

Tools For the LHC: Beyond the Standard Model

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Outline

- Goals: Software pipeline from (SM or beyond) physics process to plots
 - Realistic (beyond the LHC olympics)
 - Fast
 - User friendly
- The role of theorists
 - Why we are well poised to contribute
- The envisioned pipeline
 - MadGraph/MadEvent
 - Pythia
 - Fast CMS detector simulation (PGS-CMS)
 - ROOT analysis routines - plots
- Applications:
 - SM – validate against established tools...and **beyond!** (SUSY, Little Higgs, Extra Dimensions, ...)

Caveat

- At the moment, I am not an “expert” in any single one of these tools
 - not an author
 - ‘active’ end-user
 - model building and implementation
- Will present here goals and some preliminary results of a new theory collaboration

What are theorists good for?

- We will not be good at analyzing real LHC data
 - Just don't have the skill set or experience
- Good at simple questions
 - coming up with creative strategies
 - Implementing and understanding event generators
- We have time
 - we're not busy making sure the triggers work – making sure we understand the detector

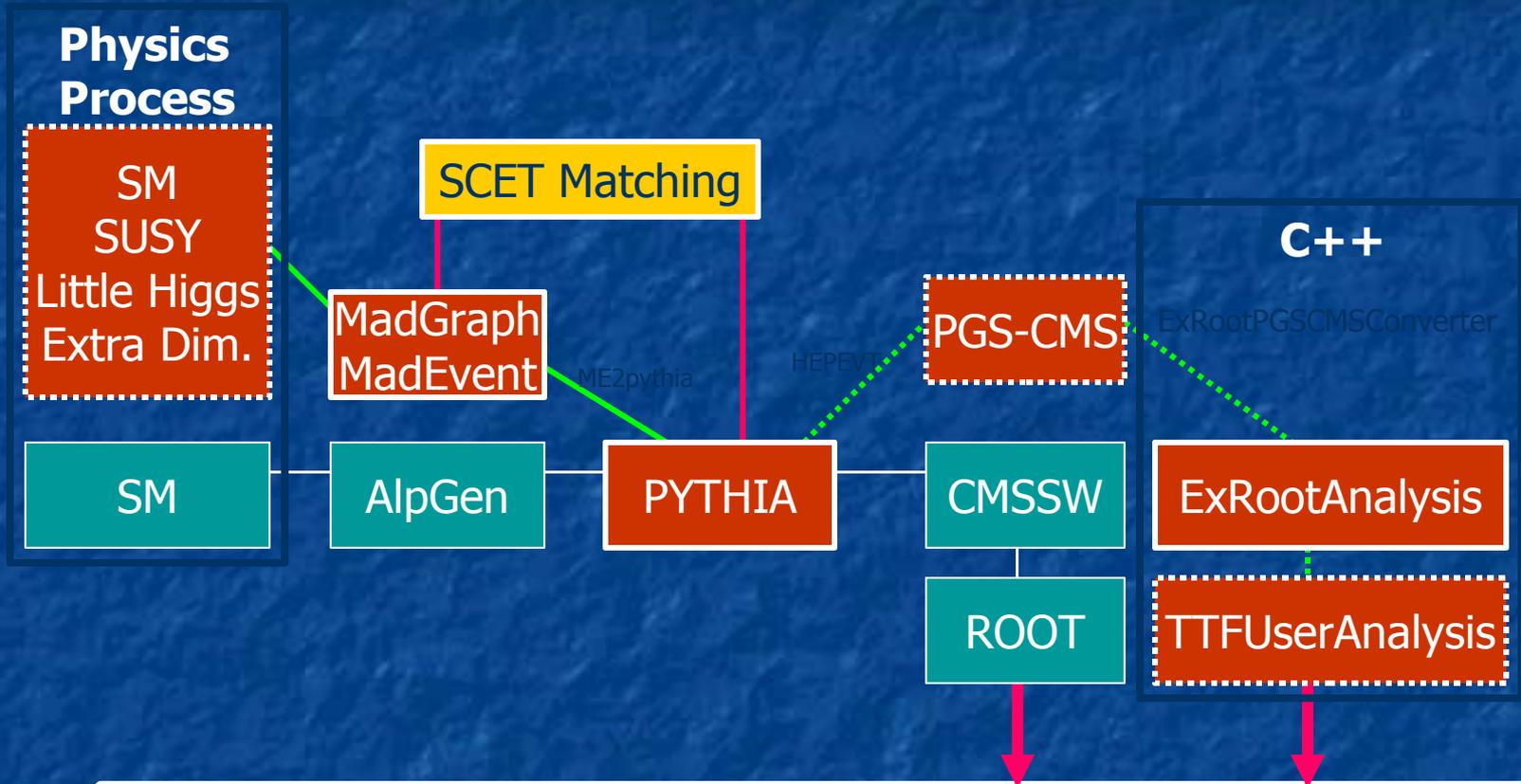
We can make important contributions, but only with the caveat that we do our best to learn the challenges associated with dealing with real data!

Formation of Theory Task Force (CMSTTF)

- Joe Lykken (Maria Spiropulu)
- Stephen Mrenna
- Marcela Carena
- JH
- Rakhi Mahbubani
- KC Kong
- Jose Santiago

Inaugural meeting: 4/18/07

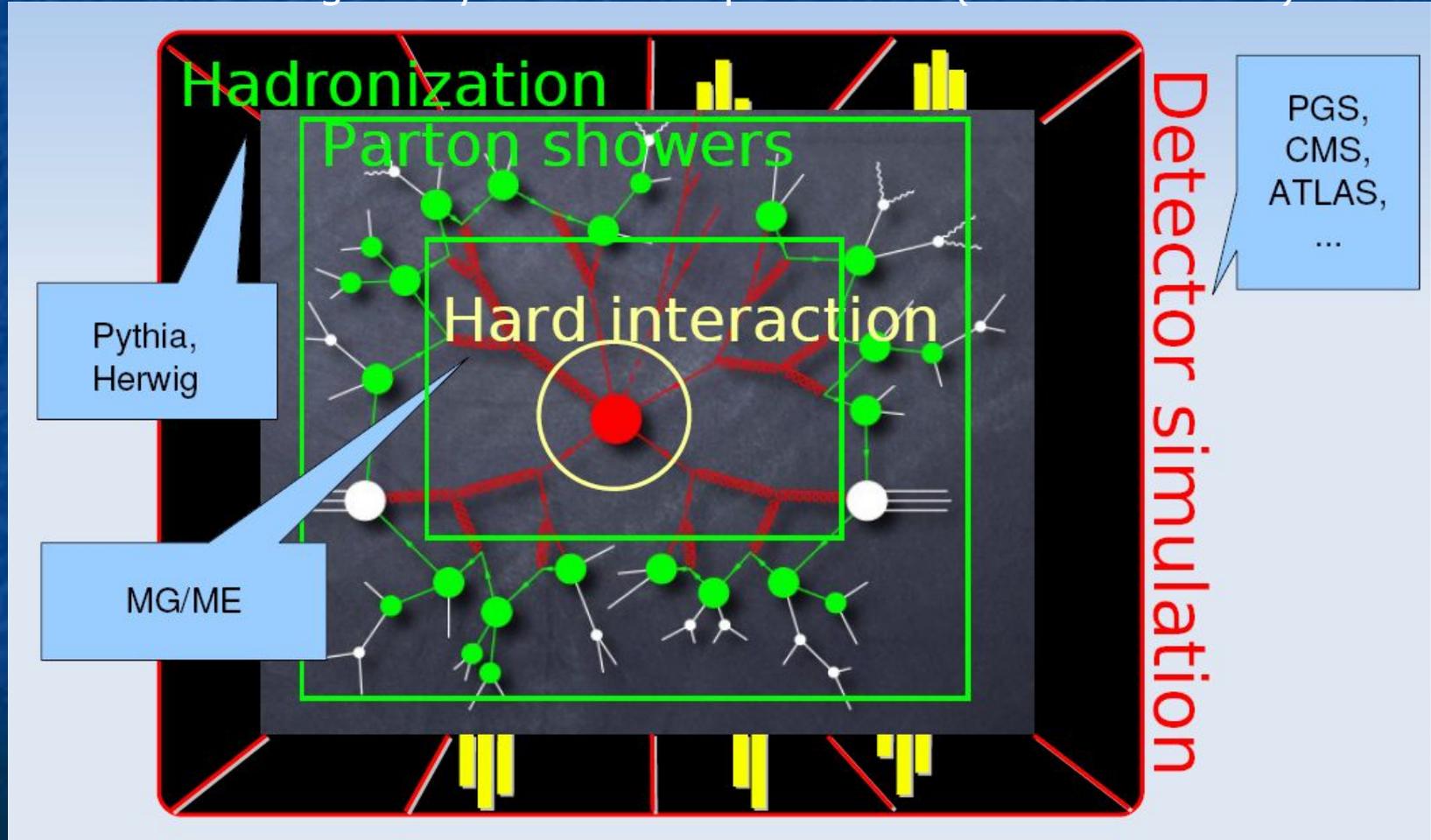
The PIPELINE



Plots! - Papers! - Fame!

"The Big Picture"

Stolen from talk given by Michael Herquet at IIHE (MG collaboration)



Tasks for the Force

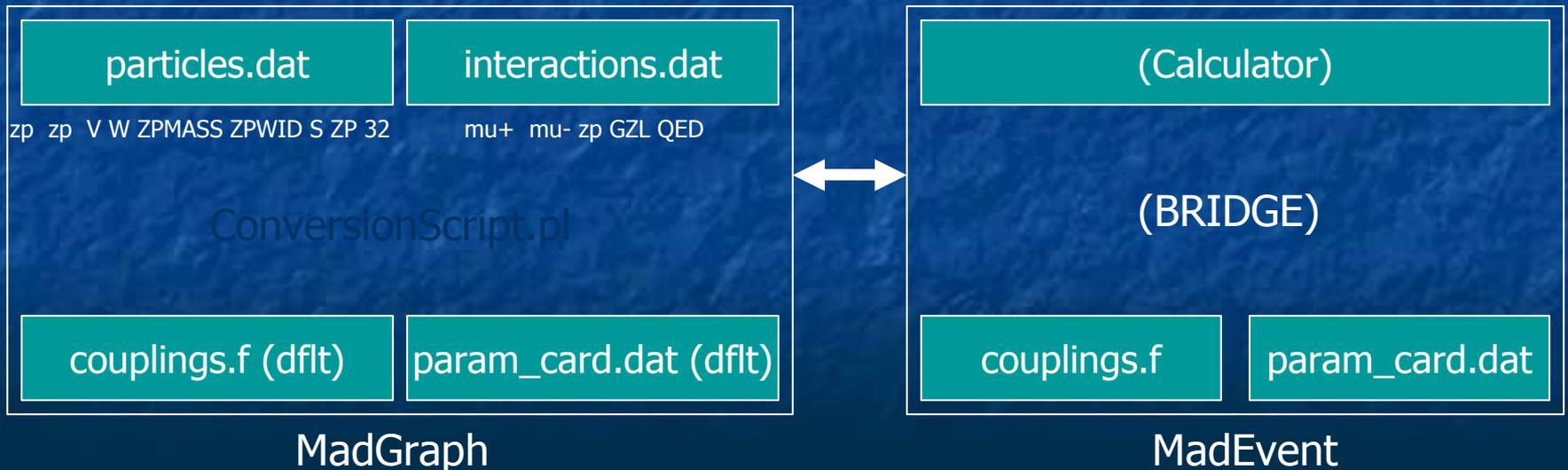
- TTF is working on:
 - PGS-CMS
 - “Realistic,” ***fast***, CMS specialized detector simulation
 - Tune using PTDR - 2008 (1 fb^{-1}) signals (SUSY benchmark)
 - Many analyses done with full GEANT based simulation
 - Validation
 - Need as many channels as possible
 - beyond the benchmarks...
 - Theorists can't run CMSSW (we need your help!)
 - Got Students?
 - Ease of use – scripts connecting links in the chain
 - One command to go from Process to Plots!
 - Implementing complete BSM theories in MadGraph

What is MadGraph?

- Tree level matrix element calculator
 - builds helicity amplitudes from HELAS subroutines
 - maintains polarization information in initial and final states
 - BRIDGE (MG add-on) performs decays maintaining nearly all correlations (factorized phase space with narrow width approx.)
- HELAS routines can be added by the savvy theorist for non-standard interactions
 - $h \rightarrow \gamma\gamma, gg$
 - Higher dimensional operators
- Resulting matrix element passed to event generator
 - MadEvent comes packaged with MG
 - Parallelizable (PBS, condor clusters supported)
- Interfaces to Pythia, PGS, ROOT, and CMSSW

Beyond the Standard Model in Madgraph

- Simple format for entering in BSM Lagrangian
 - Similar to COMPHEP/CALCHEP
 - particles.dat, interactions.dat, couplings.f, param_card.dat
 - Aided by suite of scripts (usrmod) and BRIDGE
 - Zero to Z' in 5.7 minutes!

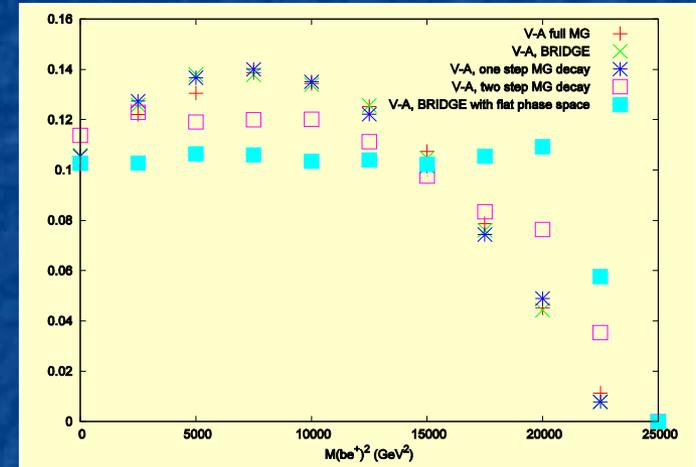


Implemented Models

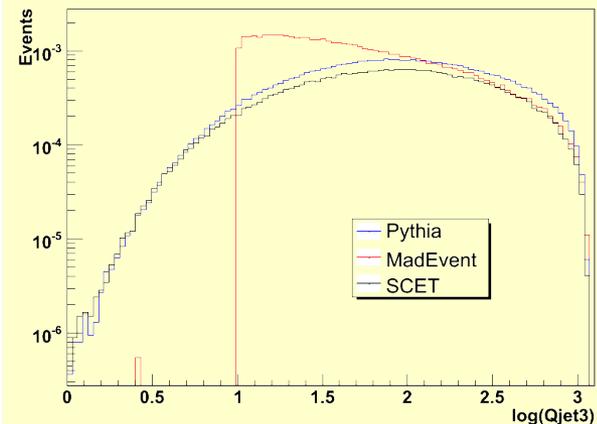
- With MadGraph:
 - SM (with or without CKM mixing)
 - MSSM (SMadGraph)
 - General 2 Higgs doublet model
 - Higgs Effective Theory (hgg coupling)
- Sold Separately:
 - Littlest Higgs with T-parity
 - partial UED
 - ...“private” codes

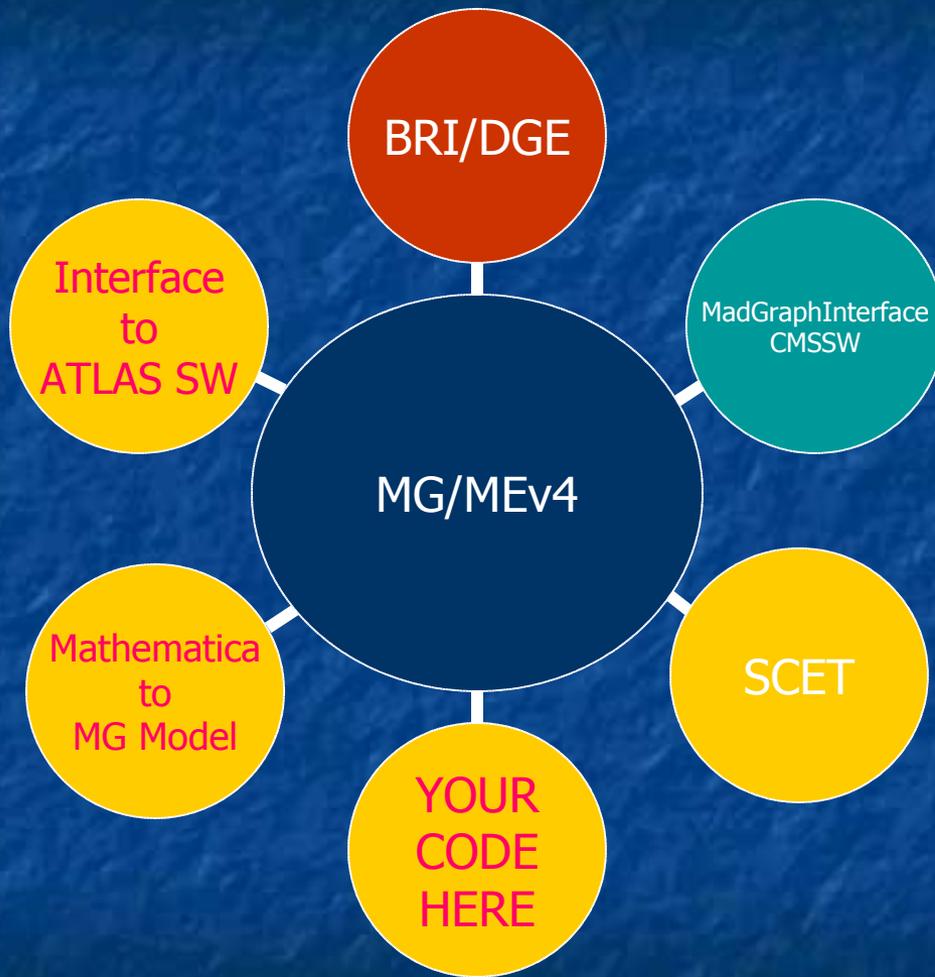
MG is modular

- Easy to add on useful pieces of code
 - BRI/DGE (Meade, Reece)
 - Branching Ratio Inquiry/Decay Generated Events
 - Branching fractions and decay tables/vegas grids
 - MG SCET matching (Schwartz, Mrenna, Alwall)
 - add SCET rules to HELAS, resum large logs
 - pass to pythia for showering at event dep. RG scale
 - **Testing phase**



Comparing Madevent, Pythia and SCET





- Real pro is **transparency** – easy to dig around the code, see what its doing
- Attitude is very much 'open source'
- MG/MEv4 authors strongly encourage innovation
- If one person needs a tool enough to write it, at least 10 more need it enough to use it!

What is PGS?

- A Pretty Good Simulation
 - evolved out of '98 SHW – Run 2 avg. of CDF and DØ
 - renamed PGS at Snowmass 2001
 - used for comparisons: VLHC, LHC, Tevatron
 - especially used by theorists (not restricted to Tevatron)
- How good (compared with full simulation)?
 - For most analyses, within factor of 2
 - Even as good as 20% agreement, for many cases

PGS is NGES

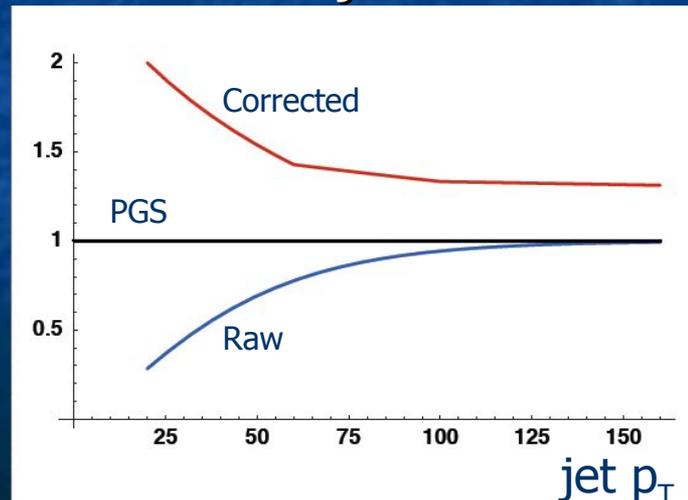
- Not good enough simulation!
 - ideally we have something that is closer to full simulation
 - at least for physics processes we are most interested in
- FAMOS not fast enough
- Tune PGS to work for CMS
 - analog of ATLFast
 - assumption: PGS is not hopeless for main features of central, high p_T signals (SUSY!)
 - **PGS-CMS** - Joe Lykken, Maria Spiropulu

PGS-CMS

- The physics of the CMS detector can be imitated in PGS
 - raw vs. corrected jets
 - add B-field
 - pileup and multiple interactions (via pythia interface)
 - z-vertex
 - ...
- What is our reference point?
 - CMS Physics TDR
 - tweak physics parameters to match 3 benchmark SUSY scenarios cut-by-cut
 - helpful to have someone “in the know” to read between the lines in the TDR

Raw, PGS, and Corrected Jets

- Biggest difference is in the jets
- Vanilla PGS “jet” is something sort of between raw and CMSSW corrected jets
 - raw jet – what you see in the detector
 - corrected jet – use tracking info, z-vertex, etc
 - aim to reproduce the jet at the parton level
- Correction is big: PGS 50 GeV jet is 75 GeV!



PGS-CMS vs PGS

	PGS-CMS	PGS
Raw jets	Yes	No
Corrected jets	Yes	No
B field	Yes	Only track smearing
z-vertex	Yes	No
Realistic muon reconstruction	Yes	No
Realistic tau reconstruction	Yes	Yes
Charged hadron track reconstruction	Yes	No
Realistic cal and track isolation	Yes	No
Brem effects	Partially	No
Realistic triggering?	No	No
Pile-up and multiple interactions	Implement in Pythia	Implement in Pythia

How is it doing?

jetmet selection	PGS-CMS efficiency	diff wrt ORCA
trigger, $MET > 200$ GeV + central jet	54.2%	+0.3%
$N_{\text{jets}} \geq 3$	72.3%	+0.2%
$ \eta_d < 1.7$ for leading jet	93.5%	+5.4%
Event Charged Fraction ≥ 0.175	98.6%	+0.7%
angular cuts: $\delta\phi_{\text{min}}$, $\delta\phi_{MET-j_2}$, $R1$, $R2$	78.8%	+1.5%
Indirect Lepton Veto	81.5%	-3.8%
$E_T(j1) > 180$ GeV, $E_T(j2) > 110$ GeV	62.8%	-0.2%
$H_T > 500$ GeV	91.9%	-0.9%
Final efficiency for LM1 signal	13.4%	+0.5%

← trigger issue

← need to model electrons faking raw jets

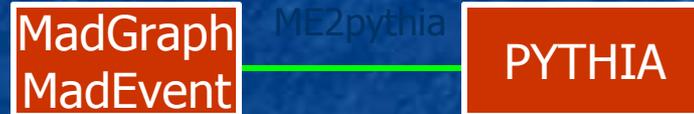
"Vanilla" PGS gives efficiency that is 30% too high

PGS-CMS “To Do” List

- Realistic b-tagging
- Model for electrons
- More detailed validation
 - more channels
 - good to have many analyses with full simulation to identify PGS-CMS strengths and weaknesses
- Goal: fast tool for both theorists and experimentalists
 - prelude to full simulation

Connecting the links

MadEvent to PYTHIA



- ME2pythia reads ME output file
 - decays (SM) + parton shower + hadronization
 - could avoid BRIDGE and use PYTHIA QNUMBERS for exotic decays
 - flat phase space approximation - good enough for most purposes
 - output in STDHEP format (.hep file)
 - can add pileup, multiple interactions at this point

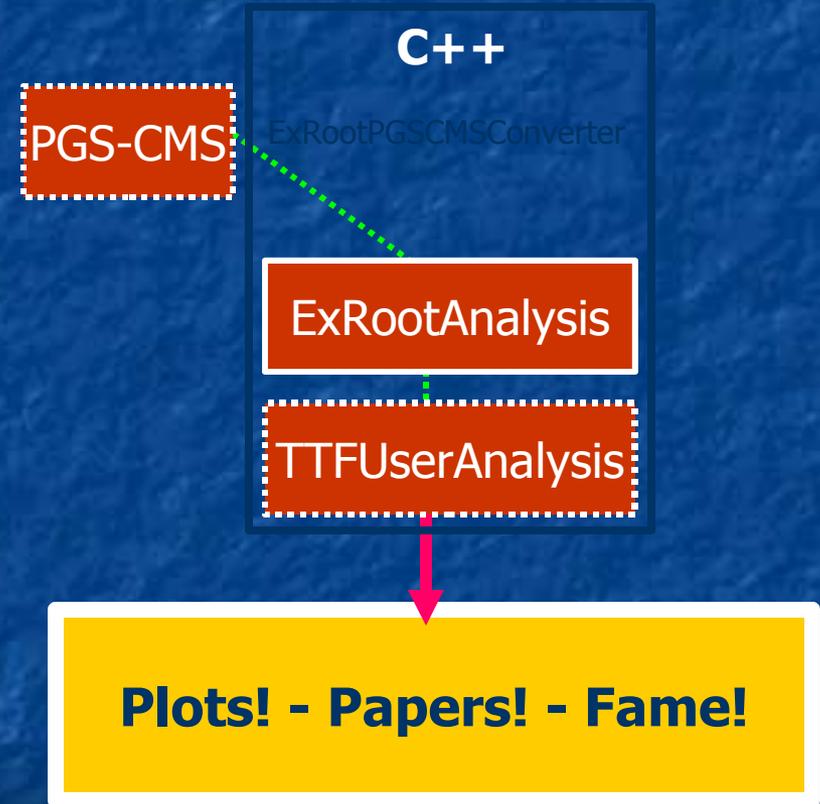
PYTHIA to PGS-CMS



- First version of PGS-CMS linked to SUSY generation via pythia
 - useful when tuning to SUSY benchmark studies
- Modified to read PYTHIA .hep output into PGSCMS format
 - keep track of number of pileup events

Analysis Tools

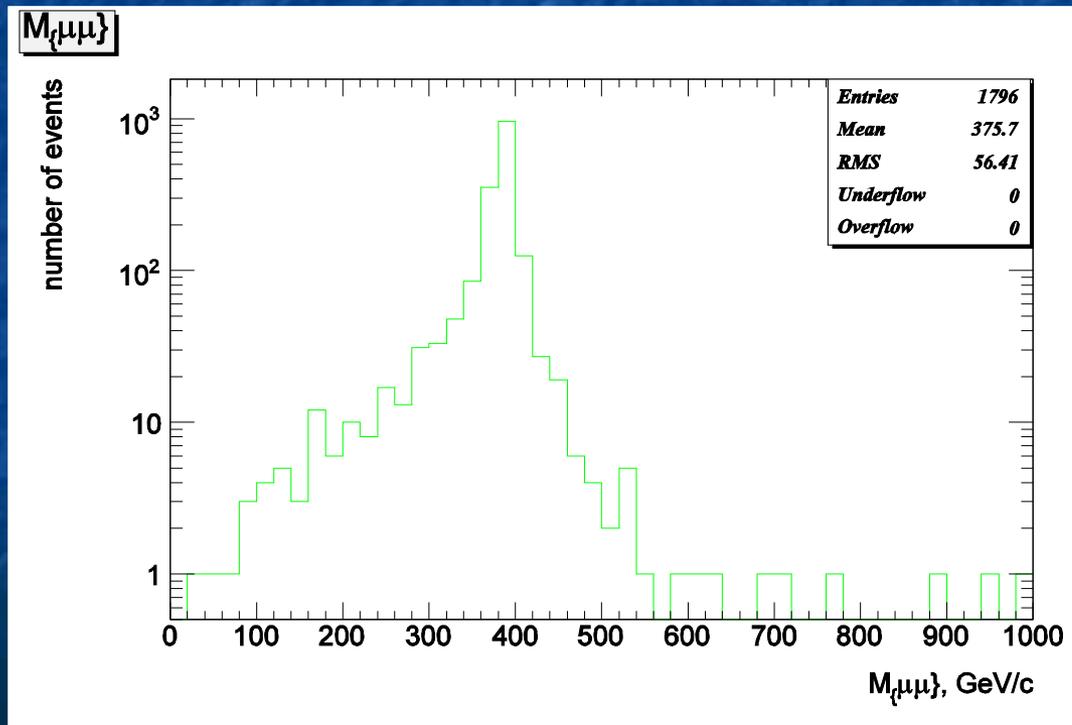
- Analysis level cuts
- define interesting functions of object variables
 - Njets, Meff, Mll, M
- booking histograms
- Once set up – immediately analyzes output of PGS-CMS and generates whatever plots you asked for



Opening the Valve!

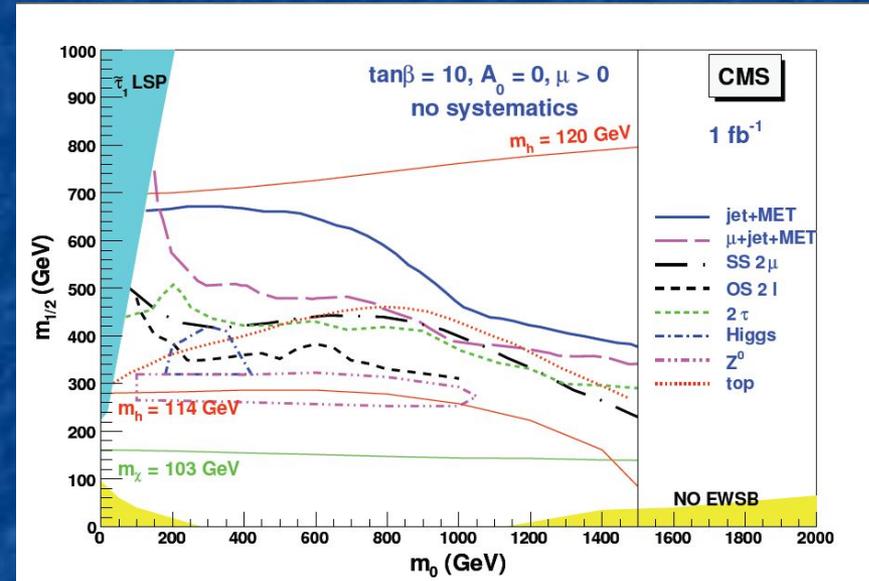
The Z'

- initialize run (run parameters set in card files)
 - `./bin/generate_events_cms 0 ZPrime`



Inclusive Signatures

- Inclusive signatures
- 2008 analyses
- More inclusive → more reach
 - Not restricted to SUSY

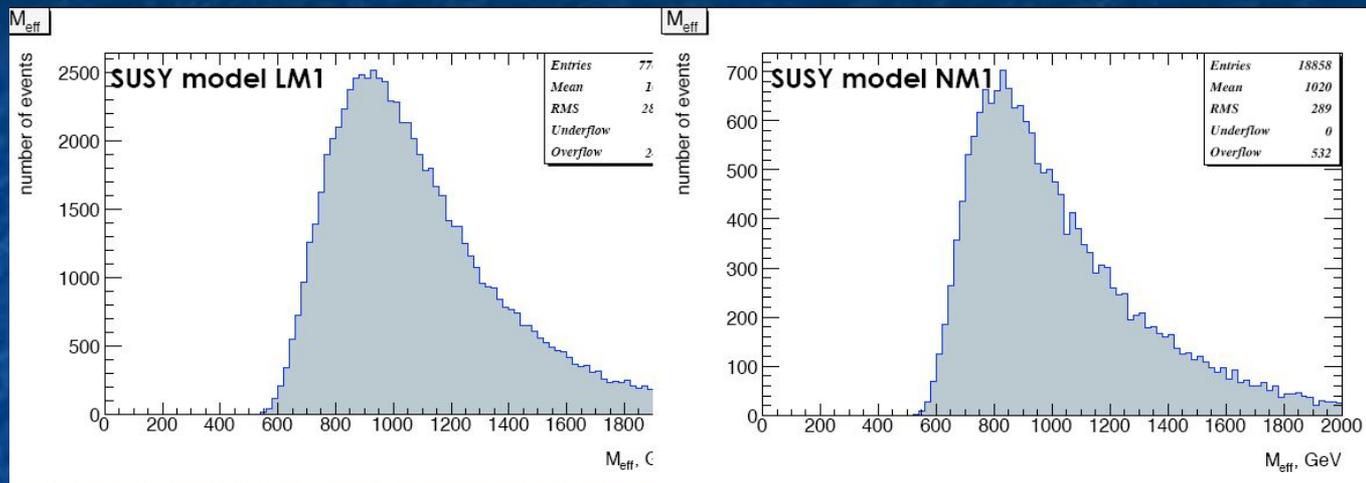


First order of business

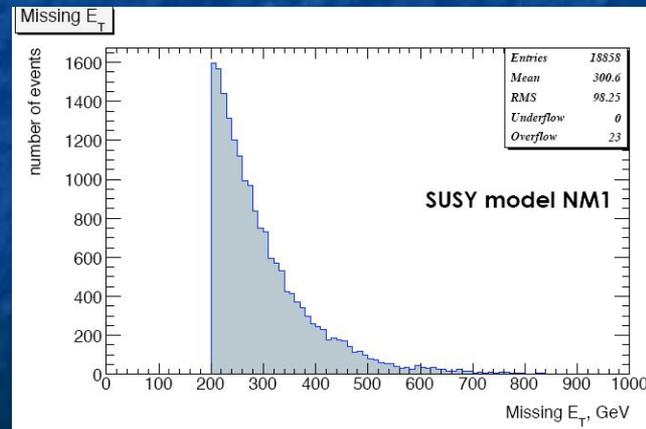
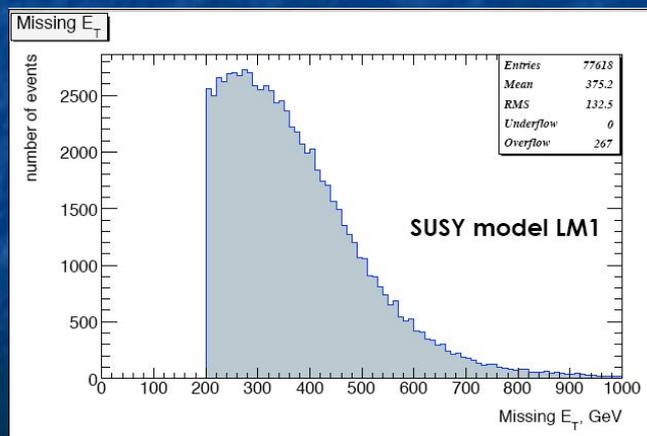
Joe Lykken, Maria Spiropulu

- What happens in 2008?
 - we go as inclusive as we can go
- SUSY
 - Jet + MET
 - Mu + Jet + MET
 - SS 2 Mu
 - OS 2 leptons
- Backgrounds done!
- Tale of Two Models
 - LM1
 - 600 GeV gluinos
 - 550 GeV squarks
 - NM1
 - 350 GeV gluinos
 - 1200 GeV squarks
- Picked to produce same signal in Jets+MET

Preliminary results



M_{eff} not a very useful observable –
doesn't actually measure SUSY scale (gluino mass)



MET above the cut more distinctive

2nd, 3rd, etc orders of business

- NOT SUSY (Little Higgs – UED – more!)
 - Jet +MET
 - Mu+Jet+MET
 - SS 2Mu
 - OS 2 l
- Comparison with SUSY inclusive footprint
 - use same techniques to compare expected signatures with 1fb^{-1}

Comparison – Distinction

- What non-SUSY models are consistent with a given excess in one of these channels?
- Goal:
 - Match jets+MET for set of non-SUSY BSM theories to that of LM1, NM1, etc and compare various observables
 - Ideally: vary continuously over model parameters keeping jets+MET cross section fixed to scan the inclusive “<your model here> footprint”

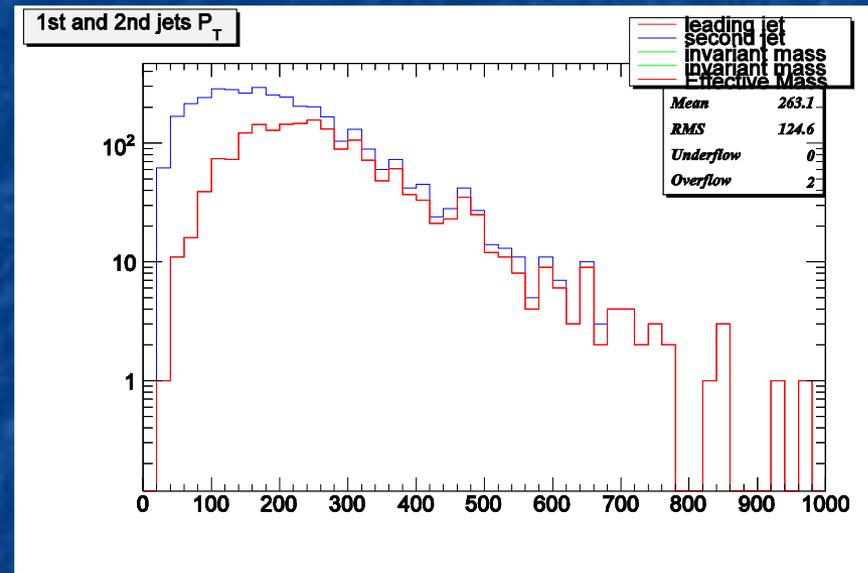
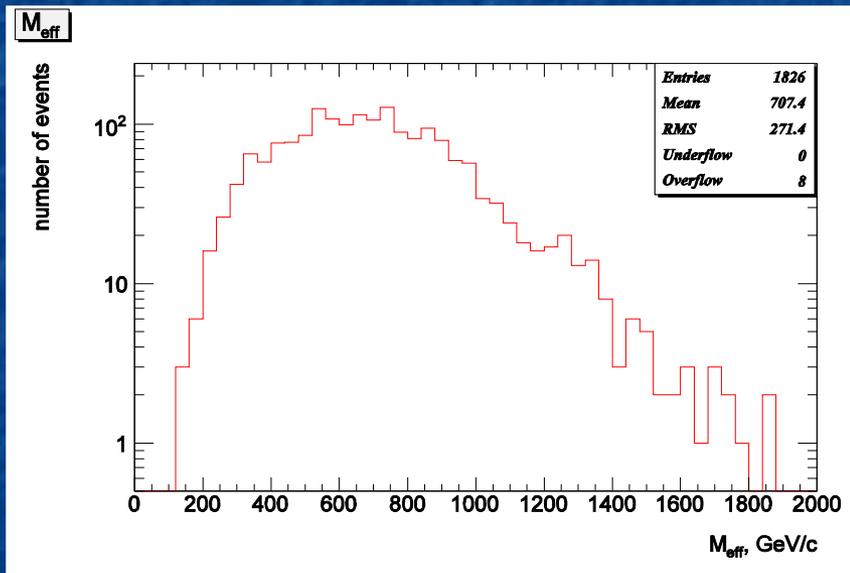
Now for a quick tour of (very)
preliminary TTF analyses

Littlest Higgs with T-parity (JH)

- Littlest Higgs with T-parity
 - T-parity is to LH as R-parity is to SUSY
 - lightest T-odd particle stable if symmetry exact
 $\sim 100\text{-}300\text{ GeV } B'$
 - MET in detector + dark matter
 - Higgs naturally light due to additional global symmetries (1-loop quadratic divergences in M_{Higgs} cancelled by new partners near 1 TeV)

Littlest Higgs Plots (JH)

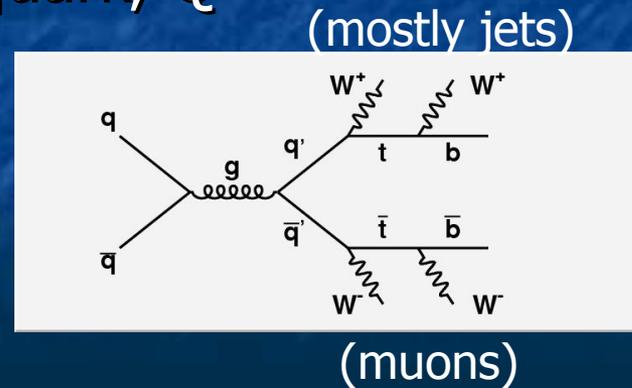
Process: $pp \rightarrow Q' \bar{Q}' \rightarrow jjB'B'$



500 GeV T-parity odd Q'

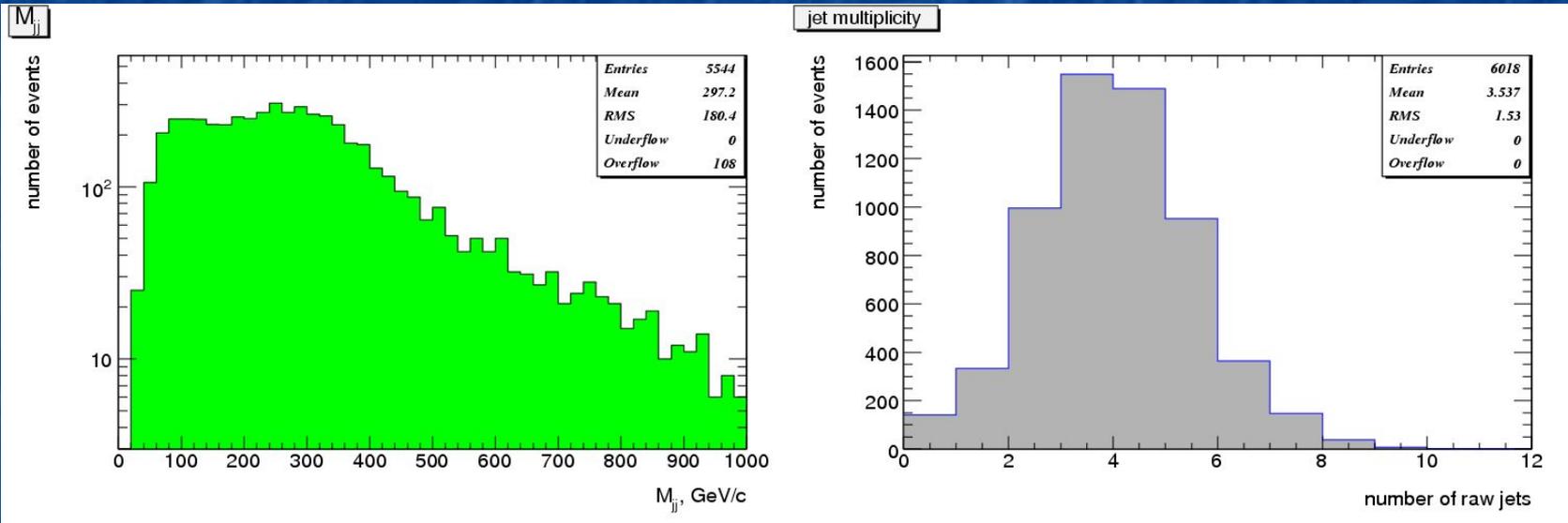
Warped Extra Dimensions (Jose Santiago)

- Randall Sundrum models with Custodial SU(2)
 - Behaves like “new and improved” strongly coupled SM extension
 - consistent with precision electroweak fits
 - new charge 5/3 quark, Q'
 - pair produced:



Randall Sundrum Plots (Jose Santiago)

$M_{Q'} = 500 \text{ GeV}$



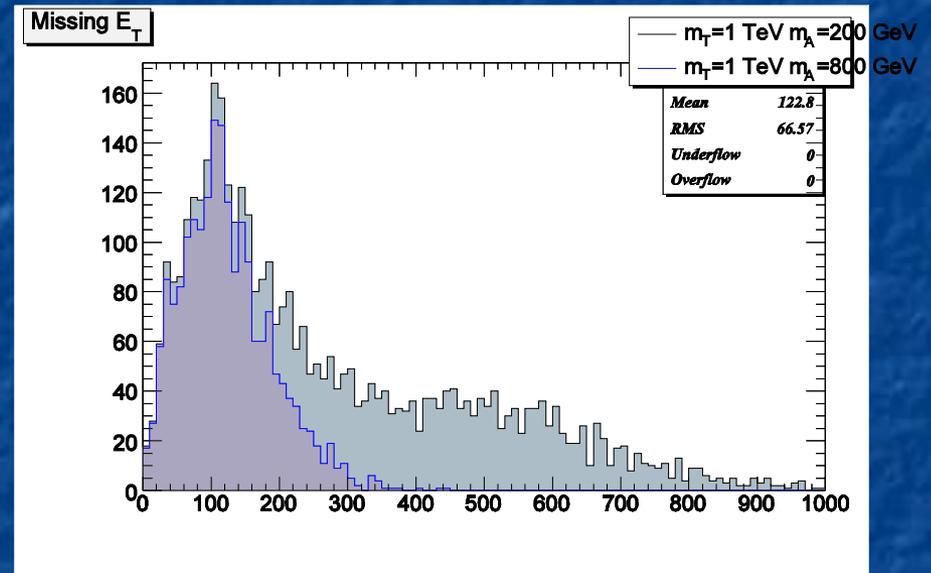
Parity Odd Top partners (Rakhi Mahbubani)

- Motivated by naturalness
 - Partner cancels one loop top quark contribution to Higgs mass
 - New gauge boson is lighter than T , and also parity odd (MET in detectors)
 - Like little Higgs model with T -parity
 - T is pair produced at the LHC:

$$pp \rightarrow T\bar{T} \rightarrow t\bar{t}A_H A_H \rightarrow b\bar{b}jjA_H A_H l\nu$$

Parity odd Top Partners (Rakhi Mahbubani)

- For small mass diff. kinematics similar to SM $t\bar{t}b\bar{b}$ background
 - MET cut not helpful



Conclusions

- We want to be as involved as we can in doing “real” collider phenomenology
 - Creating event generation pipeline through a version of PGS tuned specifically for the CMS detector
 - Useful for theorists, and even (to some degree) for experimentalists
 - PGS-CMS - prelude to full detector simulation
 - Promote MadGraph as a tool for studying both the SM and extensions
 - Easy to use, open source, well supported, versatile
- Formation of CMS Theory Task Force (CMSTTF)
 - Addressing these issues
 - 3 meetings in last month
- We need input and help from the experts!
 - Need to know how PTDR analyses were performed
 - Validation of PGS-CMS against full GEANT based simulations
 - Most important link in the chain – communication
- Status:
 - PGS-CMS up and running
 - Currently cleaning up MG/MEv4 interface

Acknowledgements

MG/MEv4

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PYTHIA

Torbjörn Sjöstrand

Stephen Mrenna

Peter Skands

PGS

John Conway

Ray Culbertson

Regina demina

Mark Kruse

Stephen Mrenna

Jason Nielson

Maria Roco

Aaron Pierce

Jesse Thaler

Tommer Wizansky

PGS-CMS

Joe Lykken

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Jose Santiago

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