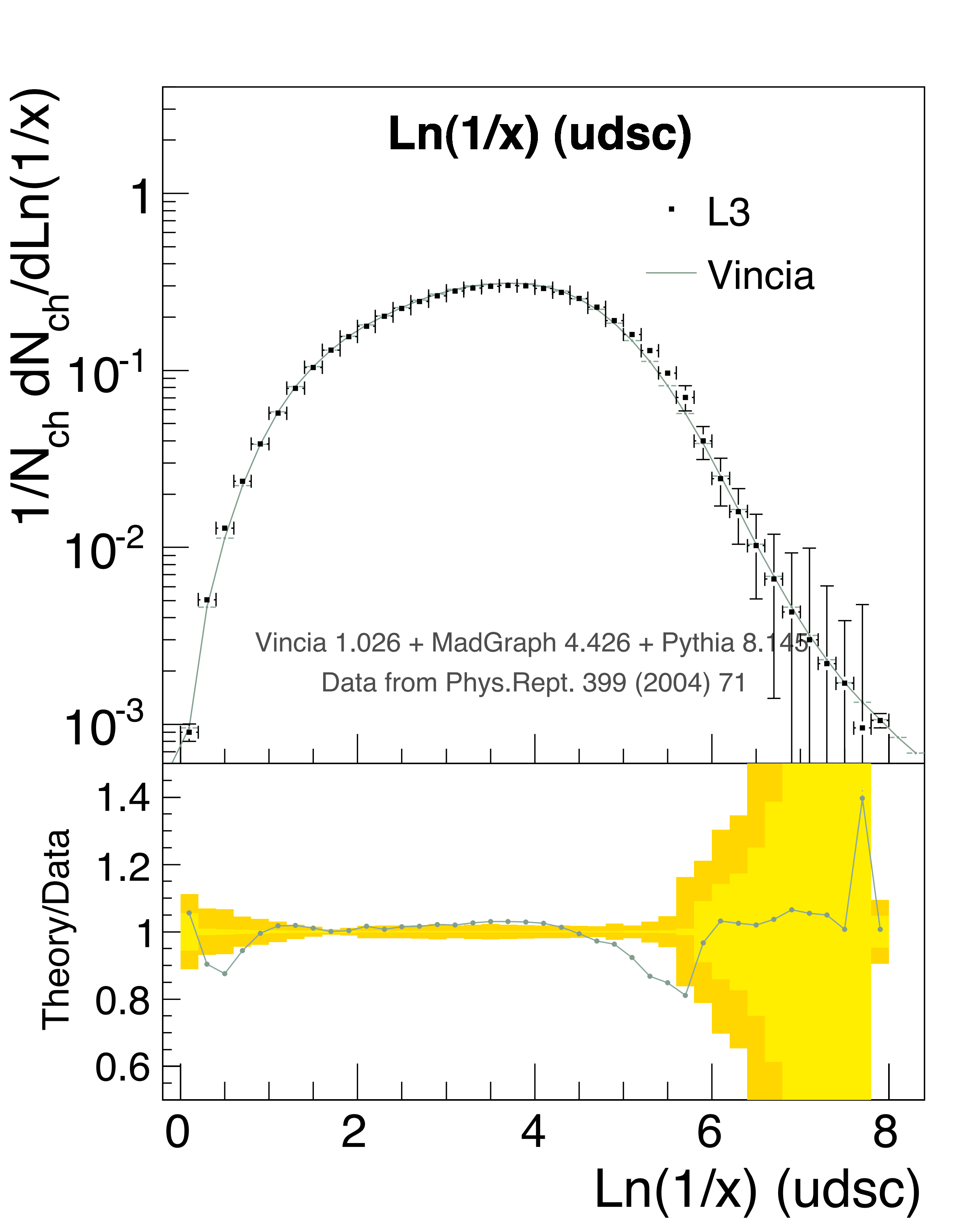
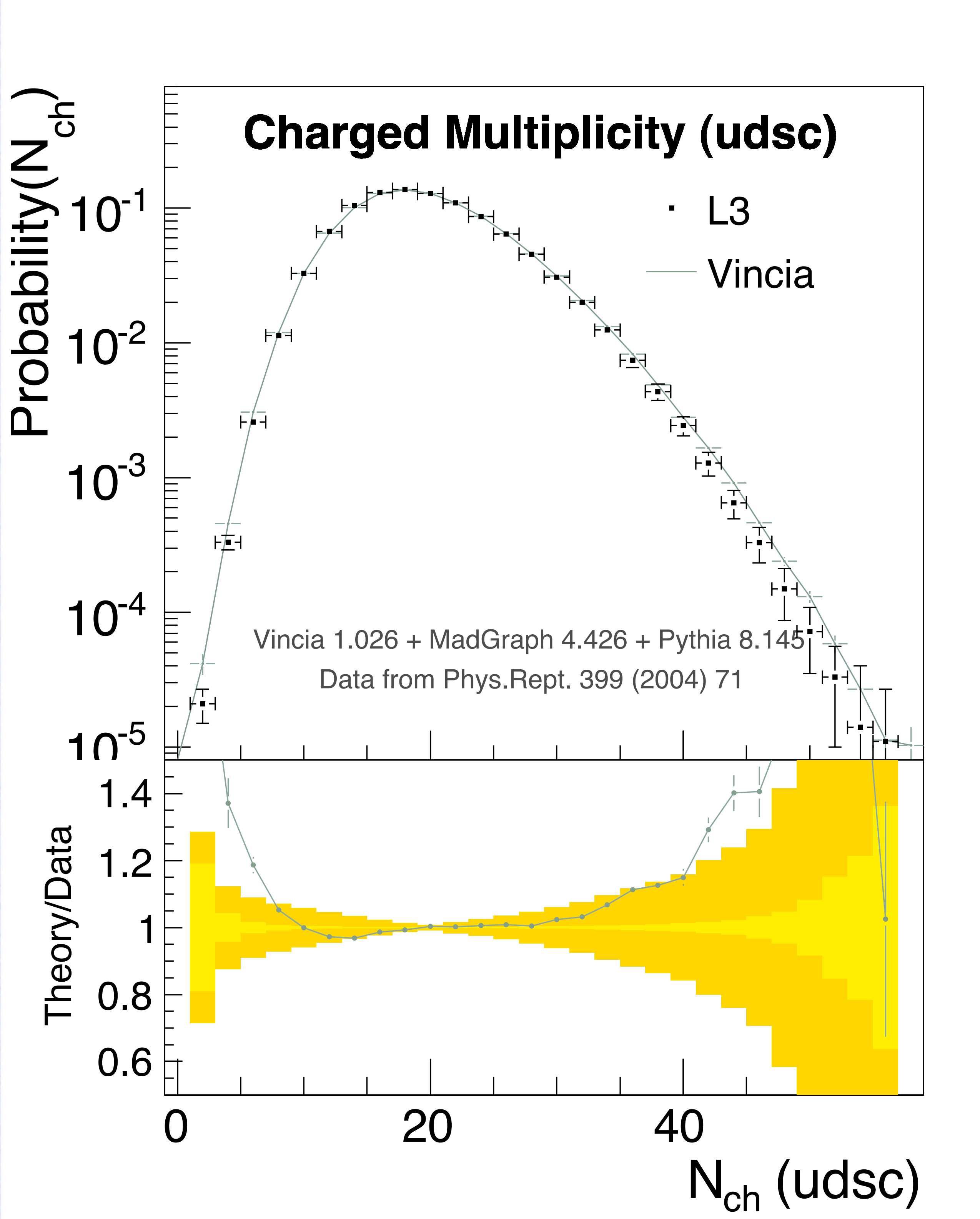
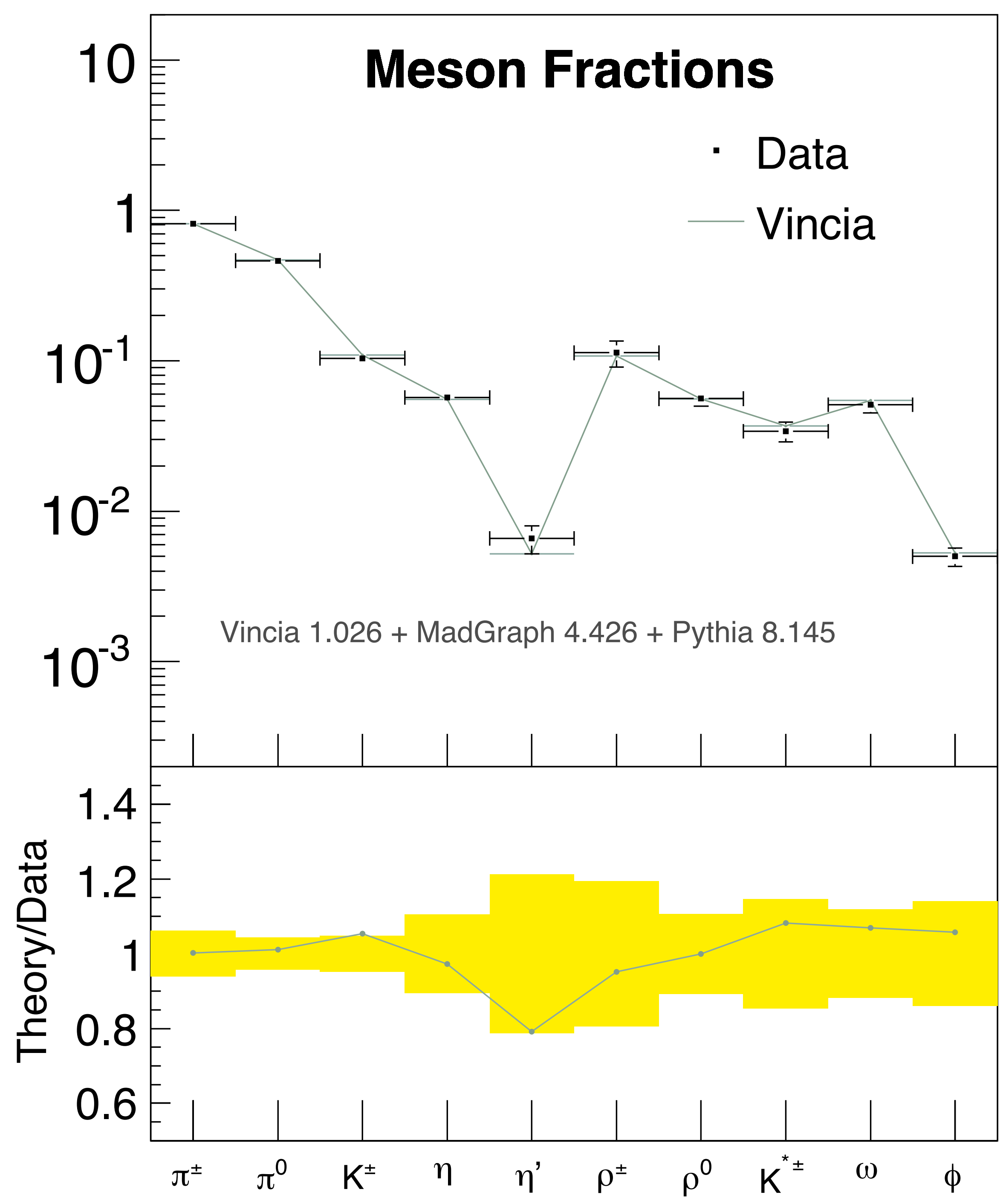
sector vs. global
sector
global strong (pT)
global smooth
$\log_{10}$(PS/ME)

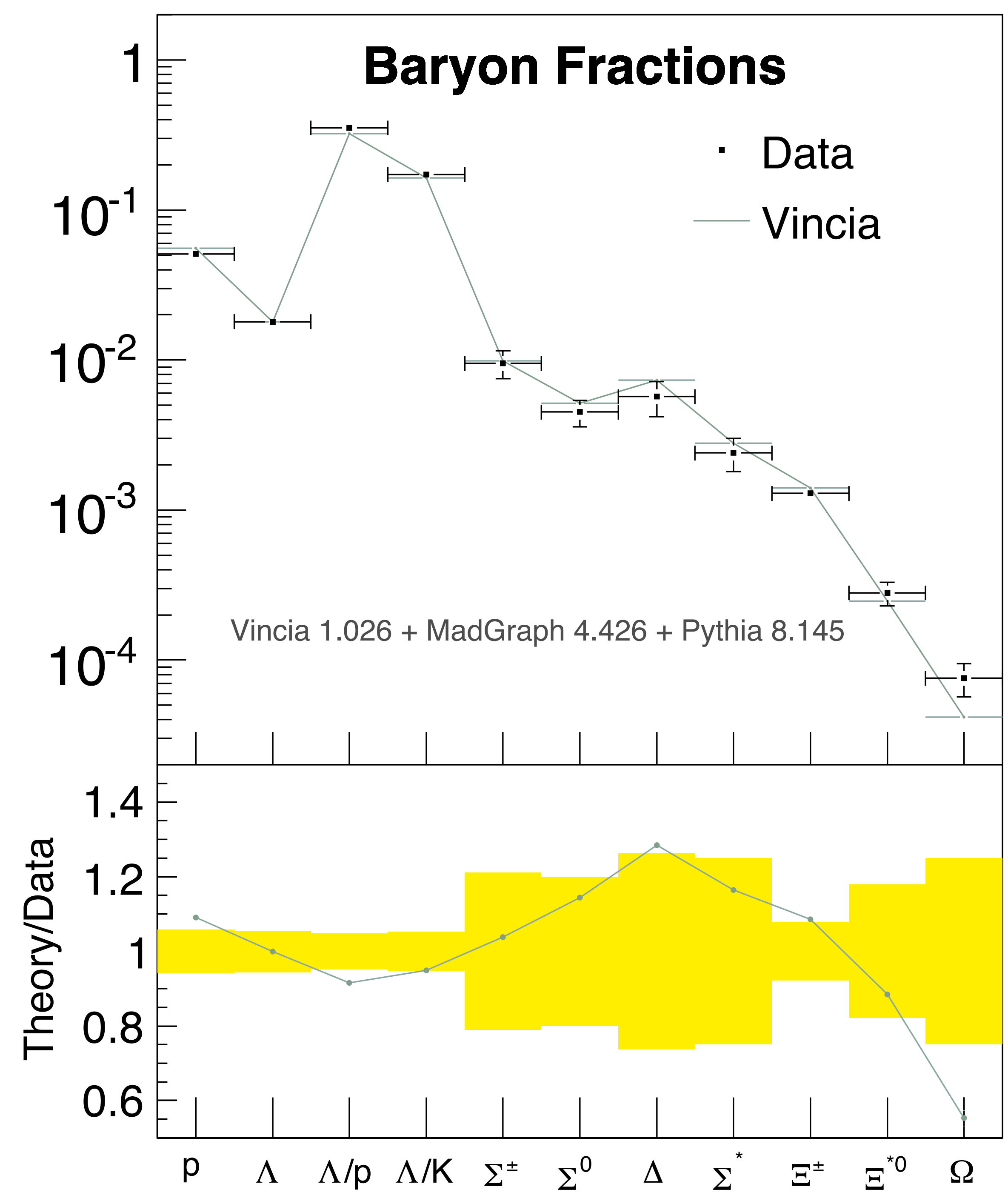
BACKUP


Ln(1/x) (udsc)
L3
Vincia
1/N_ch dN_ch/dLn(1/x)
Vincia 1.026 + MadGraph 4.426 + Pythia 8.145
Data from Phys.Rept. 399 (2004) 71
Theory/Data
Ln(1/x) (udsc)

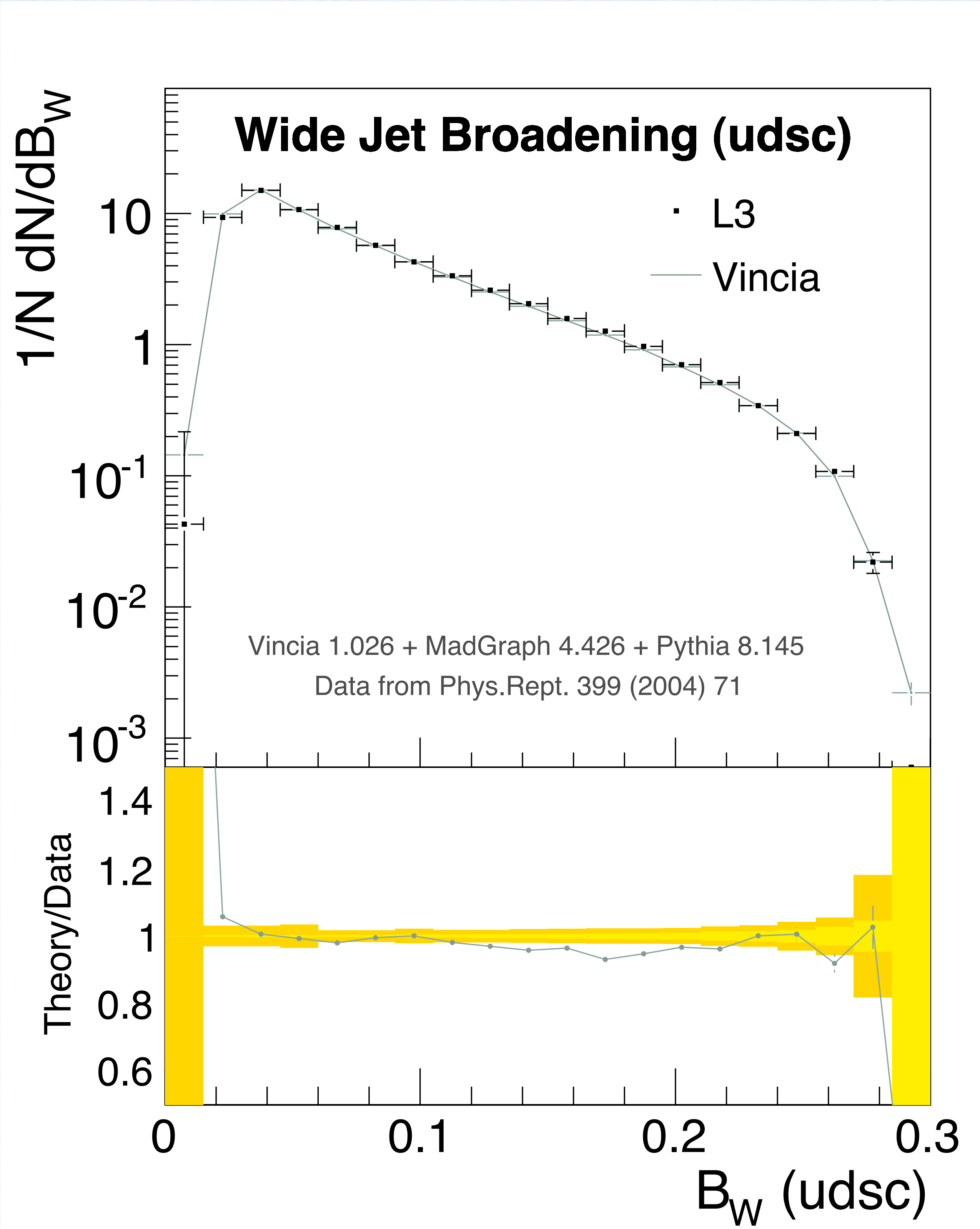

Charged Multiplicity (udsc)
L3
Vincia
Probability(N_ch)
Vincia 1.026 + MadGraph 4.426 + Pythia 8.145
Data from Phys.Rept. 399 (2004) 71
Theory/Data
N_ch (udsc)

BACKUP

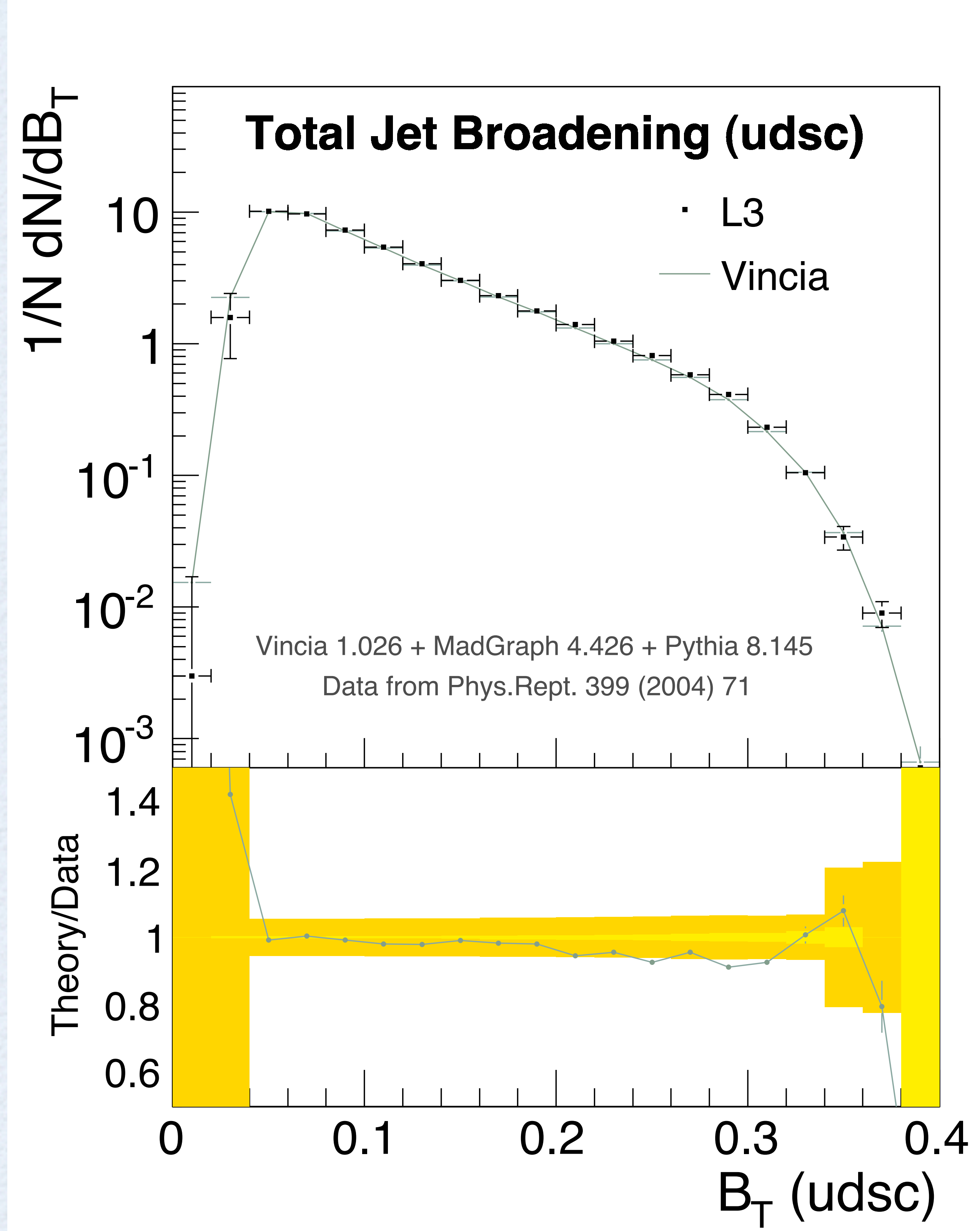

Meson Fractions
Data
Vincia
Vincia 1.026 + MadGraph 4.426 + Pythia 8.145
10
1
10^{-1}
10^{-2}
10^{-3}
Theory/Data
1.4
1.2
1
0.8
0.6
$\pi^{\pm}$ π^0 $K^{\pm}$ η η' $\rho^{\pm}$ ρ^0 $K^{*\pm}$ ω ϕ


Baryon Fractions
Data
Vincia
Vincia 1.026 + MadGraph 4.426 + Pythia 8.145
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
Theory/Data
1.4
1.2
1
0.8
0.6
p Λ Λ/p Λ/K $\Sigma^{\pm}$ Σ^0 Δ Σ^* $\Xi^{\pm}$ Ξ^{*0} Ω

BACKUP

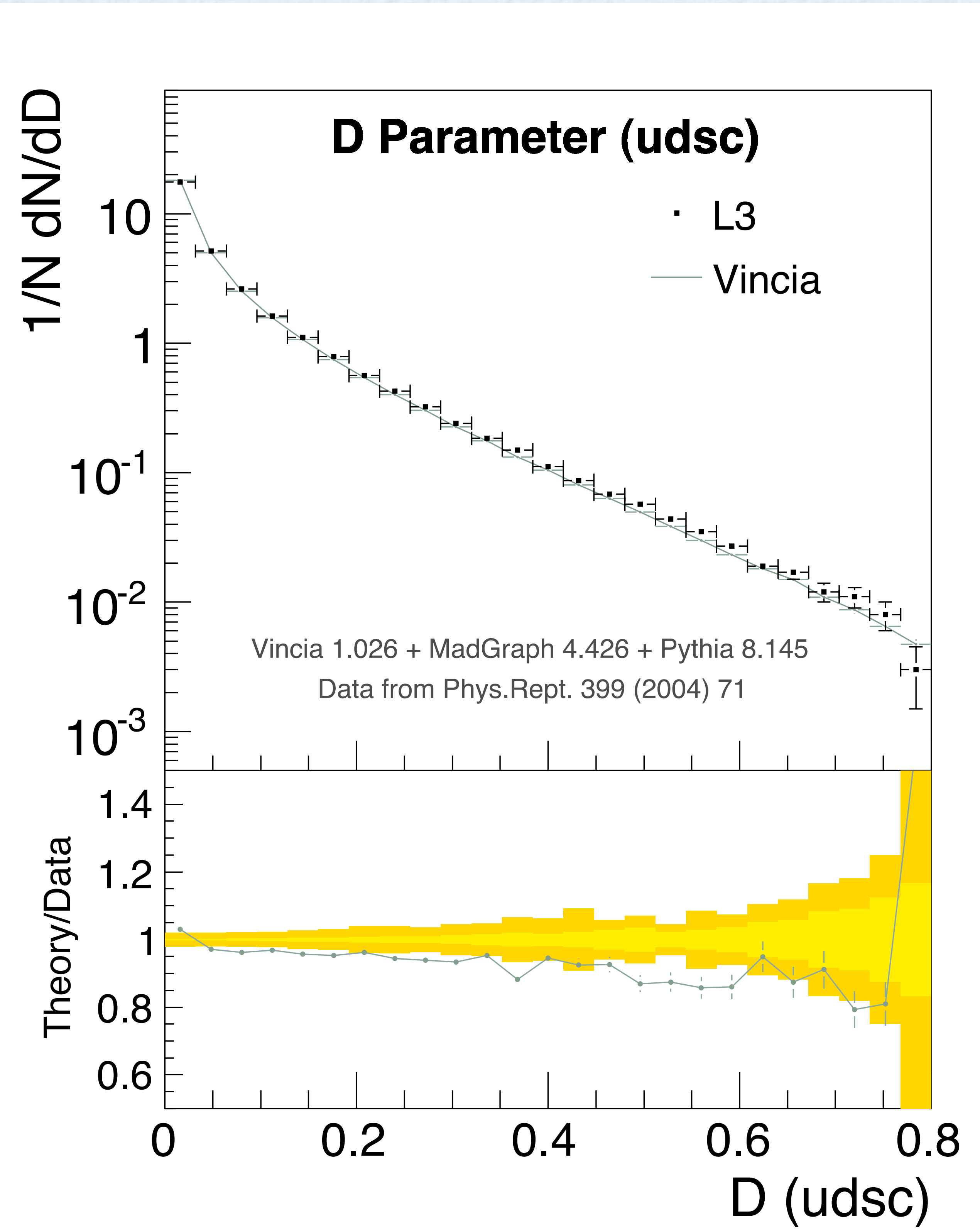


Wide Jet Broadening (udsc)
L3
Vincia
Vincia 1.026 + MadGraph 4.426 + Pythia 8.145
Data from Phys.Rept. 399 (2004) 71
1/N dN/dB_W
Theory/Data
B_W (udsc)



Total Jet Broadening (udsc)
L3
Vincia
Vincia 1.026 + MadGraph 4.426 + Pythia 8.145
Data from Phys.Rept. 399 (2004) 71
1/N dN/dB_T
Theory/Data
B_T (udsc)

BACKUP



D Parameter (udsc)
L3
Vincia
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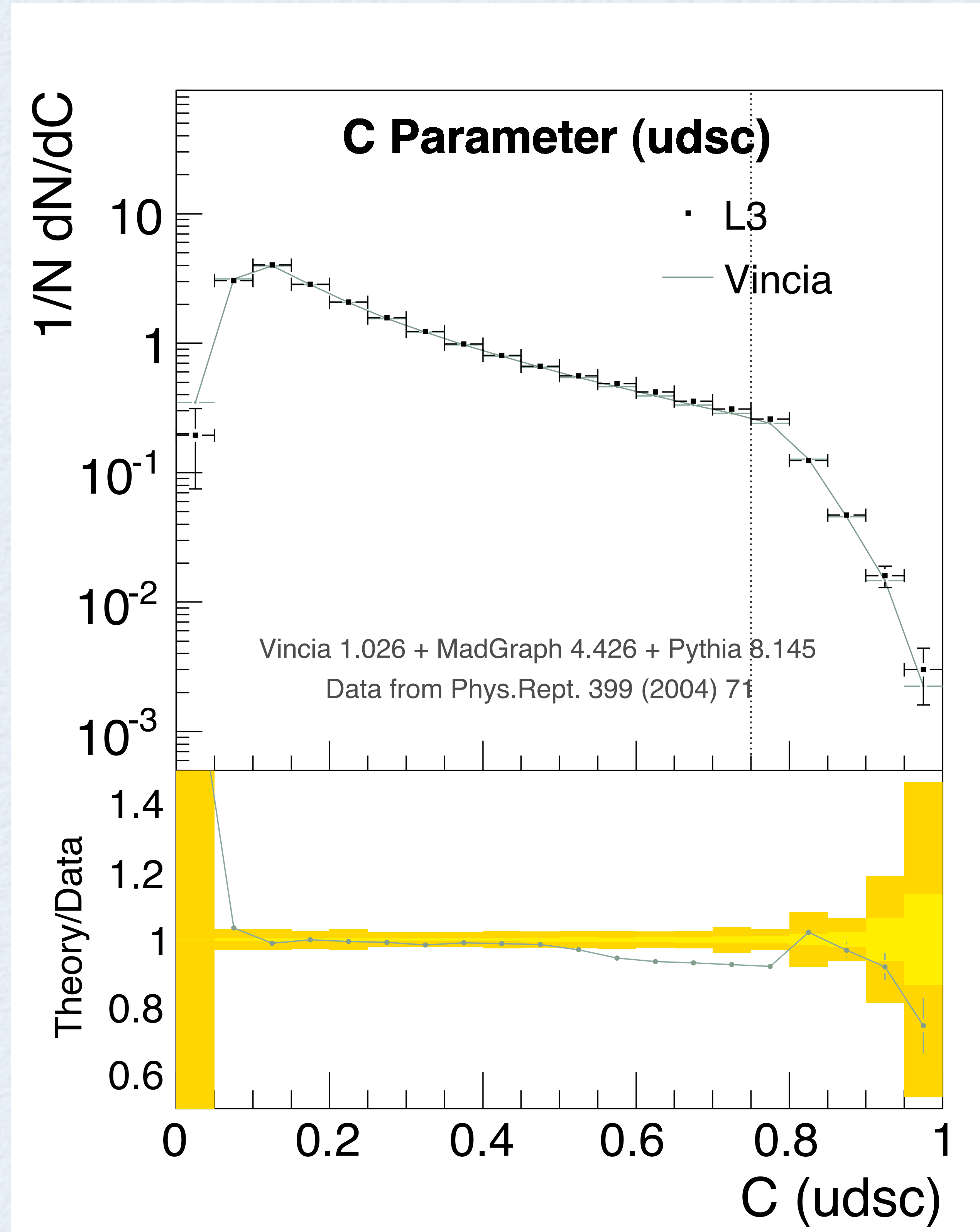
Data from Phys.Rept. 399 (2004) 71
1/N dN/dD
Theory/Data
D (udsc)



C Parameter (udsc)
L3
Vincia
Vincia 1.026 + MadGraph 4.426 + Pythia 8.145
Data from Phys.Rept. 399 (2004) 71
1/N dN/dC
Theory/Data
C (udsc)