

# Misura di anisotropia azimuthale mediante l'SPD

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- Introduzione : il flow anisotropico
- Metodi
- Risultati
- Conclusioni

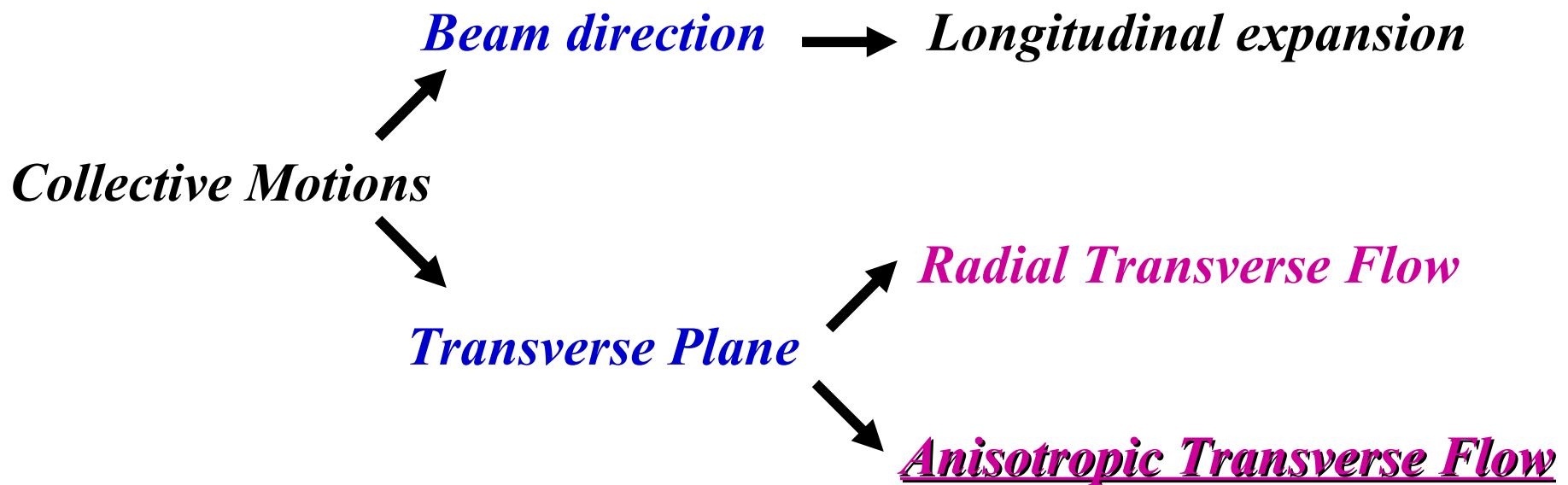
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# Introduzione: il flow

**Flow** = Moto collettivo delle particelle prodotte nella interazione.

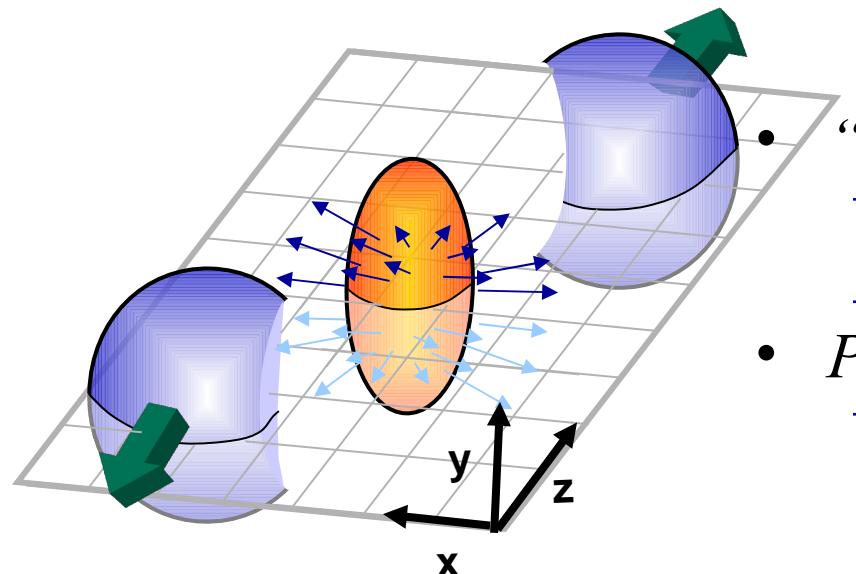




# Flusso trasverso anisotropico (Elliptic Flow)



Nasce dalla iniziale asimmetria azimuthale  
(interazione con parametro d'impatto $>0$ ).



- “Almond-shaped” overlap region ( $x$ - $y$ )
  - Larger pressure gradient in  $x$ - $z$  plane than in  $y$  direction
  - Pressure gradients in the transverse plane
- Particle rescatterings
  - Convert the initial spatial anisotropy into an observed momentum anisotropy



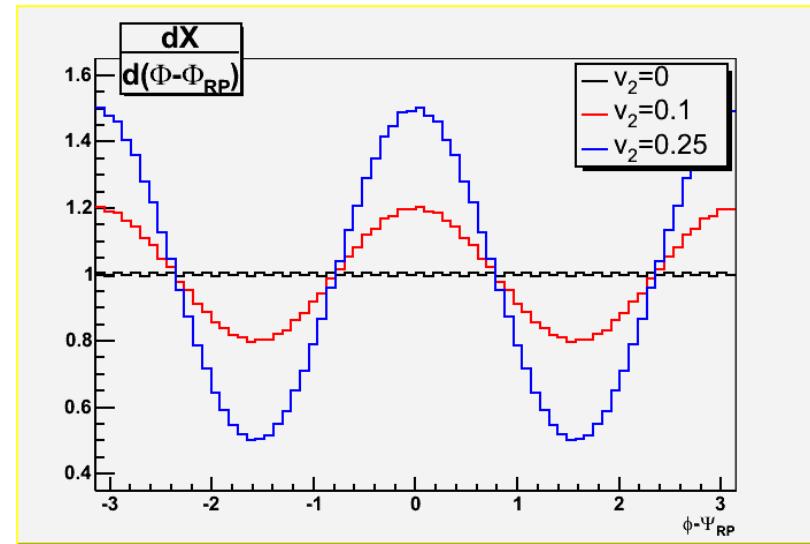
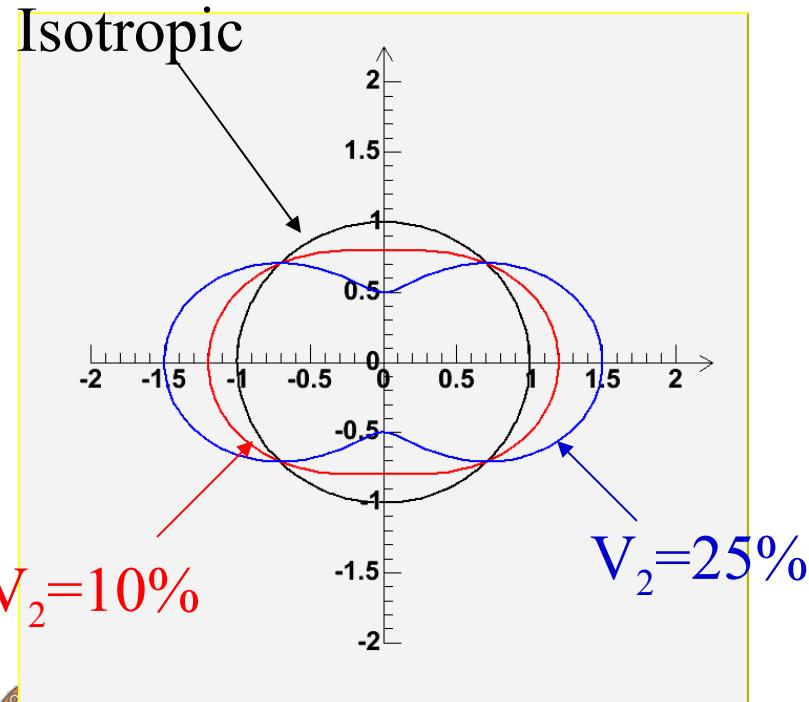


# Elliptic Flow

→ Fourier expansion of azimuthal particle distribution

(Poskanzer and Voloshin, Phys. Rev. C58, 1998)

$$\frac{dX}{d\phi} = \frac{X_0}{2\pi} \left( 1 + 2v_1 \cos(\phi - \Psi_{RP}) + \underline{2v_2} \cos(2(\phi - \Psi_{RP})) + \dots \right)$$

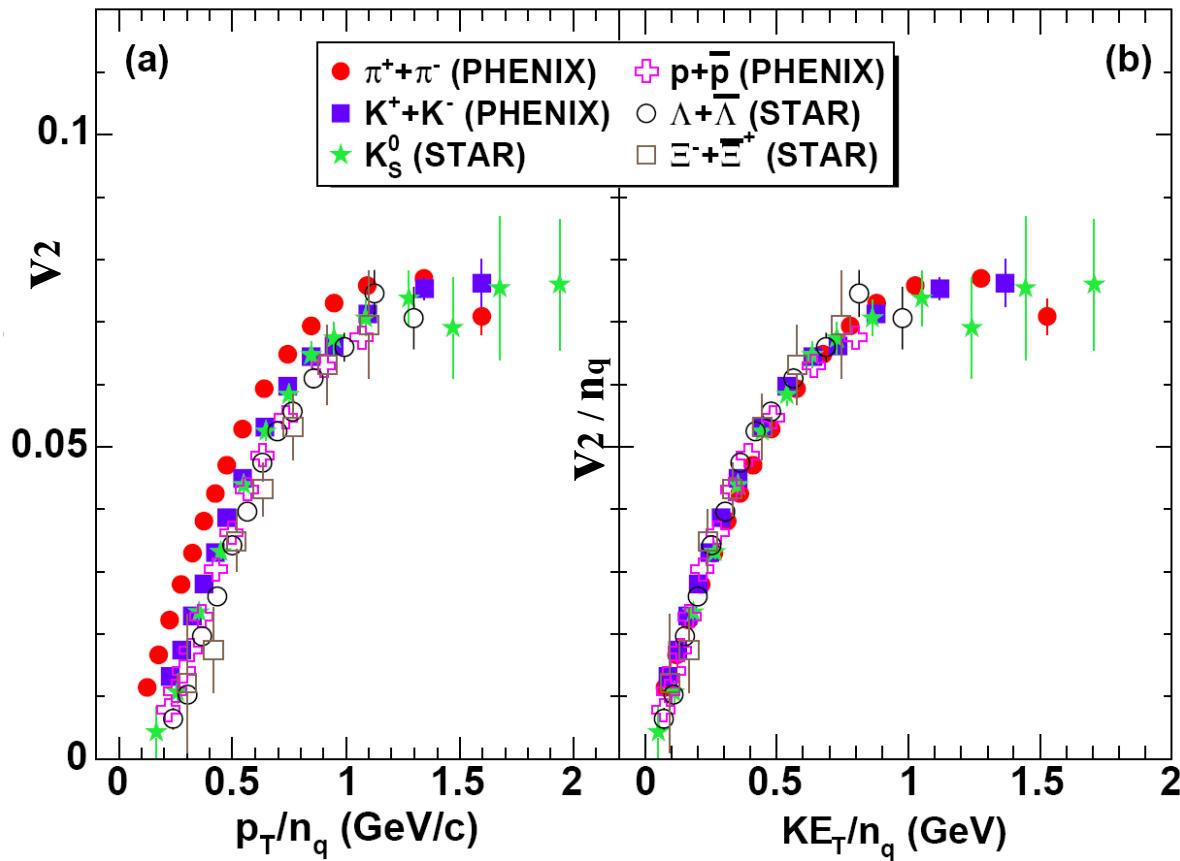




# Elliptic Flow



From RHIC : The flow parameter  $v_2$  scales with quarks contents



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# Misura di flow

The azimuthal angle  $\varphi$  is determined with good precision by the SPD => good reconstruction of  $dN/d\varphi$  => measurement of azimuthal anisotropy

- Fast analysis (full tracking not required, easier calibration).
- Respect to the full reconstruction (ITS+TPC) the SPD has larger acceptance in both  $\eta$  and  $p_t$  :
  - ⇒ a lower multiplicity limit (more peripheral events) can be explored.
  - ⇒ comparable or better  $\Psi_2$  determination



# Misura di flow

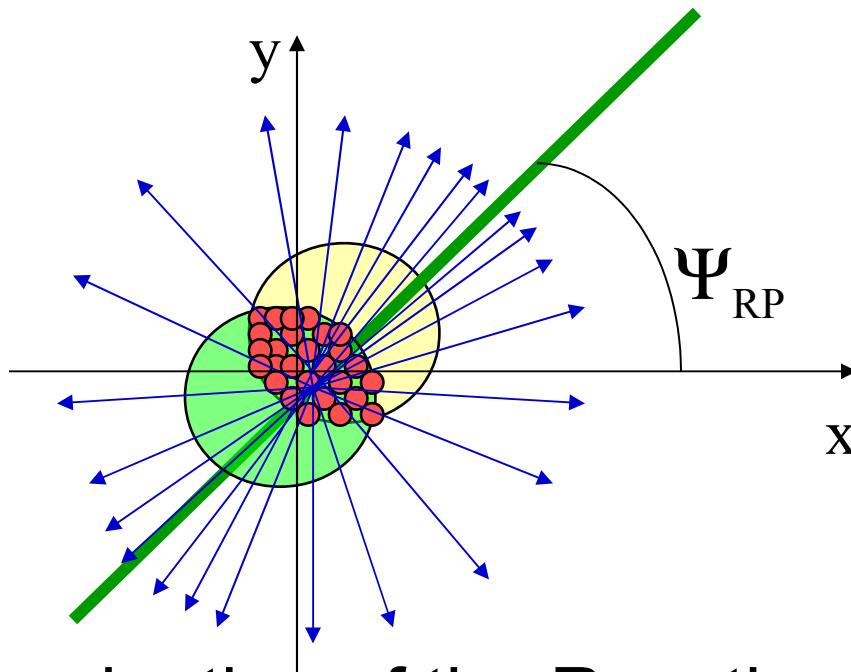
The methods proposed are based on the event-by event determination of the Reaction Plane  $\Psi_2$ .

This can be obtained from the diagonalization of the transverse sphericity tensor:  $\mathbf{S}_{ij} = \sum_k \cos(\varphi_{k,i}) \cos(\varphi_{k,j})$  (k=particle index, i and j = transverse axes).

$\varphi_{k,i}$  = clusters or tracklets azimuthal angle (x or y)

The ratio  $(f_2 - f_1)/(f_2 + f_1)$  between the two eigenvalues is equal to  $v_2$  ( $f_2 > f_1$ ), and the rotation of the reference system gives  $\Psi_2$ . An estimate of the errors can be obtained by considering two independent set of tracks (**sub-event** method).

# Misura di flow



From the determination of the Reaction Plane  $\Psi_2$  one can also build a global distribution  $dN/d(\varphi - \Psi_2)$ . (Events with same multiplicity/centrality only!)

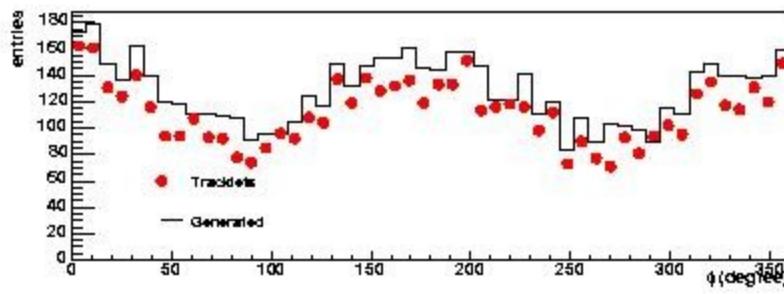
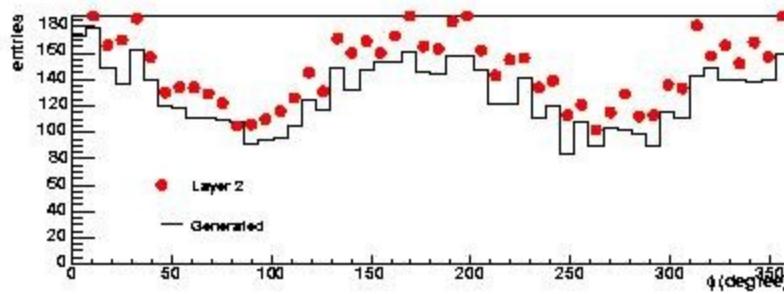
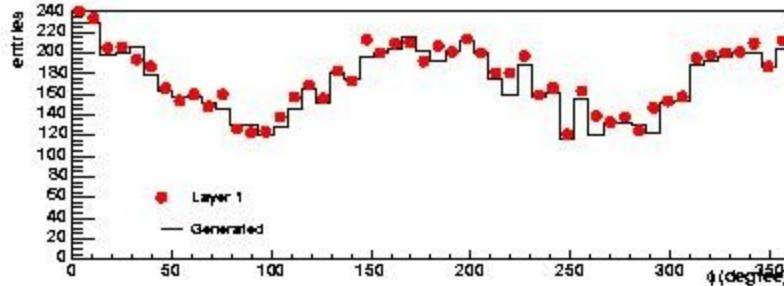
This can be fitted with the following expression:  
 $dN/d\varphi = \text{cost.} (1/2\pi) + 2 v_2 \cos(2\varphi)$ .



# Misura di flow

Ultimo lavoro: PPR Vol. 2 Cap. 6.4.5 (2006)

Differences  
between  
generated and  
reconstructed  $\phi$   
distribution.





# Misura di flow

Rispetto al PPR:

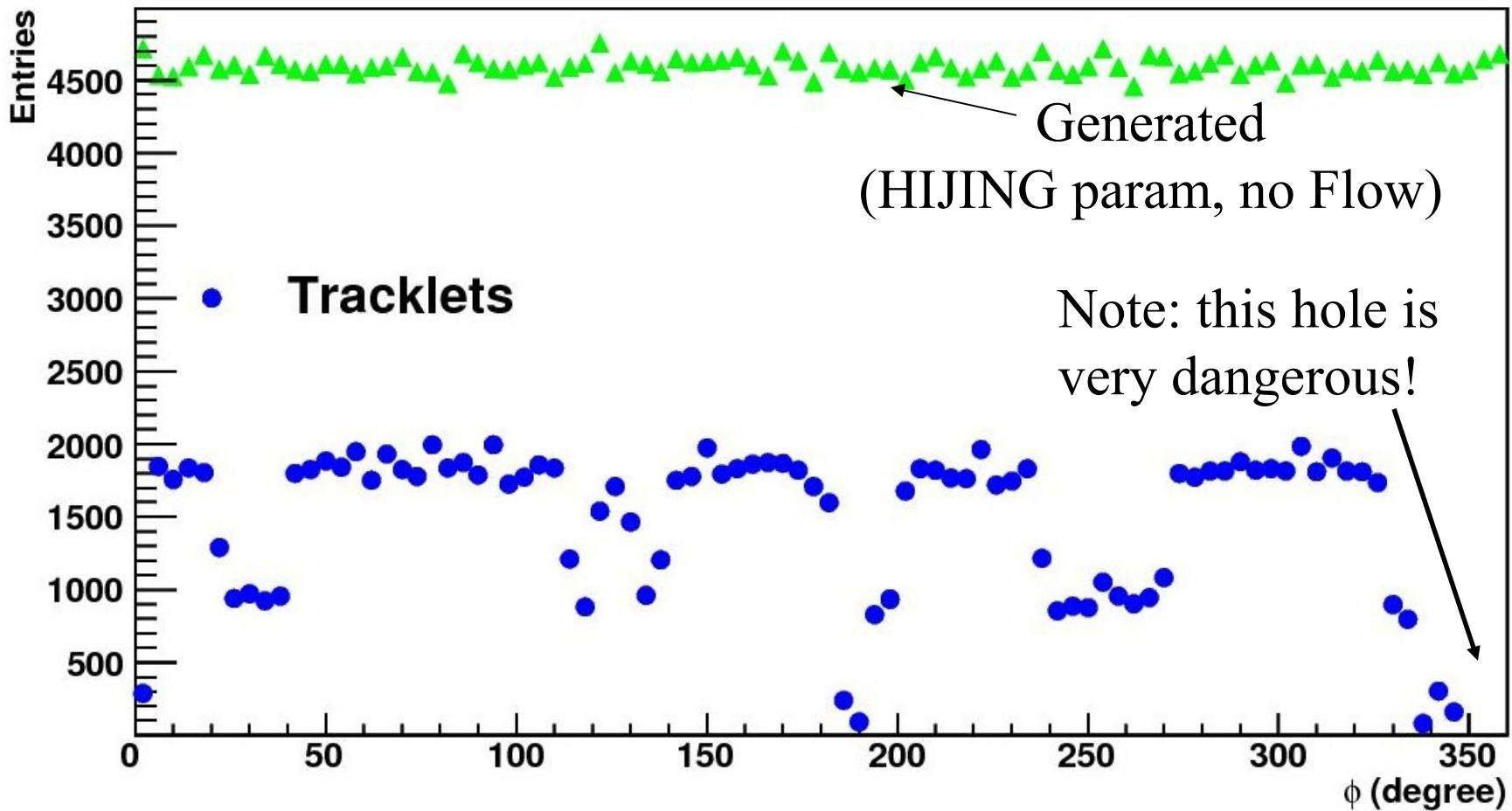
- Nuova versione AliRoot (V4-17-Release, “PDC09”)
  - Geometria “definitiva”
  - Efficienza “PDC09”:  $\sim 12.7\%$  canali morti (contro 1% PPR)
  - Nuovo algoritmo per tracklets ( $\Rightarrow$  Talk di M. Nicassio)
  - Tolleranze tracklets più strette ( $\Rightarrow$  Talk di M. Nicassio)
  - Generazione : HIJING param + “GEVSIM” (flow impl.)
- Generazione a bassa molteplicità (rispetto al PPR):
  - 30 Eventi Pb-Pb HIJING Param, con  $dN/d\eta = 2000$
  - GEVSIM afterburner, con parametro “ $V_2$ ” = 0.1

Nota: tutti gli eventi sono stati generati con  $Zv \sim 0$ .





# Misura di flow



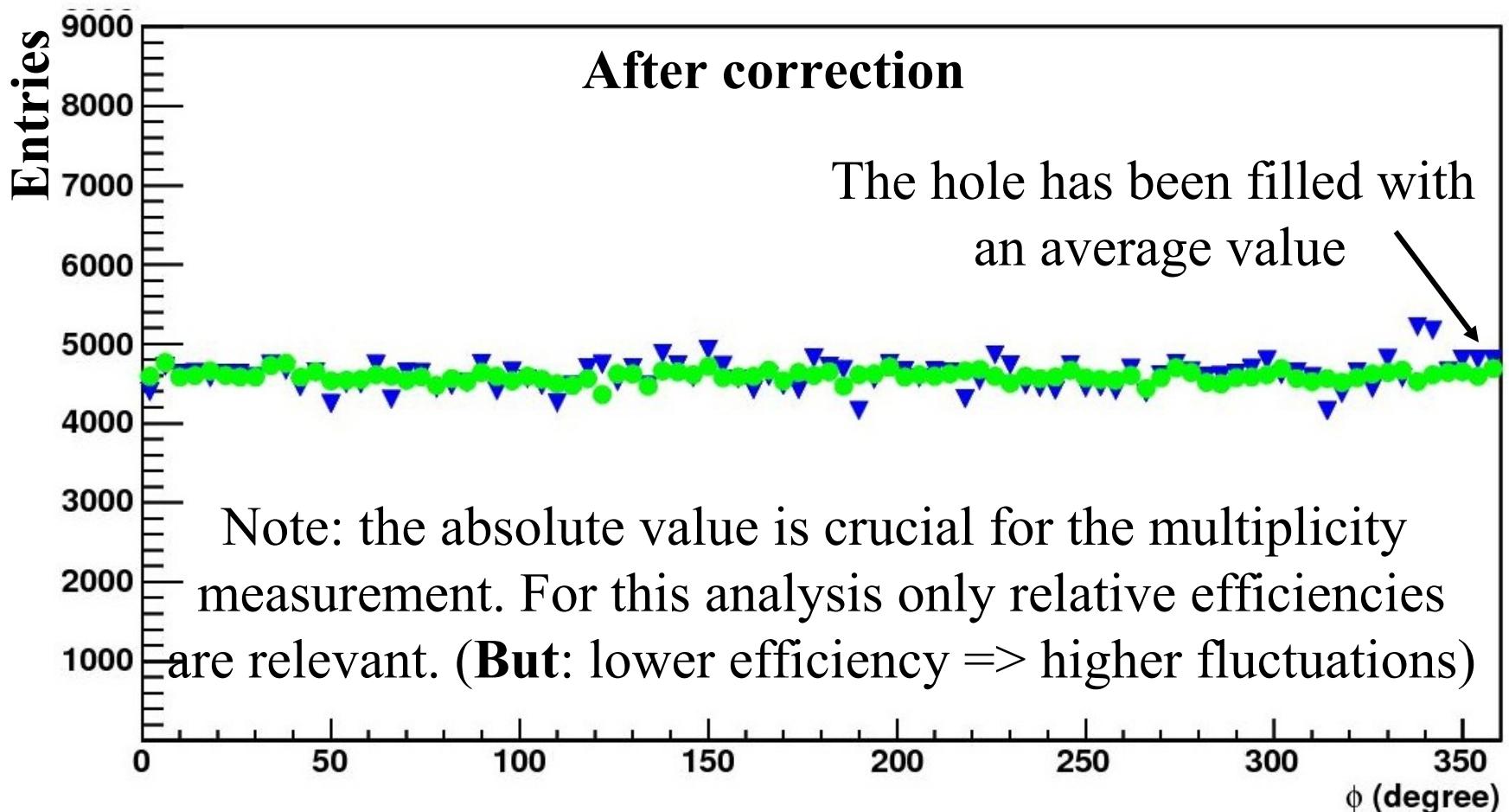
Acceptance ( $Zv=0$ )

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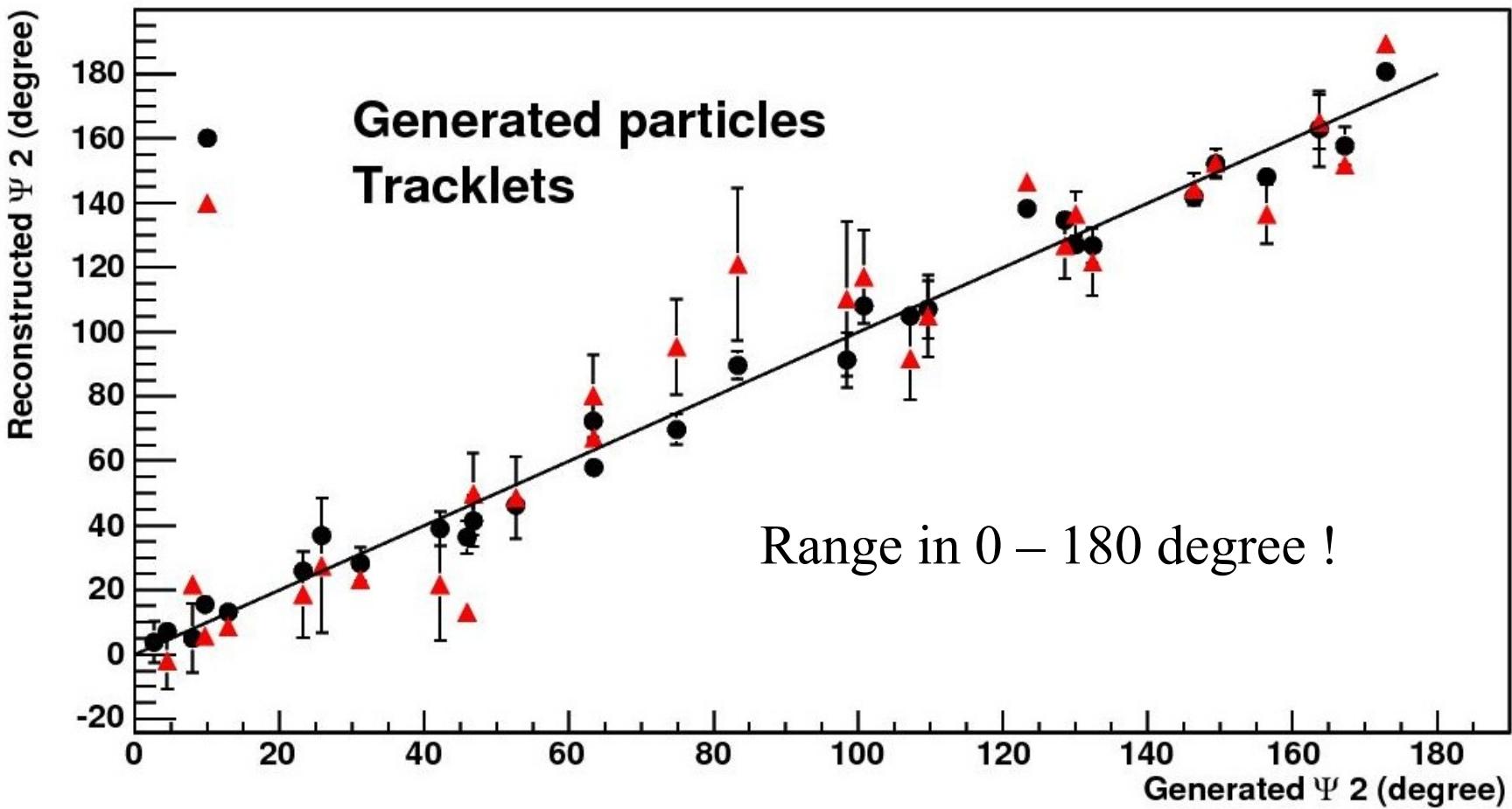


# Misura di flow





# Misura di flow

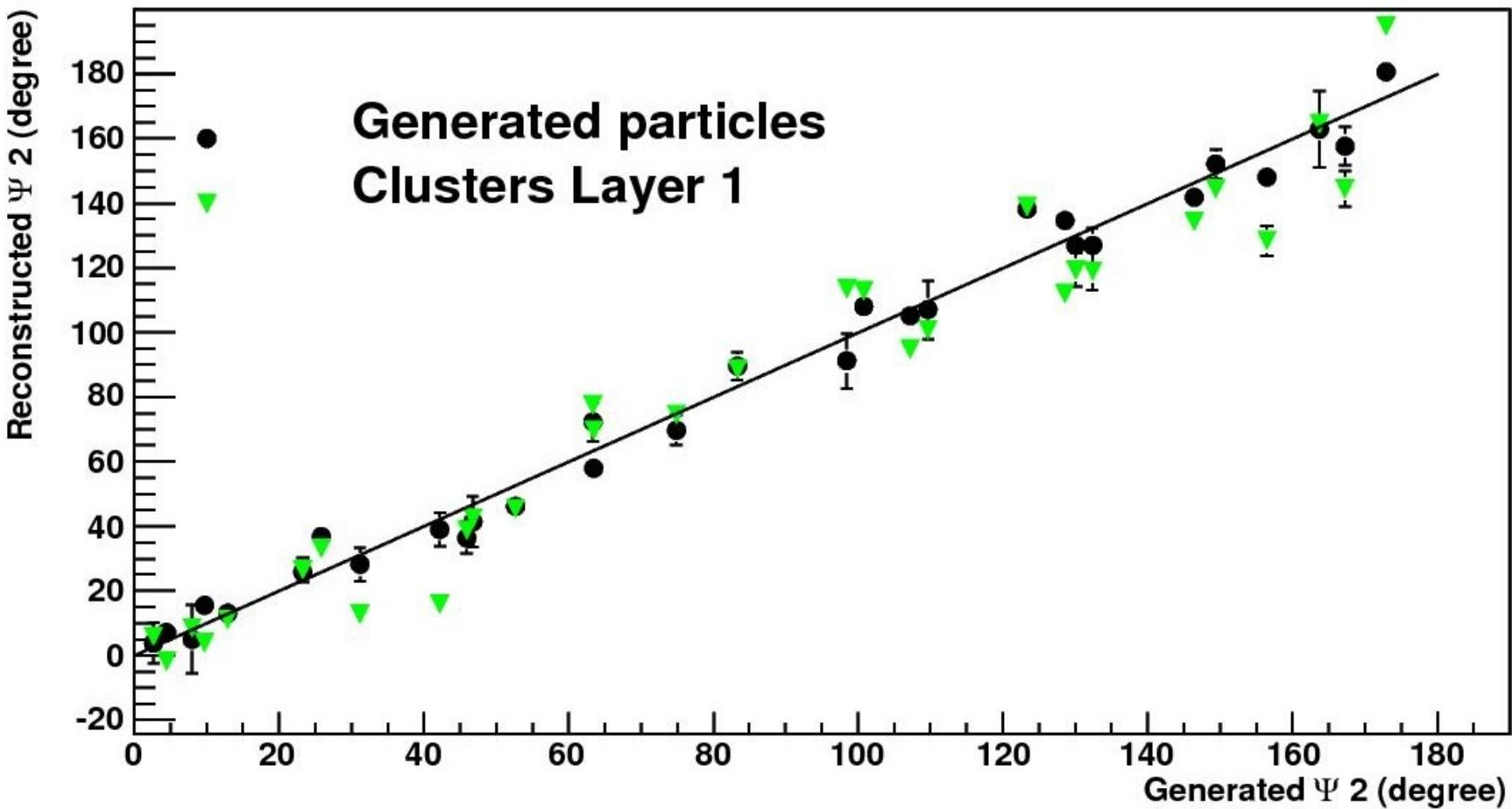


The larger deviations are located near the acceptance “holes”!





# Misura di flow

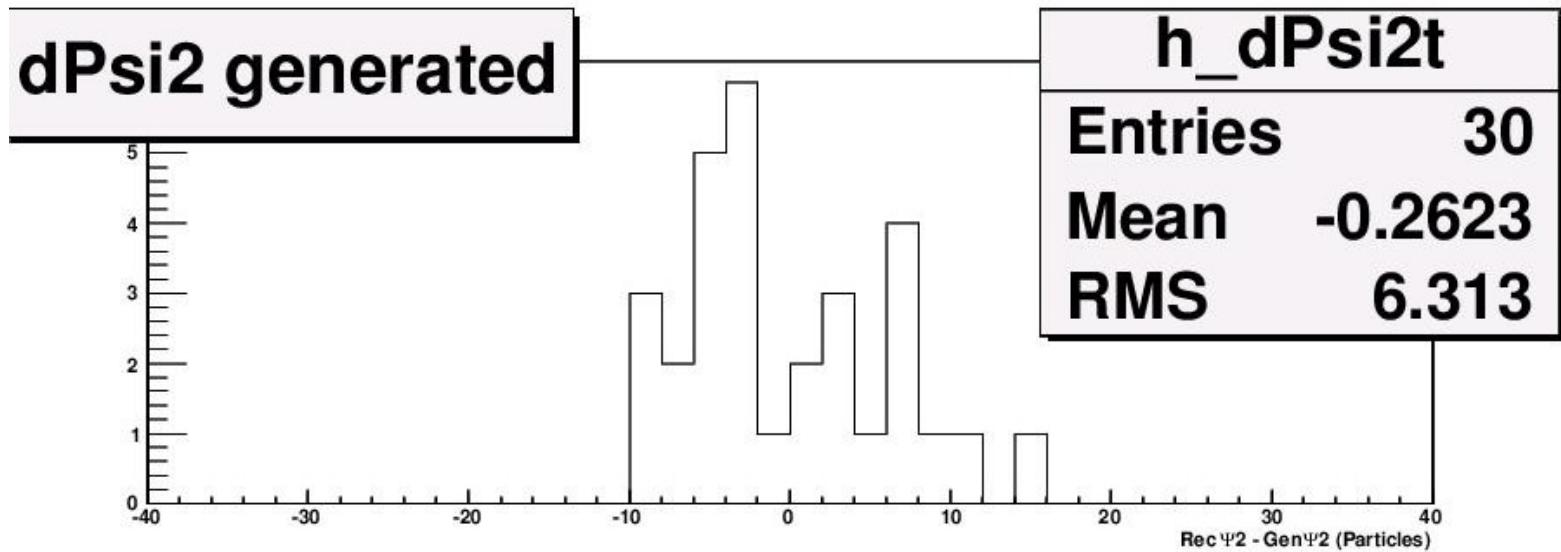


Fluctuations are lower with clusters ! (higher acceptance)





# Misura di flow



Distribution of Rec – Gen  $\Psi^2$

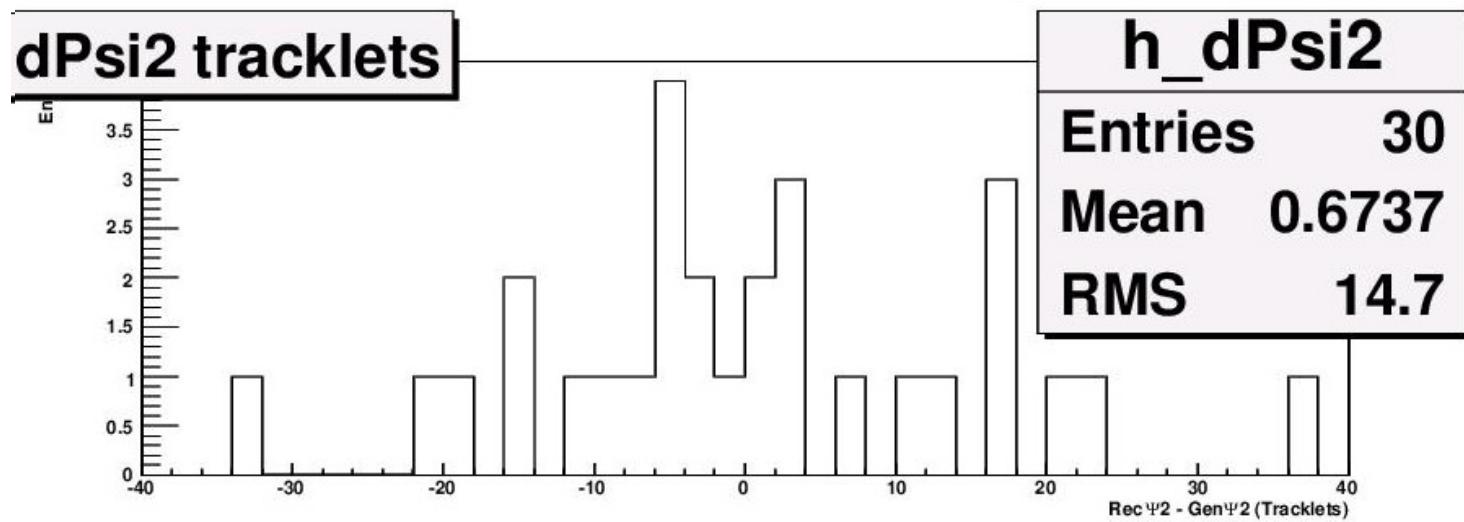


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# Misura di flow

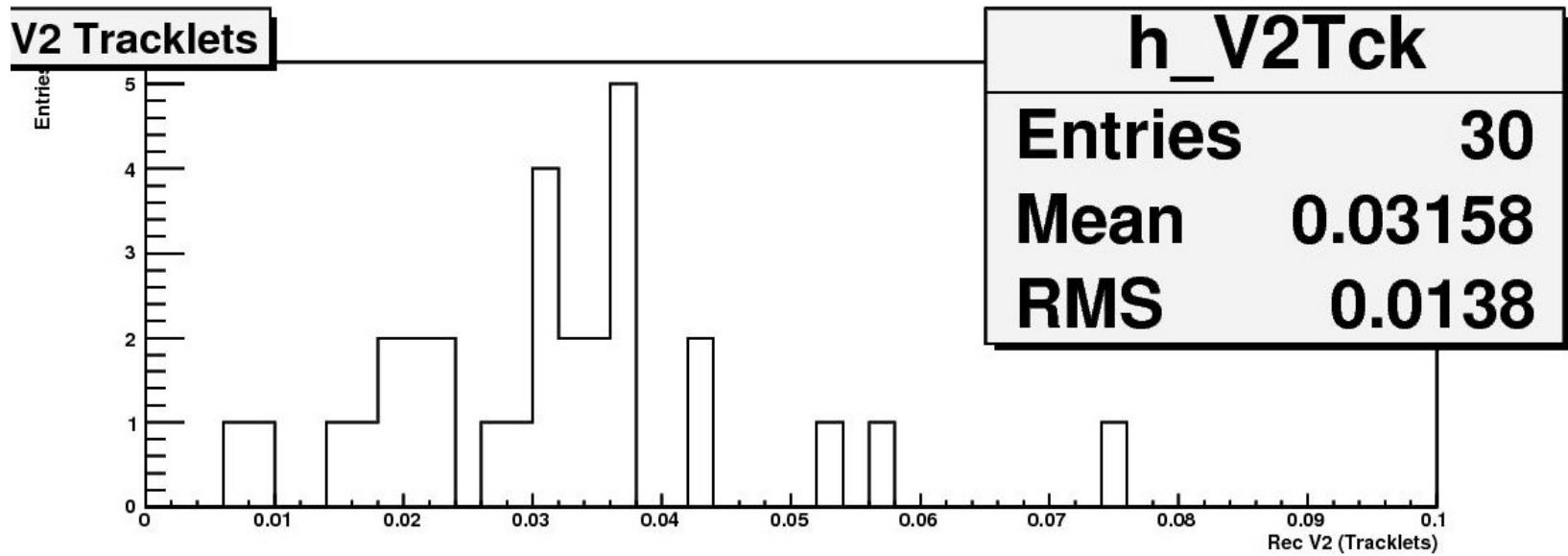


Distribution of Rec – Gen  $\Psi^2$   
(Higher statistic is needed for a more accurate result)



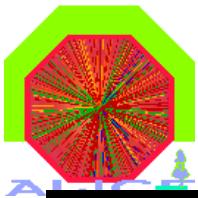


# Misura di flow



## Distributions of v2

Note: the parameter “ $V_2$ ” used in GEVSIM  
doesn’t correspond to this average!



# Misura di flow

Sample	True particles		Clusters		Tracklets	
dN/dη	<V2>	RMS	<V2>	RMS	<V2>	RMS
2000	0.028	0.006	0.025	0.007	0.032	0.014
2000	0.016	0.006	0.017	0.008	0.022	0.010
1000	0.031	0.009	0.030	0.014	0.038	0.020

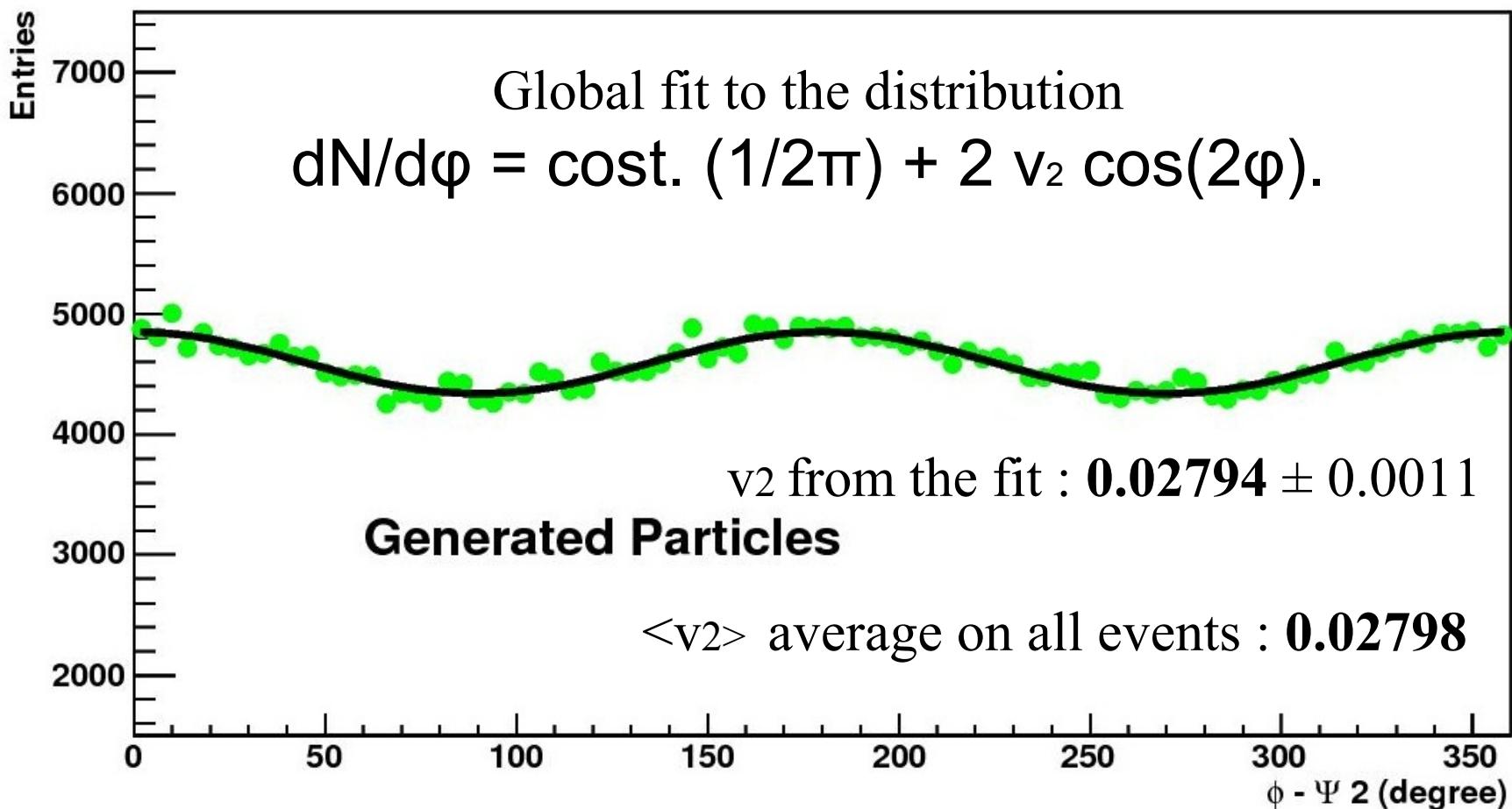
Average and RMS of the distributions of V2

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# Misura di flow

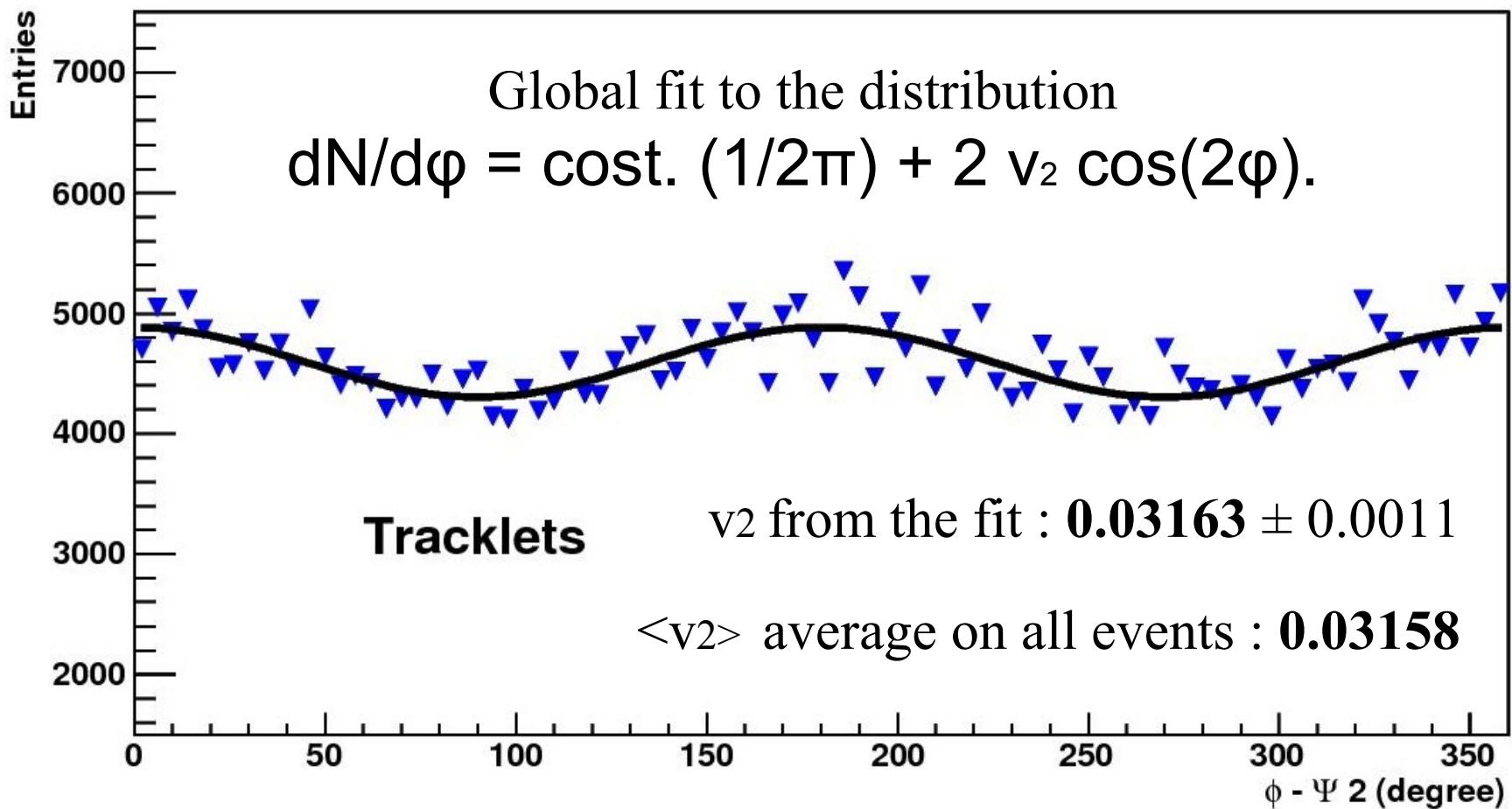


The fit result is almost equivalent to  $\langle v_2 \rangle$  from e.b.e determination!





# Misura di flow



The fit result is almost equivalent to  $\langle v_2 \rangle$  from e.b.e determination!





# Misura di flow

Cosa accade “peggiorando” le cose ?  
La risoluzione evidentemente peggiora se:

- si riduce l’effetto ( $v_2$ );
- si riduce la molteplicità.

=> Nuova generazione :

- 40 Eventi Pb-Pb HIJING Param, con  $dN/d\eta = 1000$
- GEVSIM afterburner, con parametro “ $V_2$ ” = 0.1
- 30 Eventi Pb-Pb HIJING Param, con  $dN/d\eta = 2000$
- GEVSIM afterburner, con parametro “ $V_2$ ” = 0.05

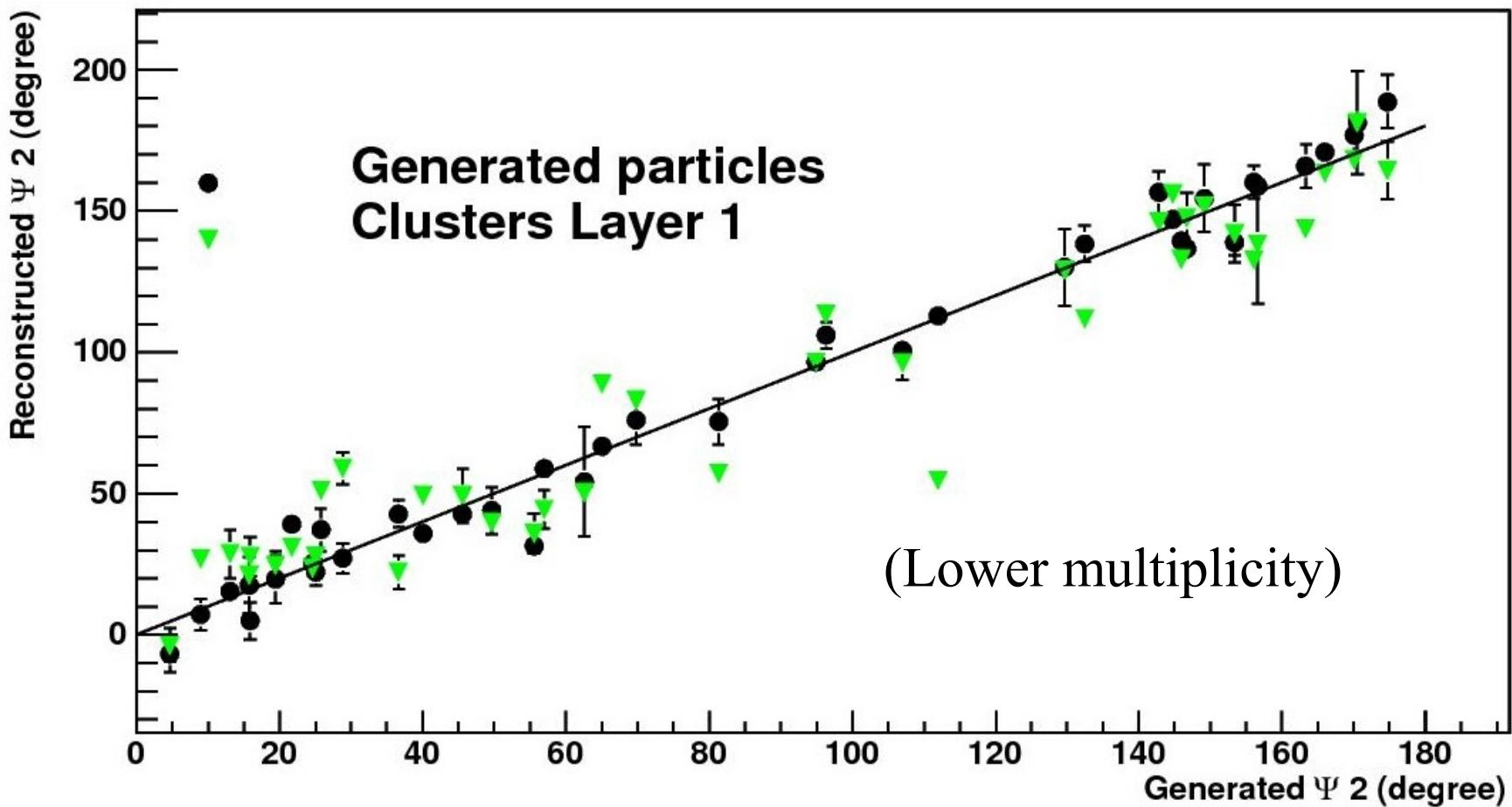


Nota: tutti gli eventi sono stati generati con  $Z_v \sim 0$ .





# Misura di flow



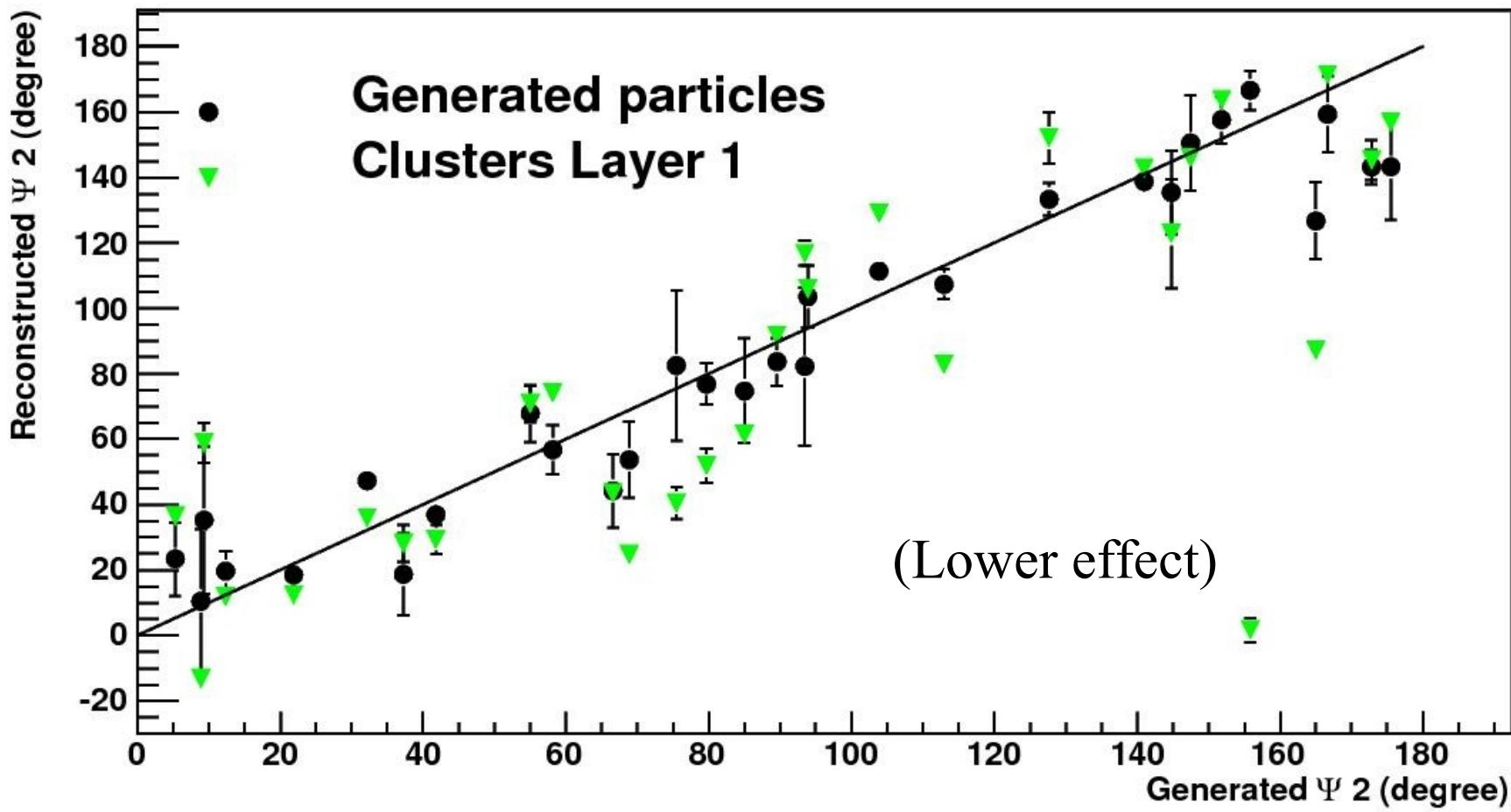
$$dN/d\eta = 1000, "v2" = 0.1$$

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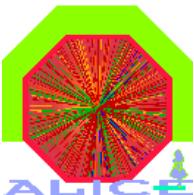


# Misura di flow



$$dN/d\eta = 2000, "v_2" = 0.05$$





# Misura di flow

Sample	True particles		Clusters		Tracklets	
dN/d $\eta$	<ΔΨ2>	RMS	<ΔΨ2>	RMS	<ΔΨ2>	RMS
2000 ("v2"=0.1)	-0.3°	6.3 °	-3.4 °	12.4 °	0.7 °	14.7 °
1000 ("v2"=0.1)	0.6 °	7.3 °	0 °	13.1 °	4.9 °	18 °
2000 ("v2"=0.05)	-3 °	15 °	-3.4 °	19 °	-2.1 °	21 °

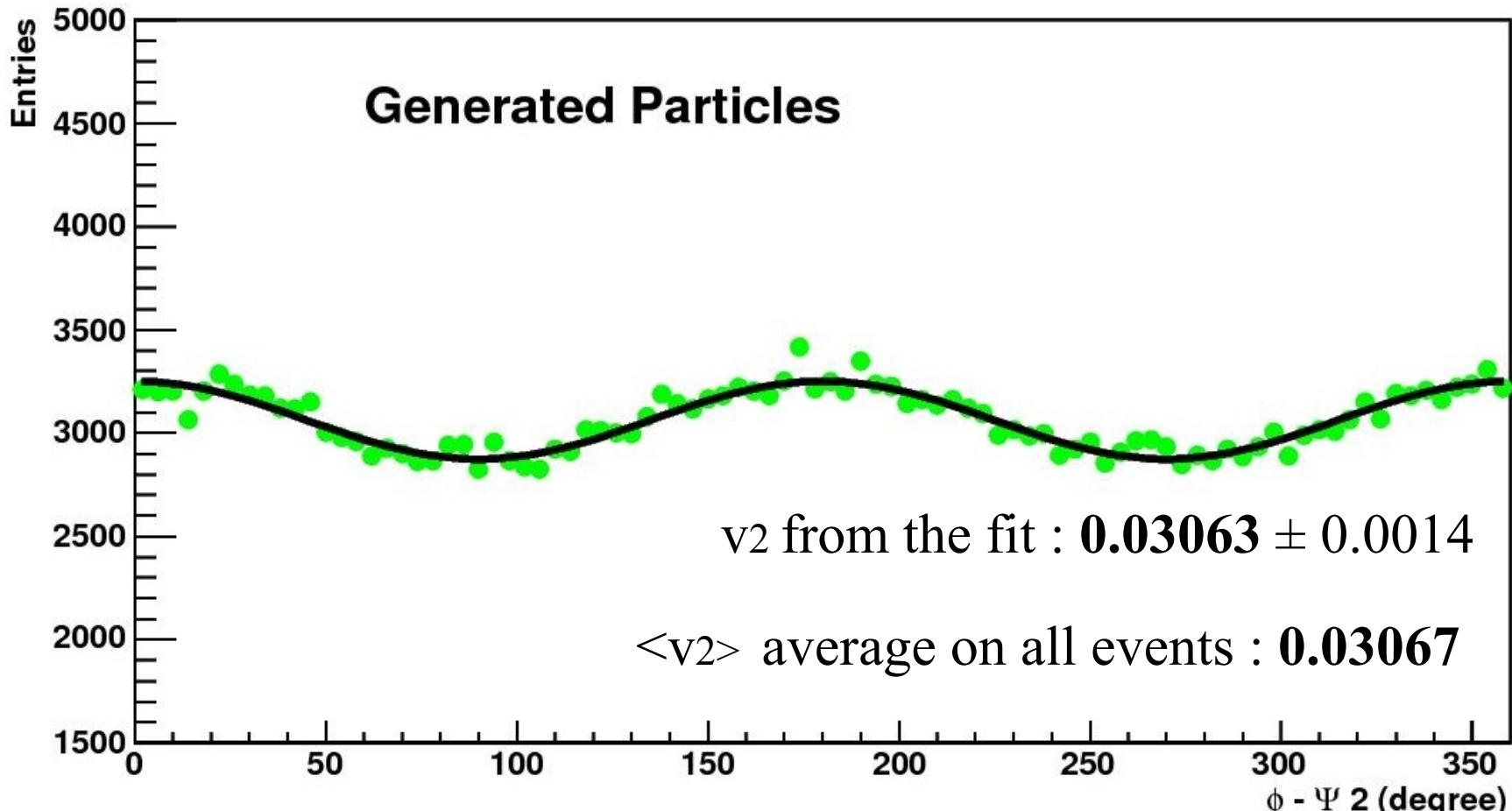
Average and RMS of the distributions of Rec – Gen  $\Psi_2$

La determinazione di  $\Psi_2$  peggiora al diminuire di V2





# Misura di flow

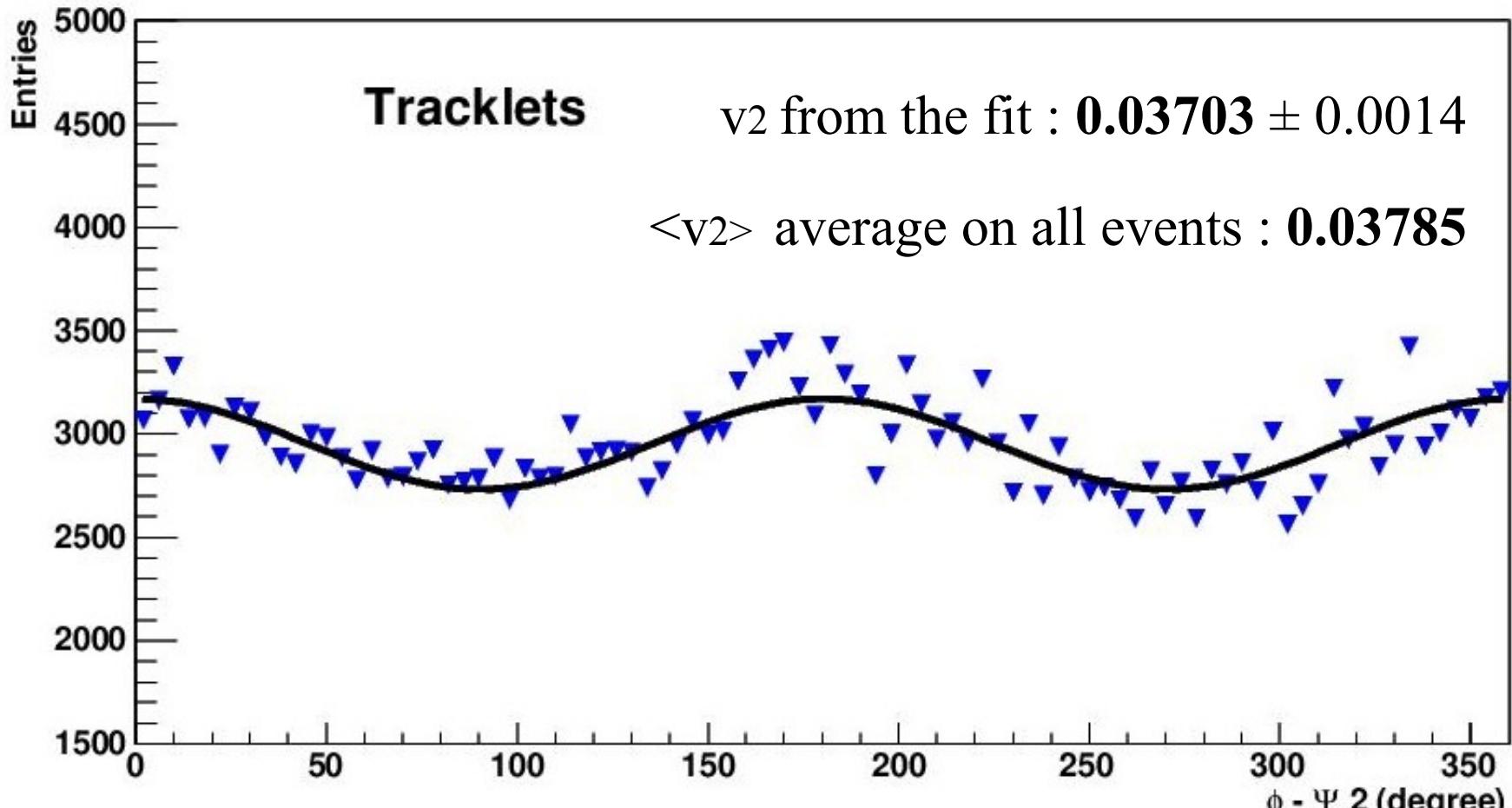


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# Misura di flow



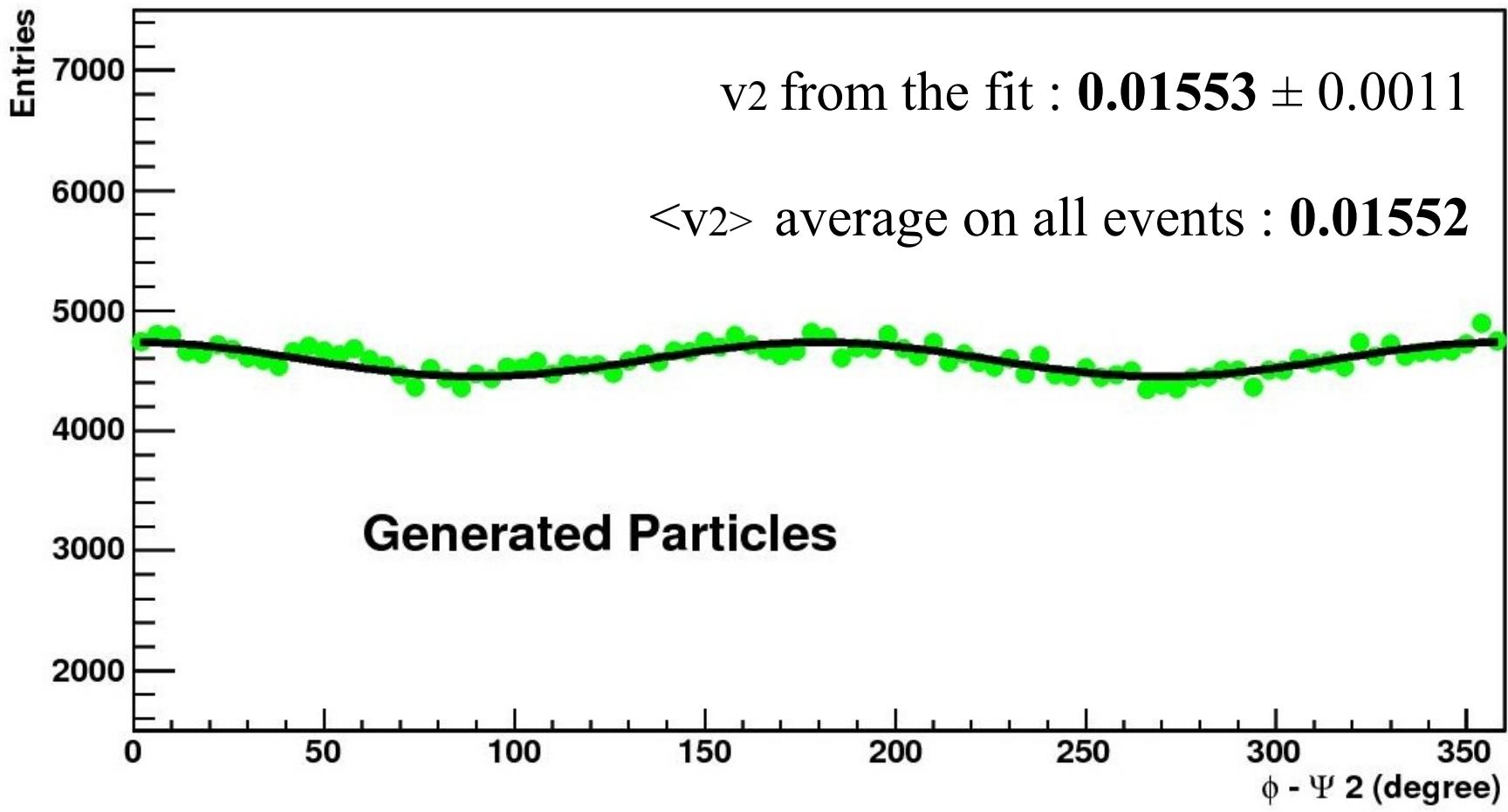
$$dN/d\eta = 1000, "v2" = 0.1$$

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# Misura di flow



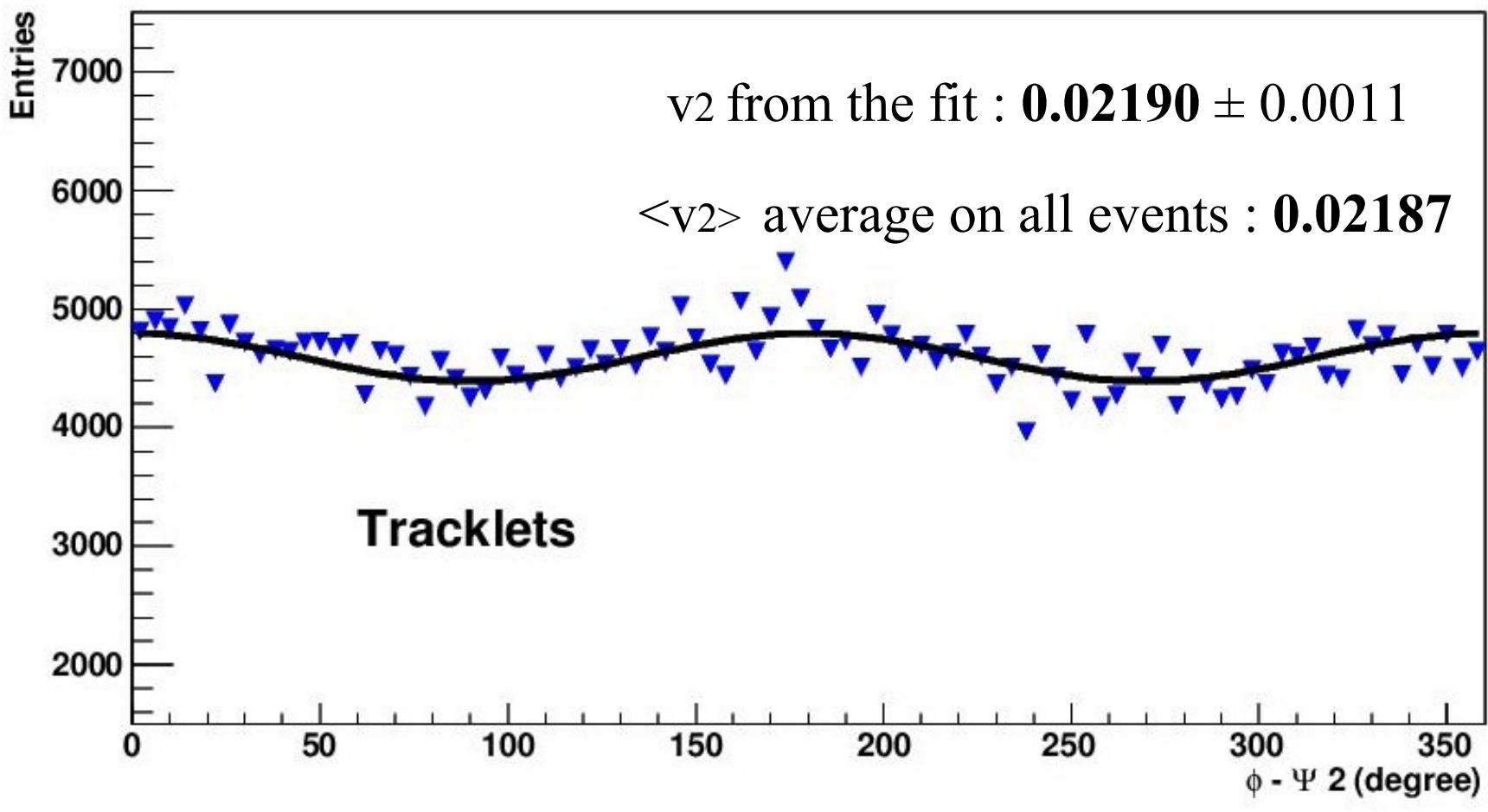
$$dN/d\eta = 2000, "v2" = 0.05$$

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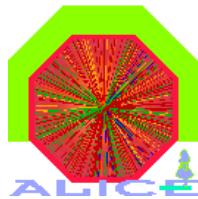
# Misura di flow



$$dN/d\eta = 2000, "v2" = 0.05$$

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# Misura di flow

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2000	0.028	0.006	0.025	0.007	0.032	0.014
2000	0.016	0.006	0.017	0.008	0.022	0.010
1000	0.031	0.009	0.030	0.014	0.038	0.020

Average and RMS of the distributions of V2

La determinazione di V2 peggiora in entrambi i casi.





# Misura di flow

Up to now we considered the global  $\langle V_2 \rangle$   
⇒ study of  $\langle V_2 \rangle$  vs. centrality (multiplicity)

On the other hand the  $V_2$  parameter depends strongly on  $p_t$

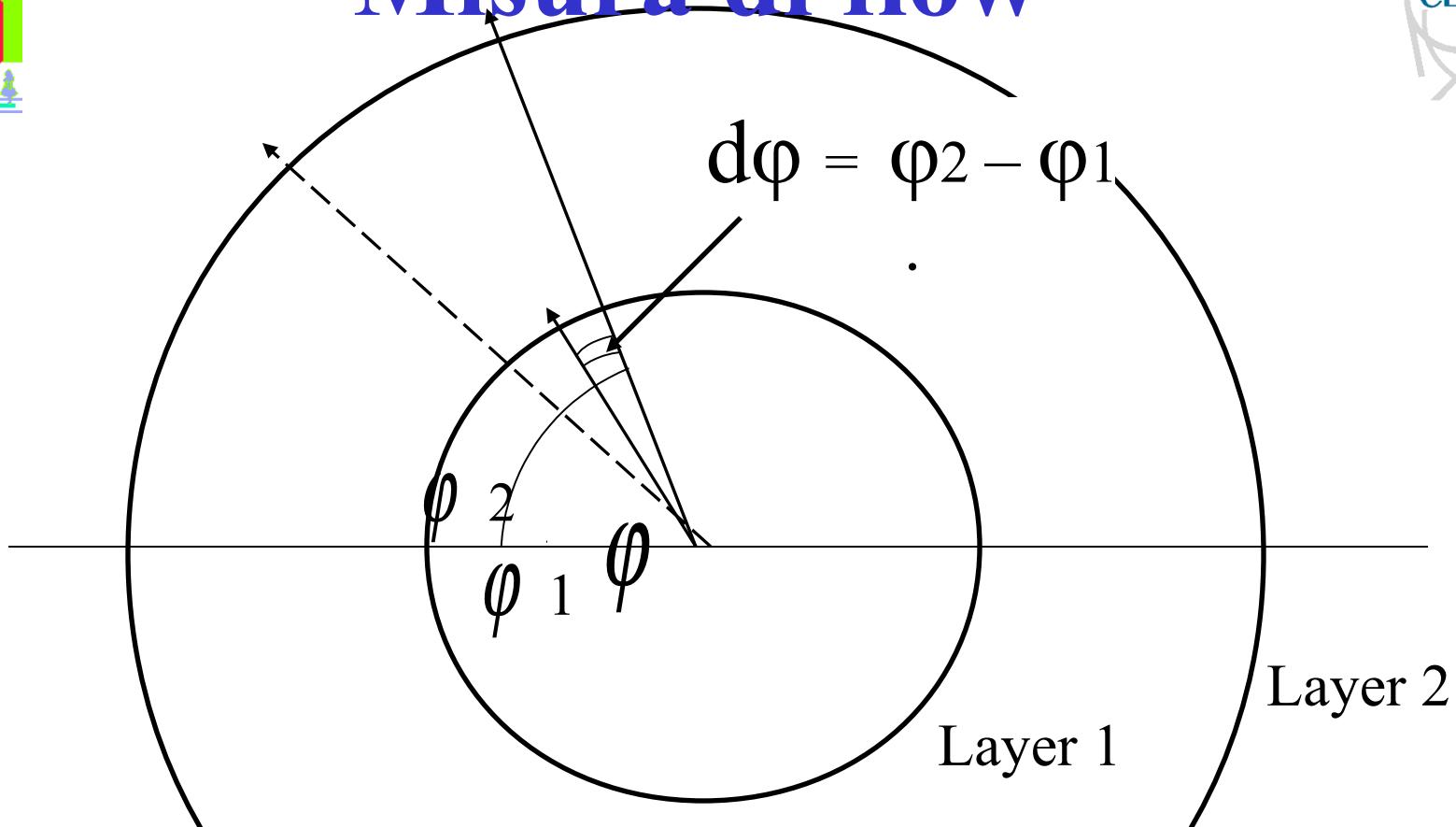
What can be done with the SPD standalone ?

⇒ From the analysis of the differences between  $\varphi_2 - \varphi_1$  (azimuthal angles determined in the first and second layer) it is possible to separate tracklets in  $P_t$  classes !





# Misura di flow



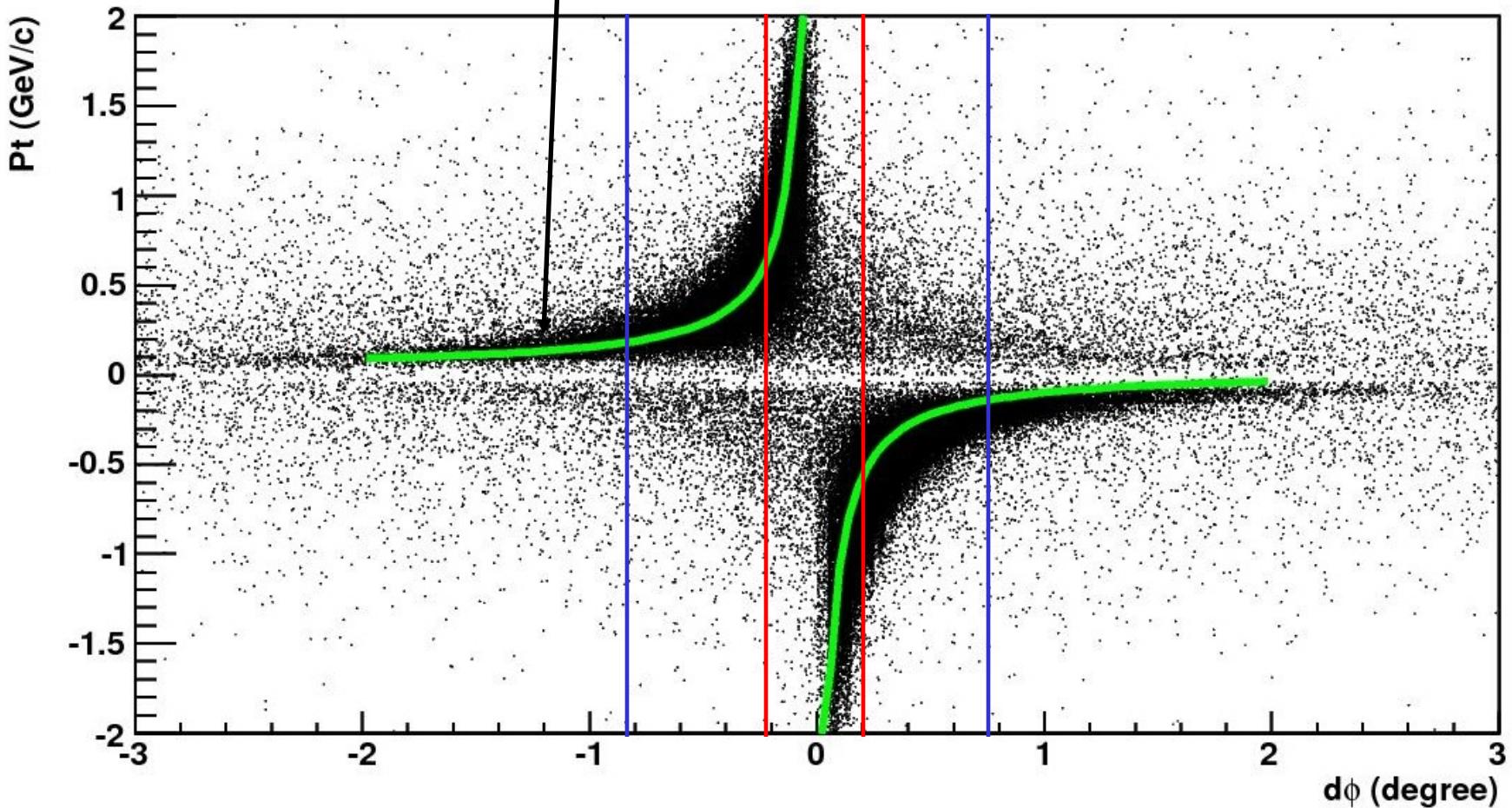
$d\phi$  depends on the Pt and on the charge of the particles.





# Misura di flow

Result of a fit



Correlation between  $P_t$  and  $d\phi$

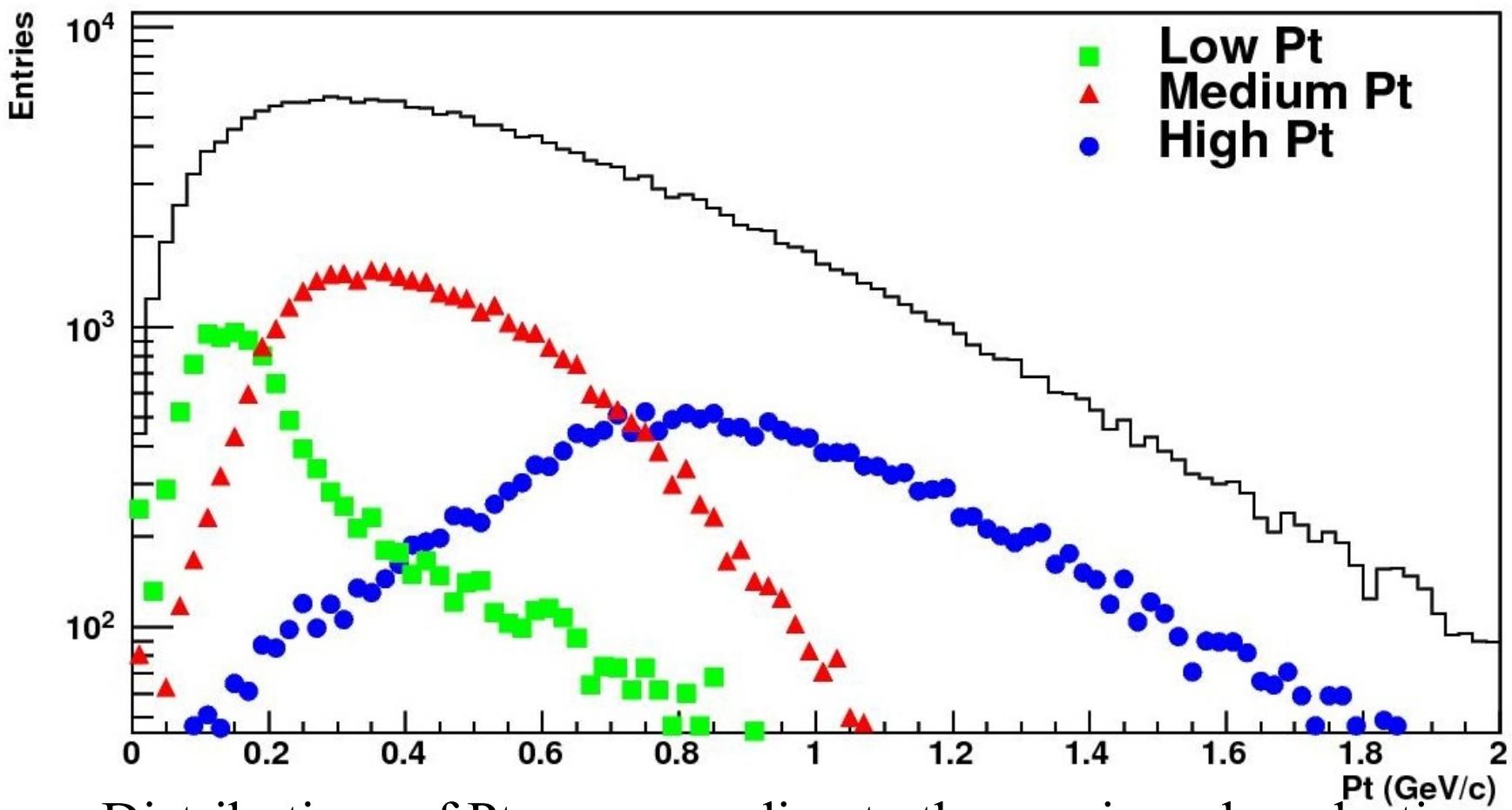
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# Misura di flow

## Pt classes separation :



Distributions of Pt corresponding to the previous  $d\phi$  selection

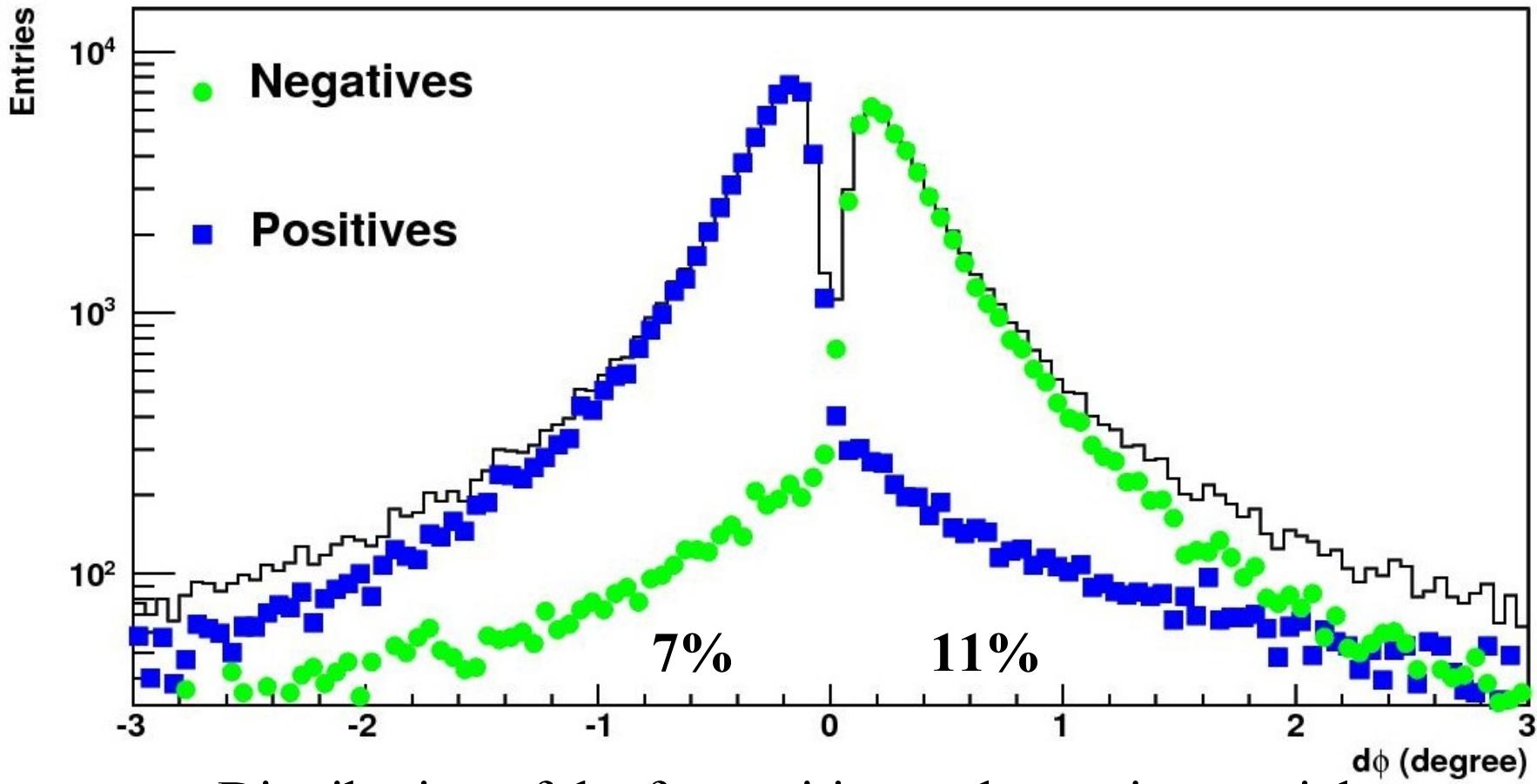




# Misura di flow



## Charge identification :

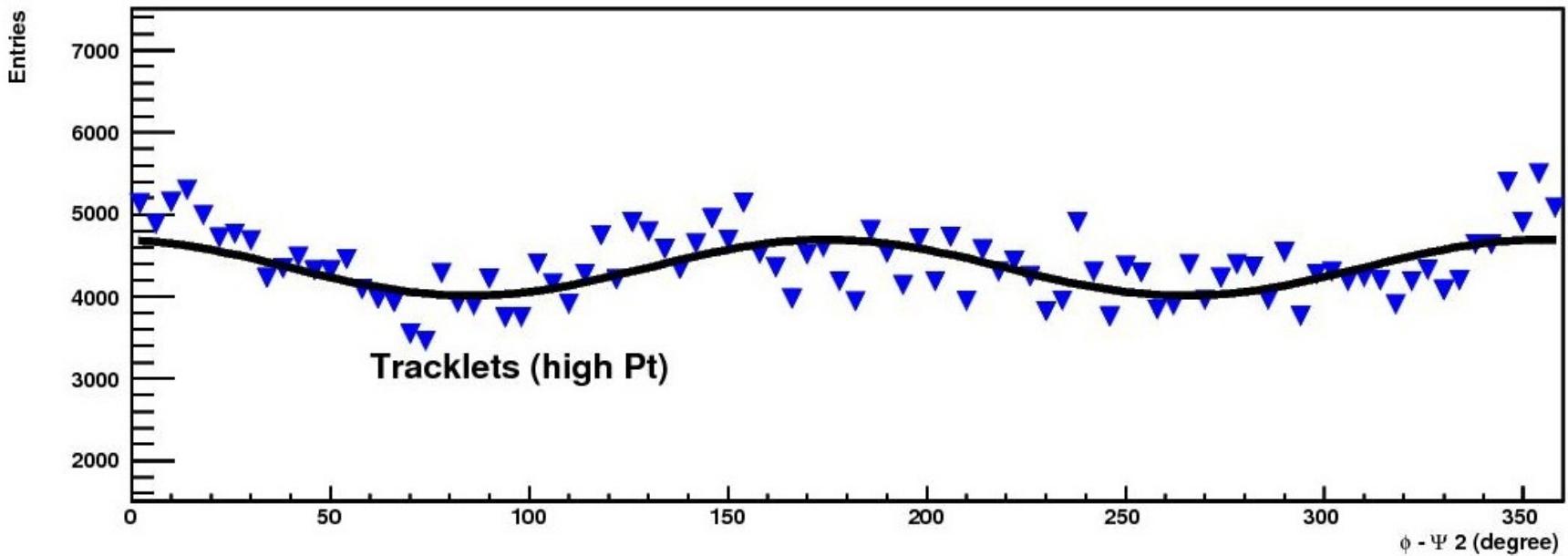


Distribution of  $d\phi$  for positive and negative particles





# Misura di flow



$$dN/d\eta = 2000, "v_2" = 0.1$$

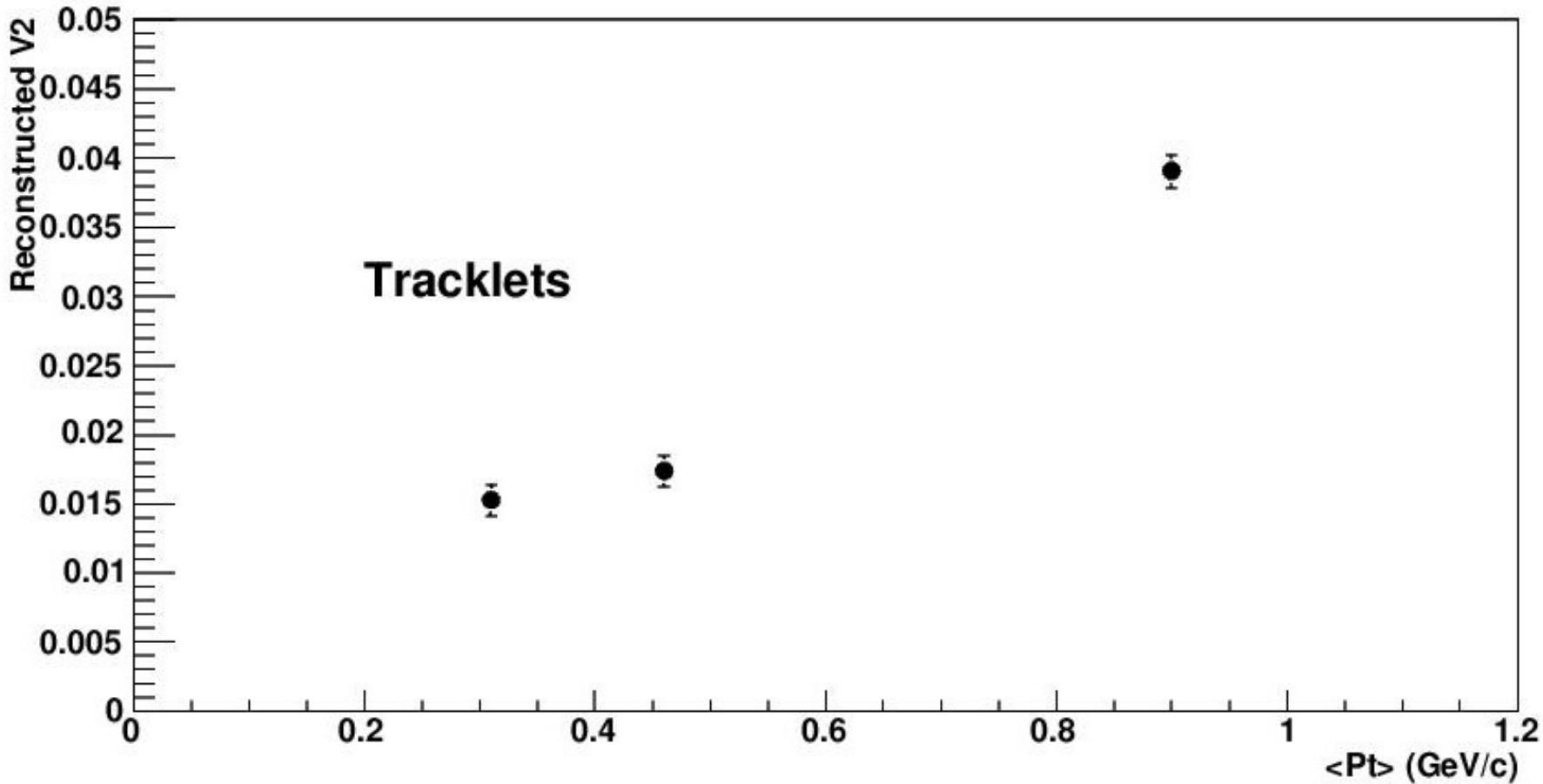


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# Misura di flow

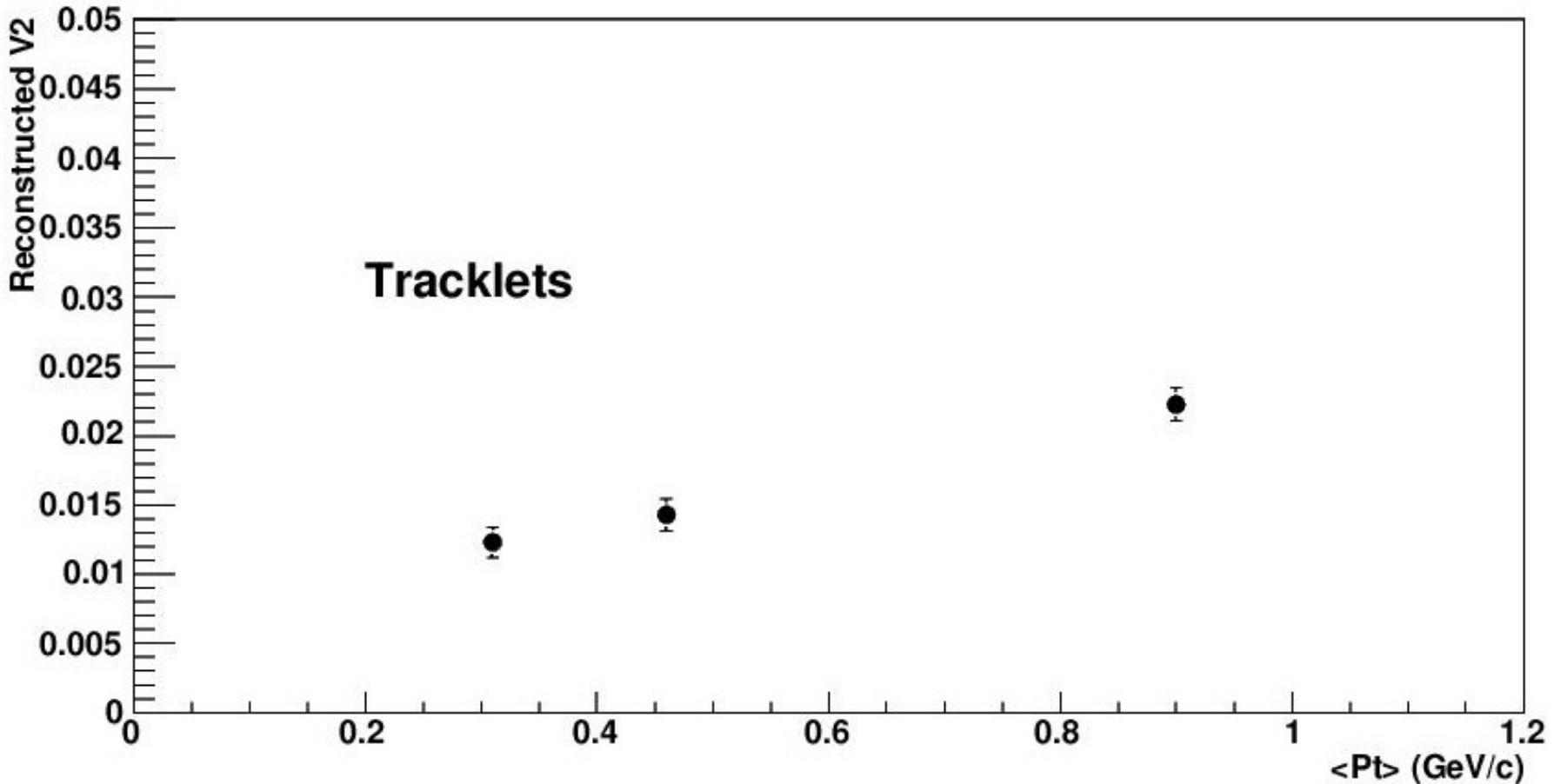


$\langle P_t \rangle$  comes from the simulation !!





# Misura di flow



$$dN/d\eta = 2000, "v_2" = 0.05$$

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# Conclusioni :

- Il rivelatore SPD consente di determinare con buona precisione sia il piano di reazione  $\Psi_2$  che il parametro  $v_2$  per ogni singolo evento. I metodi proposti danno risultati equivalenti.
- L'accettanza del rivelatore risulta cruciale nel contenimento delle fluttuazioni: con la configurazione “PDC09” i migliori risultati si ottengono considerando i soli **clusters**.
- E’ possibile separare i tracklets in modo da ottenere una stima di  $v_2$  in diverse classi di Pt.



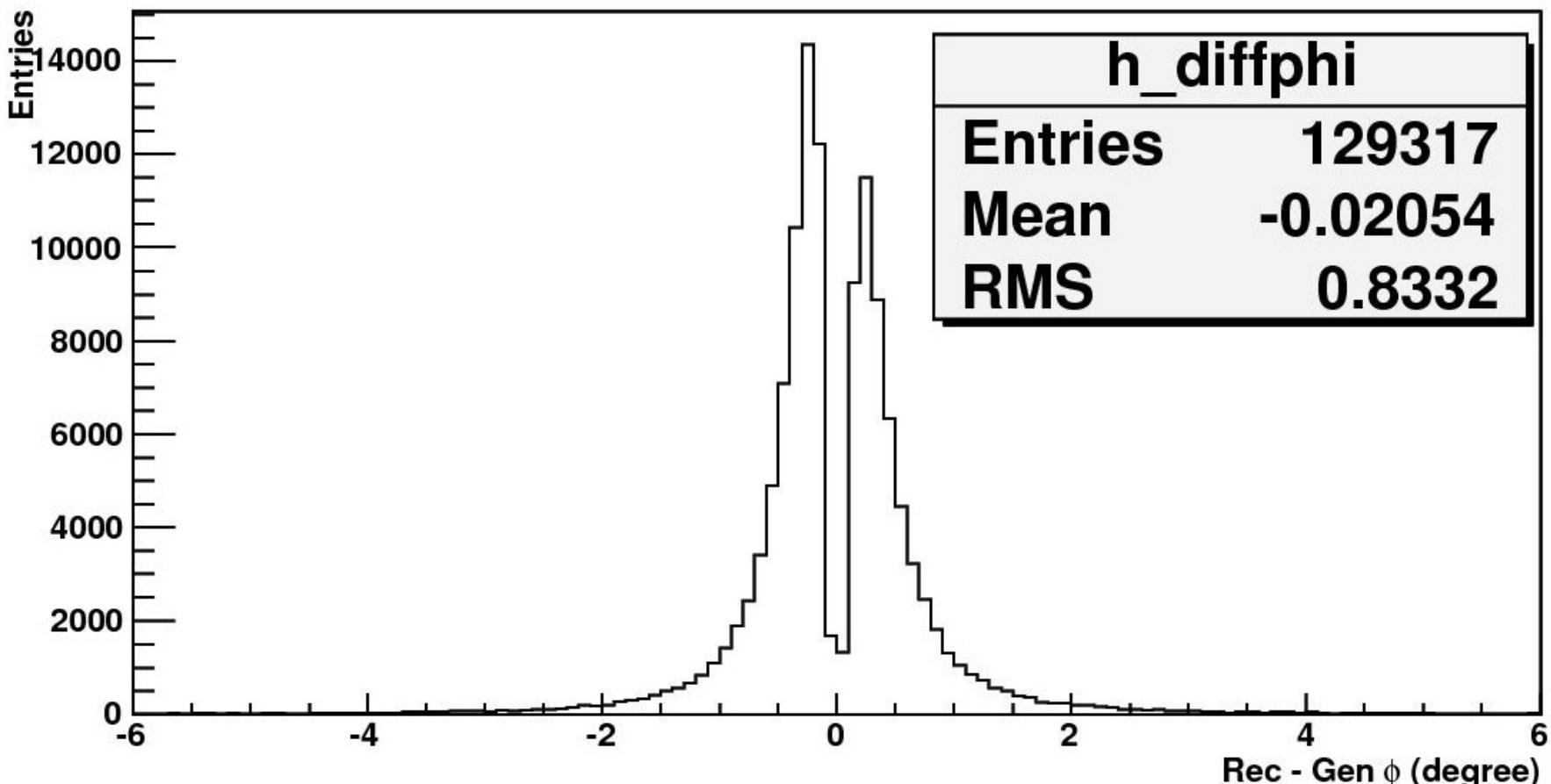
# Prospettive :

- Utilizzo delle nuove produzioni “PDC09 Pb-Pb” con flow per uno studio sistematico dei limiti di sensibilità della misura (limite di basse molteplicità, basso flow).
- Studio dettagliato degli effetti sistematici presenti.
- Studio di ulteriori applicazioni dell’identificazione di carica (es. fluttuazioni intrinseche) e della separazione in classi di Pt (es. correlazioni molteplicità a lungo range).
- Applicazione ai dati reali !





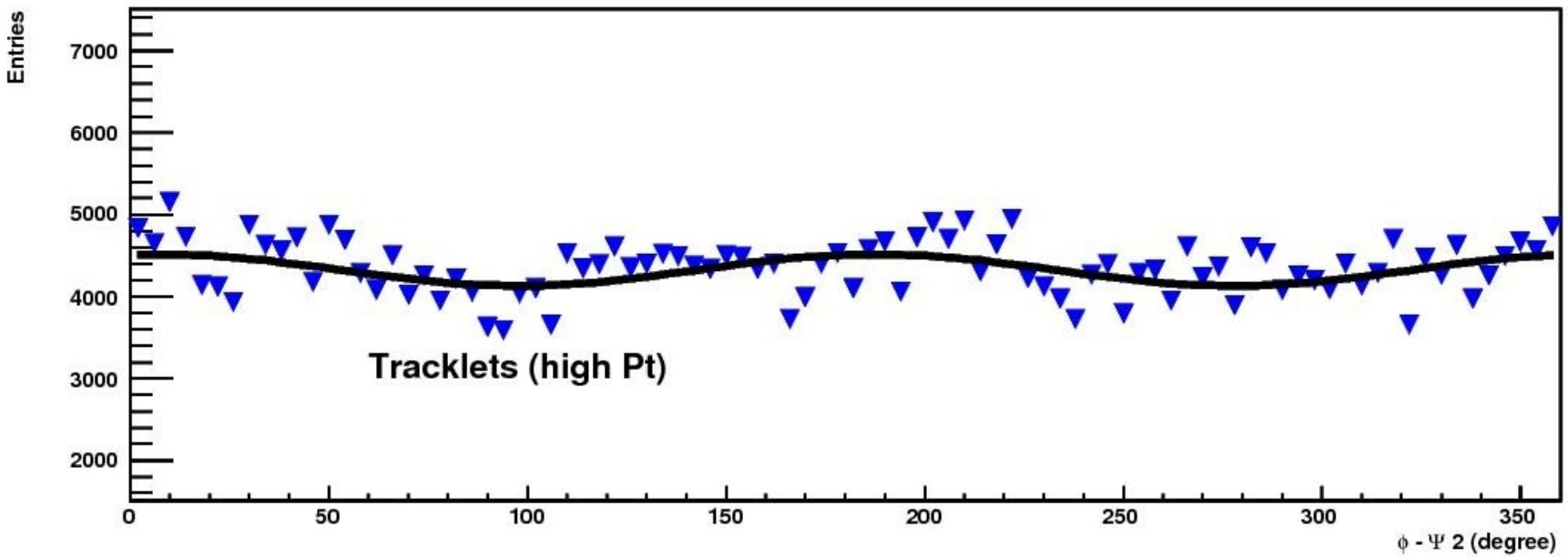
# Backup



Risoluzione in  $\phi$



# Misura di flow



$$dN/d\eta = 2000, "v_2" = 0.05$$



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